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(54) **NONINVASIVE MULTI-PARAMETER PATIENT MONITOR**

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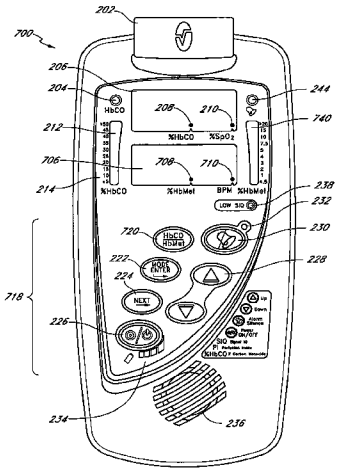
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(57) **ABSTRACT**

Embodiments of the present disclosure include a handheld multi-parameter patient monitor capable of determining multiple physiological parameters from the output of a light sensitive detector capable of detecting light attenuated by body tissue. For example, in an embodiment, the monitor is capable of advantageously and accurately displaying one or more of pulse rate, plethysmograph data, perfusion quality, signal confidence, and values of blood constituents in body tissue, including for example, arterial carbon monoxide saturation ("HbCO"), methemoglobin saturation ("HbMet"), total hemoglobin ("Hbt"), arterial oxygen saturation ("SpO_2"), fractional arterial oxygen saturation ("$SpaO_2$"), or the like. In an embodiment, the monitor advantageously includes a plurality of display modes enabling more parameter data to be displayed than the available physical display real estate.

15 Claims, 18 Drawing Sheets



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Second Amended Complaint for Patent Infringement, Doc. 42, *Masimo Corporation* v. *Philips Electronics North America Corporation and Philips Medizin Systeme Böblingen GmbH*, (District of Delaware, Case No. 1:11-cv-00742 (LPS/MPT) dated Apr. 25, 2012.

Steven W. Smith, *The Scientist and Engineer's Guide to Digital Signal Processing*, § 8 (1st ed. 1997).

Supplemental Expert Report of Dr. Robert Stone Regarding the invalidity of Masimo's Patents-in-Suit (U.S. Patent No. 5,632,272, U.S. Patent No. 6,263,222, U.S. Patent No. 7,215,984, and U.S. Patent No. 6,699,194, *Masimo Corporation* v. *Philips Electronics North America Corporation and Philips Medizin Systeme Böblingen GmbH*, (District of Delaware, Case No. 1:09-cv-00080 (LPS/MPT) dated Mar. 18, 2012.

U.S. Appl. No. 90/012,551, filed Sep. 13, 2012, requesting ex parte reexamination of Patent No. 6,970,792, including accompanying Reexam Request, claim charts, and other documentation filed under 37 C.F.R. § 1.510 and 35 U.S.C. § 302.

U.S. Appl. No. 90/012,553, filed Sep. 13, 2012, requesting ex parte reexamination of Patent No. 7,024,233, including accompanying Reexam Request, claim charts, and other documentation filed under 37 C.F.R. § 1.510 and 35 U.S.C. § 302.

U.S. Appl. No. 90/012,403, filed Jul. 23, 2012, requesting ex parte reexamination of Patent No. 6,263,222, including accompanying Reexam Request, claim charts, and other documentation filed under 37 C.F.R. § 1.510 and 35 U.S.C. § 302.

U.S. Appl. No. 90/012,409, filed Aug. 17, 2012, requesting ex parte reexamination of Patent No. 6.699,194, including accompanying Reexam Request, claim charts, and other documentation filed under 37 C.F.R. § 1.510 and 35 U.S.C. § 302.

U.S. Appl. No. 90/012,463, filed Sep. 5, 2012, requesting ex parte reexamination of of Patent No. 7,215,984, including accompanying Reexam Request, claim charts, and other documentation filed under 37 C.F.R. § 1.510 and 35 U.S.C. § 302.

U.S. Appl. No. 90/012,532, filed Sep. 13, 2012, requesting ex parte reexamination of Patent No. 7,499,835, including accompanying Reexam Request, claim charts, and other documentation filed under 37 C.F.R. § 1.510 and 35 U.S.C. § 302.

U.S. Appl. No. 90/012,534, filed Sep. 13, 2012, requesting ex parte reexamination of Patent No. 7,962,188, including accompanying Reexam Request, claim charts, and other documentation filed under 37 C.F.R. § 1.510 and 35 U.S.C. § 302.

U.S. Appl. No. 90/012,538, filed Sep. 13, 2012, requesting ex parte reexamination of Patent No. 7,377,899, including accompanying Reexam Request, claim charts, and other documentation filed under 37 C.F.R. § 1.510 and 35 U.S.C. § 302.

U.S. Appl. No. 90/012,541, filed Sep. 13, 2012, requesting ex parte reexamination of Patent No. 7,899,507, including accompanying Reexam Request, claim charts, and other documentation filed under 37 C.F.R. § 1.510 and 35 U.S.C. § 302.

U.S. Appl. No. 90/012,542, filed Sep. 13, 2012, requesting ex parte reexamination of Patent No. 8,180,420, including accompanying Reexam Request, claim charts, and other documentation filed under 37 C.F.R. § 1.510 and 35 U.S.C. § 302.

U.S. Appl. No. 90/012,543, filed Sep. 13, 2012, requesting ex parte reexamination of Patent No. 6,850,787, including accompanying Reexam Request, claim charts, and other documentation filed under 37 C.F.R. § 1.510 and 35 U.S.C. § 302.

U.S. Appl. No. 90/012,546, filed Sep. 13, 2012, requesting ex parte reexamination of Patent No. 7,438,683, including accompanying Reexam Request, claim charts, and other documentation filed under 37 C.F.R. § 1.510 and 35 U.S.C. § 302.

U.S. Appl. No. 90/012,548, filed Sep. 13, 2012, requesting ex parte reexamination of Patent No. 7,880,606, including accompanying Reexam Request, claim charts, and other documentation filed under 37 C.F.R. § 1.510 and 35 U.S.C. § 302.

U.S. Appl. No. 90/012,557, filed Sep. 13, 2012, requesting ex parte reexamination of Patent No. 8,150,487, including accompanying Reexam Request, claim charts, and other documentation filed under 37 C.F.R. § 1.510 and 35 U.S.C. § 302.

U.S. Appl. No. 90/012,561, filed Sep. 14, 2012, requesting ex parte reexamination of Patent No. 8,019400, including accompanying Reexam Request, claim charts, and other documentation filed under 37 C.F.R. § 1.510 and 35 U.S.C. § 302.

U.S. Appl. No. 90/012,562, filed Sep. 14, 2012 requesting ex parte reexamination of Patent No. 6,463,311, including accompanying Reexam Request, claim charts, and other documentation filed under 37 C.F.R. § 1.510 and 35 U.S.C. § 302.

U.S. Appl. No. 90/012,566, filed Sep. 14, 2012, requesting ex parte reexamination of Patent No. 7,530,955, including accompanying Reexam Request, claim charts, and other documentation filed under 37 C.F.R. § 1.510 and 35 U.S.C. § 302.

U.S. Appl. No. 90/012,567, filed Sep. 14, 2012, requesting ex parte reexamination of Patent No. 6,684,090, including accompanying Reexam Request, claim charts, and other documentation filed under 37 C.F.R. § 1.510 and 35 U.S.C. § 302.

U.S. Appl. No. 90/012,568, filed Sep. 14, 2012, requesting ex parte reexamination of Patent No. 8,128,572, including accompanying Reexam Request, claim charts, and other documentation filed under 37 C.F.R. § 1.510 and 35 U.S.C. § 302.

U.S. Appl. No. 90/012,699, filed Oct. 4, 2012, requesting ex parte reexamination of Patent No. 6,002,952, including accompanying Reexam Request, claim charts, and other documentation filed under 37 C.F.R. § 1.510 and 35 U.S.C. § 302.

U.S. Appl. No. 90/012.555, filed Sep. 13, 2012, requesting ex parte reexamination of Patent No. 7,440,787, including accompanying Reexam Request, claim charts, and other documentation filed under 37 C.F.R. § 1.510 and 35 U.S.C. § 302.

U.S. Appl. No. 95/002,183, filed Sep. 12, 2012, requesting inter partes reexamination of Patent No. 7,530,955, including accompanying Reexam Request, claim charts, and other documentation filed under 37 C.F.R. § 1.913 and 35 U.S.C. § 311.

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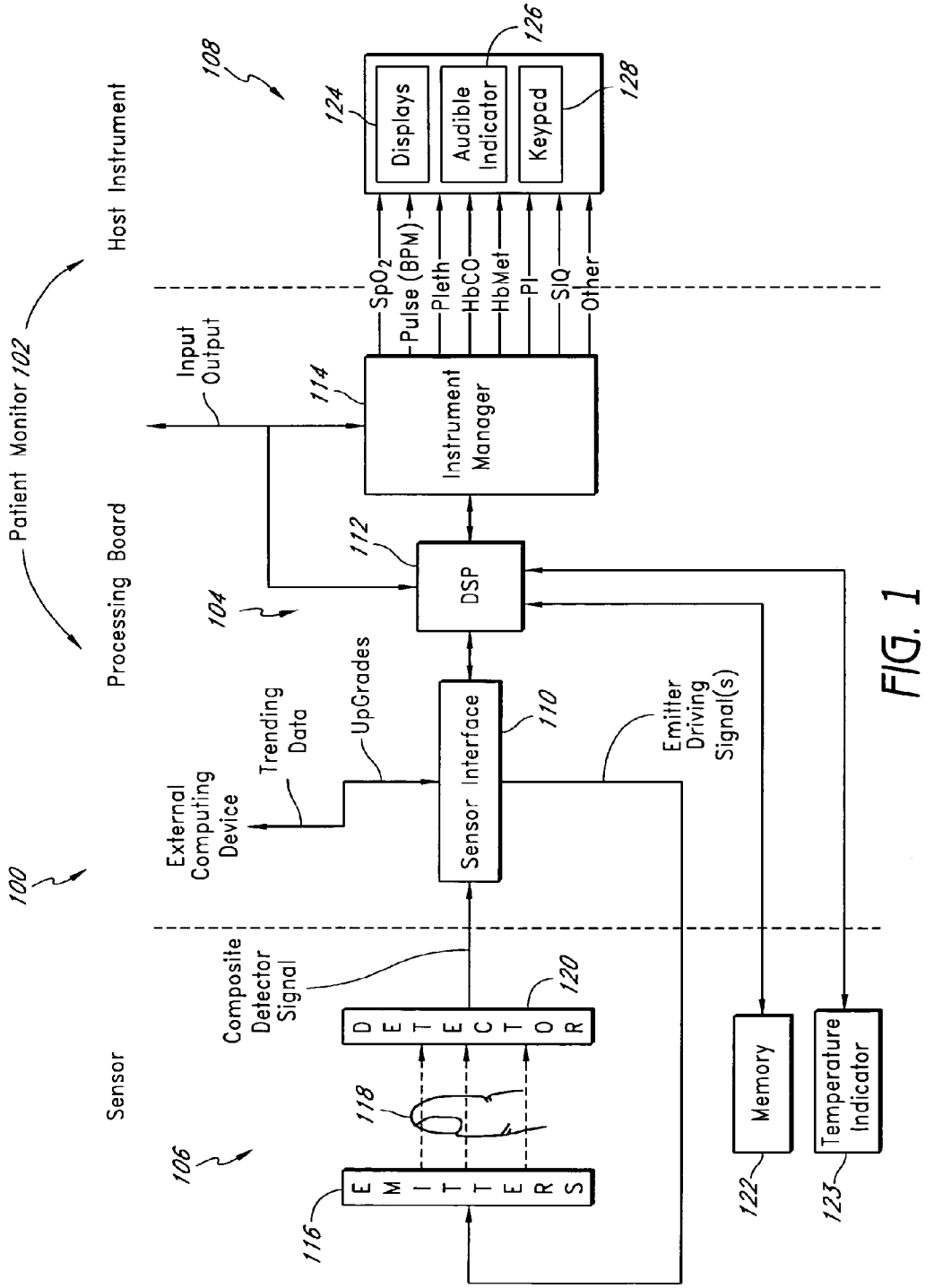

Patient Monitor 102
Host Instrument
Processing Board
Sensor
100
108
126
124
Displays
Audible Indicator
Keypad
128
SpO2
Pulse (BPM)
Pleth
HbCO
HbMet
PI
SIQ
Other
Input
Output
114
Instrument Manager
112
DSP
104
Trending Data
UpGrades
Sensor Interface
110
Emitter Driving Signal(s)
External Computing Device
Composite Detector Signal
DETECTOR
120
118
EMITTERS
116
106
Memory
122
Temperature Indicator
123

FIG. 1

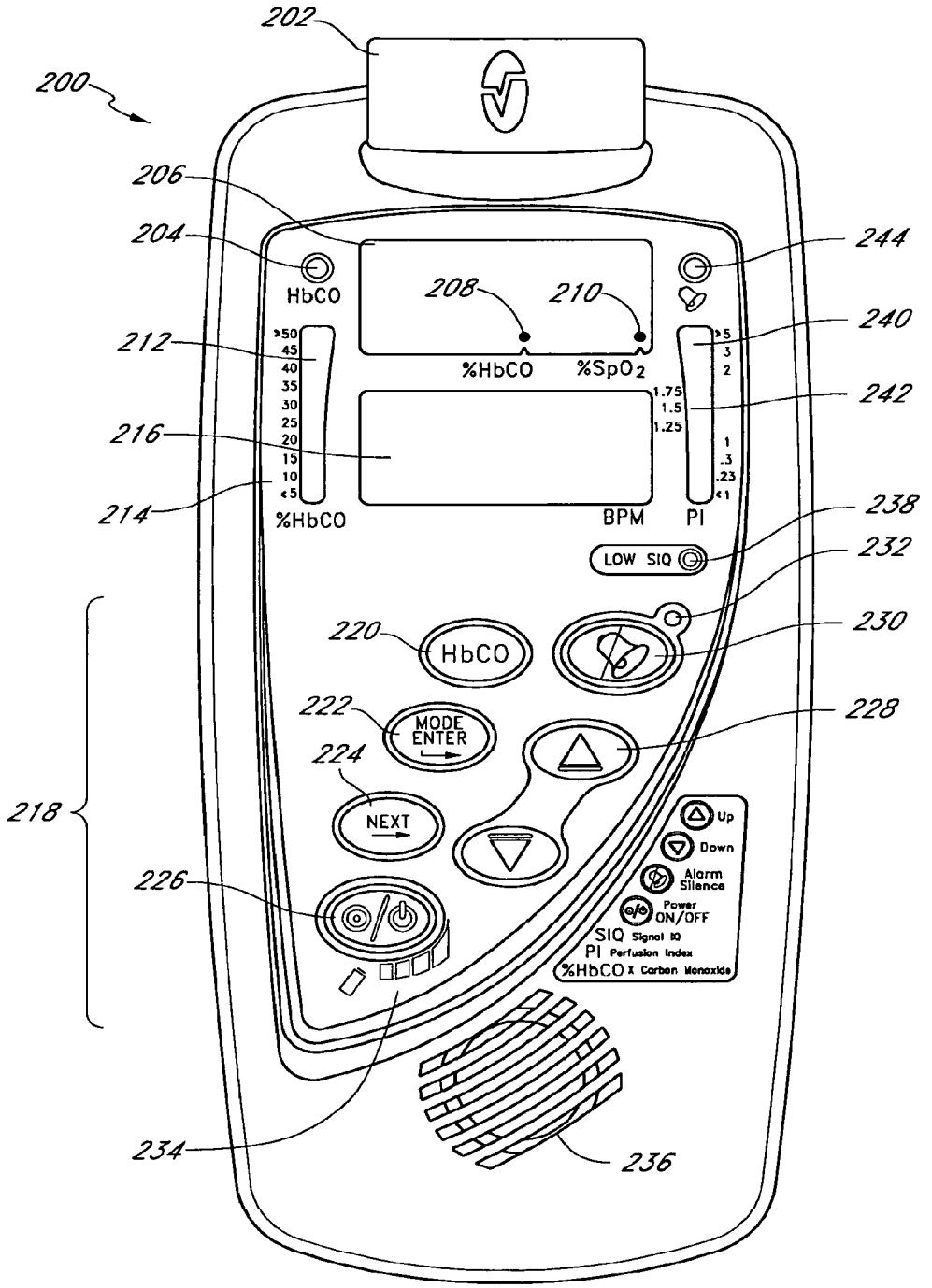

202
200
206
204
244
HbCO
208
210
240
212
%HbCO
%SpO2
242
216
BPM
PI
214
%HbCO
238
LOW SIQ
232
220
HbCO
230
222
MODE ENTER
228
224
218
NEXT
Up
Down
Alarm Silence
Power ON/OFF
SIQ Signal IQ
PI Perfusion Index
%HbCO x Carbon Monoxide
226
234
236

FIG. 2

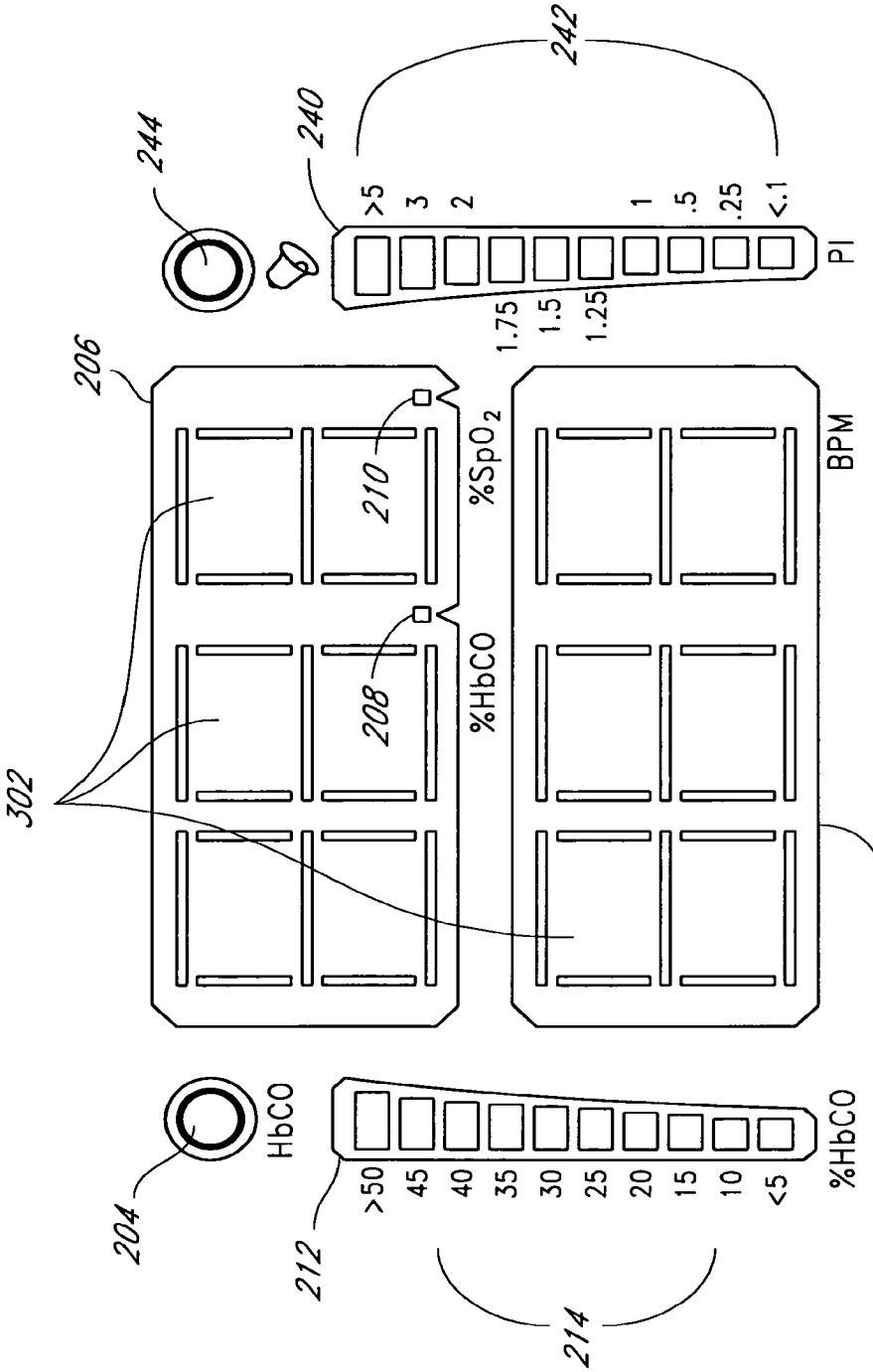

242
240
244
>5
3
2
1
.5
.25
<.1
PI
1.75
1.5
1.25
206
210
%SpO2
BPM
208
%HbCO
302
216
HbCO
204
212
>50
45
40
35
30
25
20
15
10
<5
%HbCO
214

FIG. 3

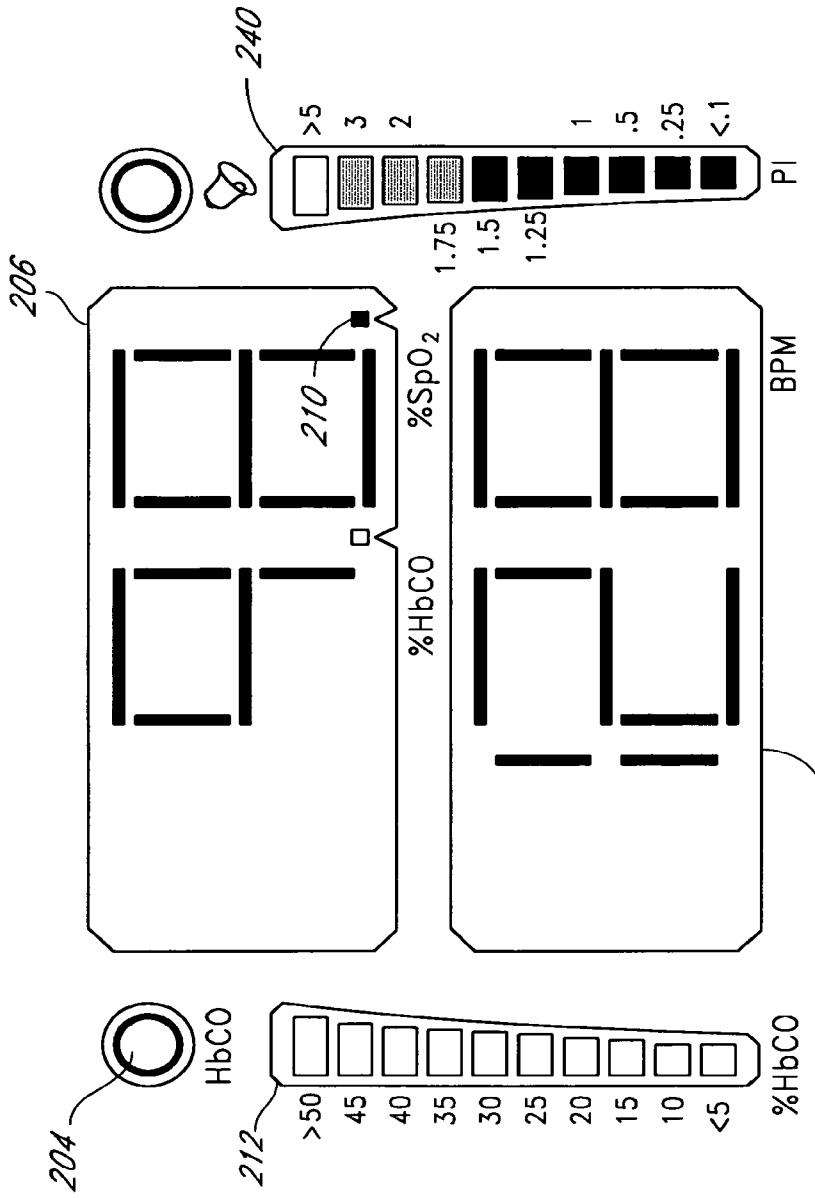

240
>5
3
2
1
.5
.25
<.1
PI
1.75
1.5
1.25
206
210
%SpO2
BPM
%HbCO
216
204
HbCO
212
>50
45
40
35
30
25
20
15
10
<5
%HbCO

FIG. 4

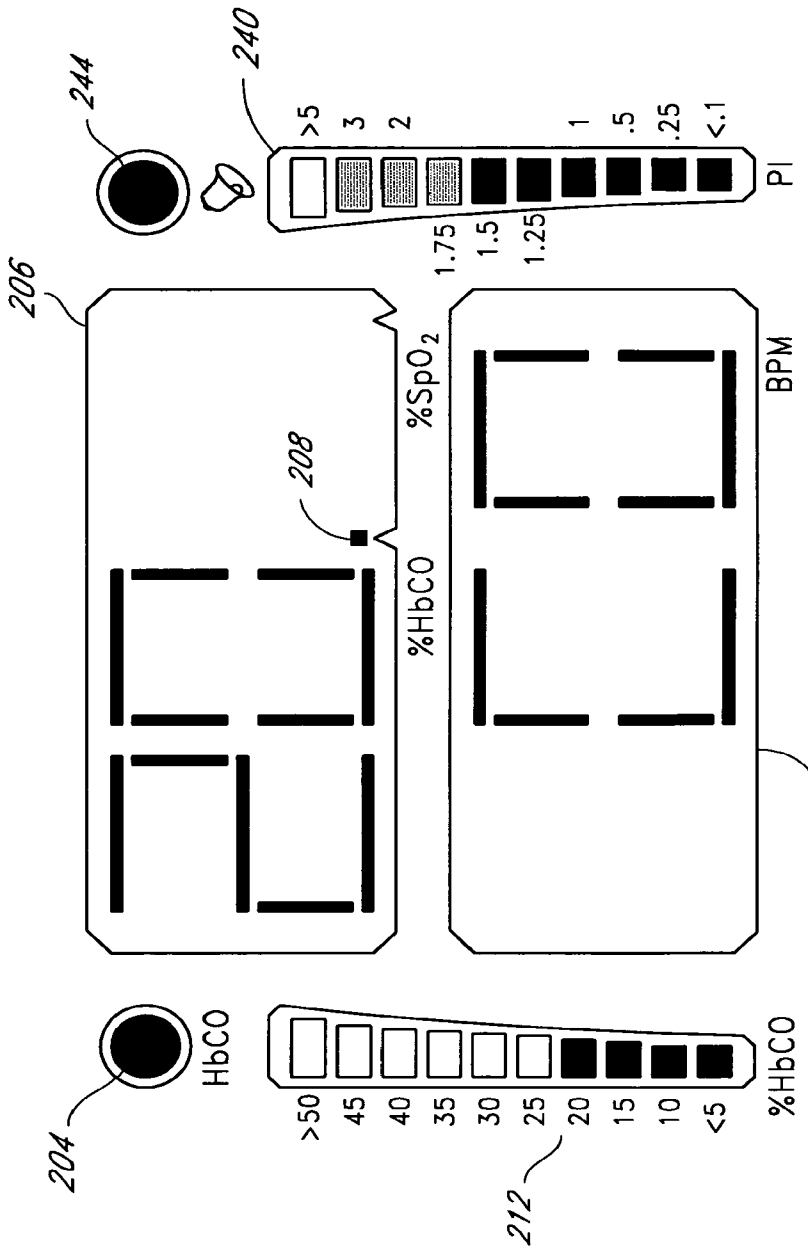

244
240
>5
3
2
1
.5
.25
<.1
PI
1.75
1.5
1.25
206
%SpO2
208
BPM
%HbCO
216
HbCO
204
>50
45
40
35
30
25
20
15
10
<5
%HbCO
212

FIG. 5

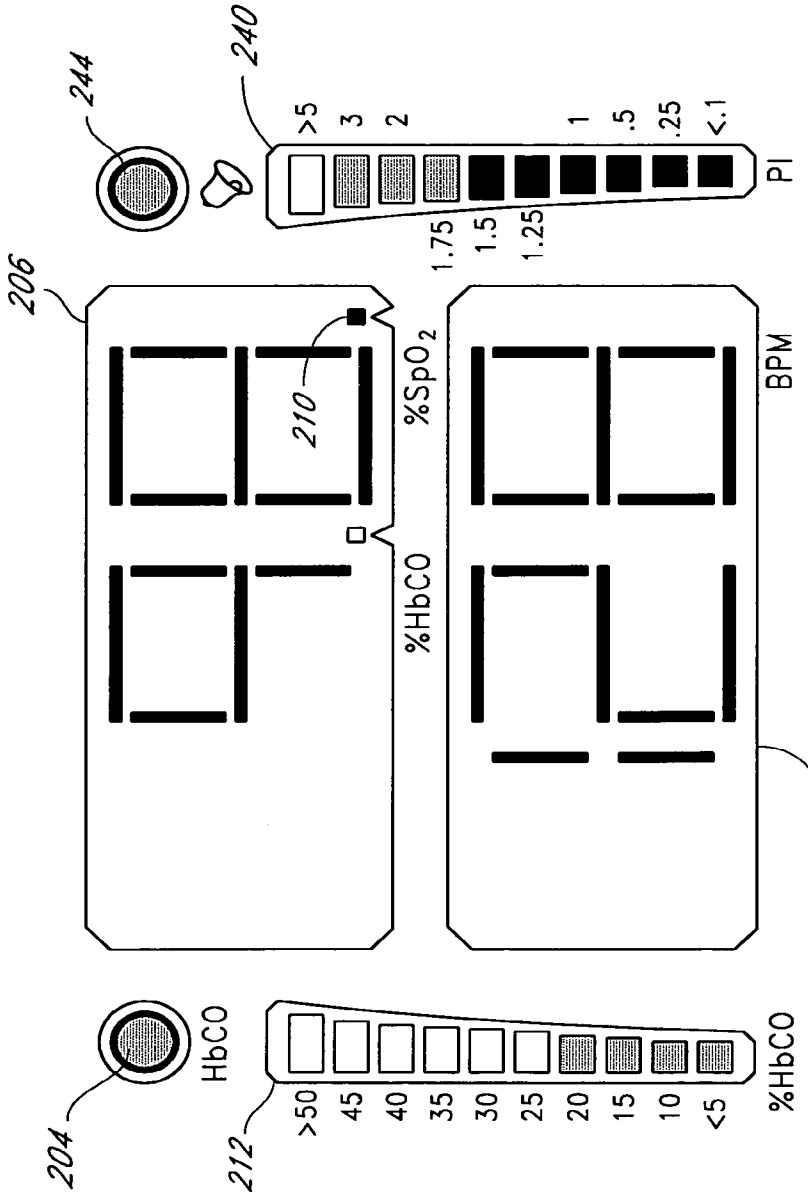

244
240
>5
3
2
1
.5
.25
<.1
PI
1.75
1.5
1.25
206
210
%SpO2
%HbCO
BPM
216
204
HbCO
212
>50
45
40
35
30
25
20
15
10
<5
%HbCO

FIG. 6

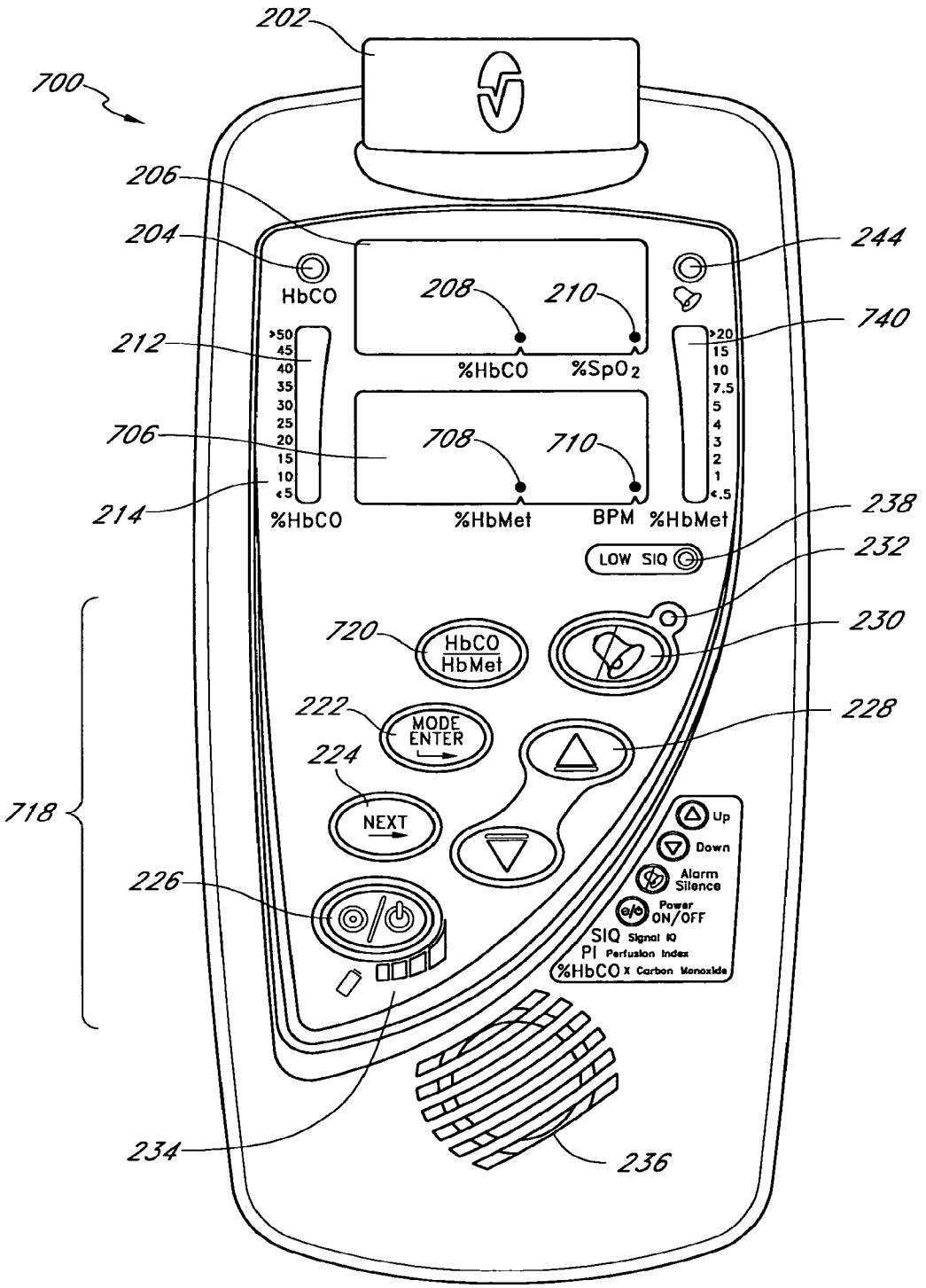

202
700
206
204
244
HbCO
208
210
740
212
%HbCO
%SpO2
706
708
710
214
%HbCO
%HbMet
BPM
%HbMet
238
LOW SIQ
232
720
HbCO
HbMet
230
222
MODE
ENTER
228
224
NEXT
718
Up
Down
Alarm
Silence
Power
ON/OFF
SIQ Signal IQ
PI Perfusion Index
%HbCO x Carbon Monoxide
226
234
236

FIG. 7

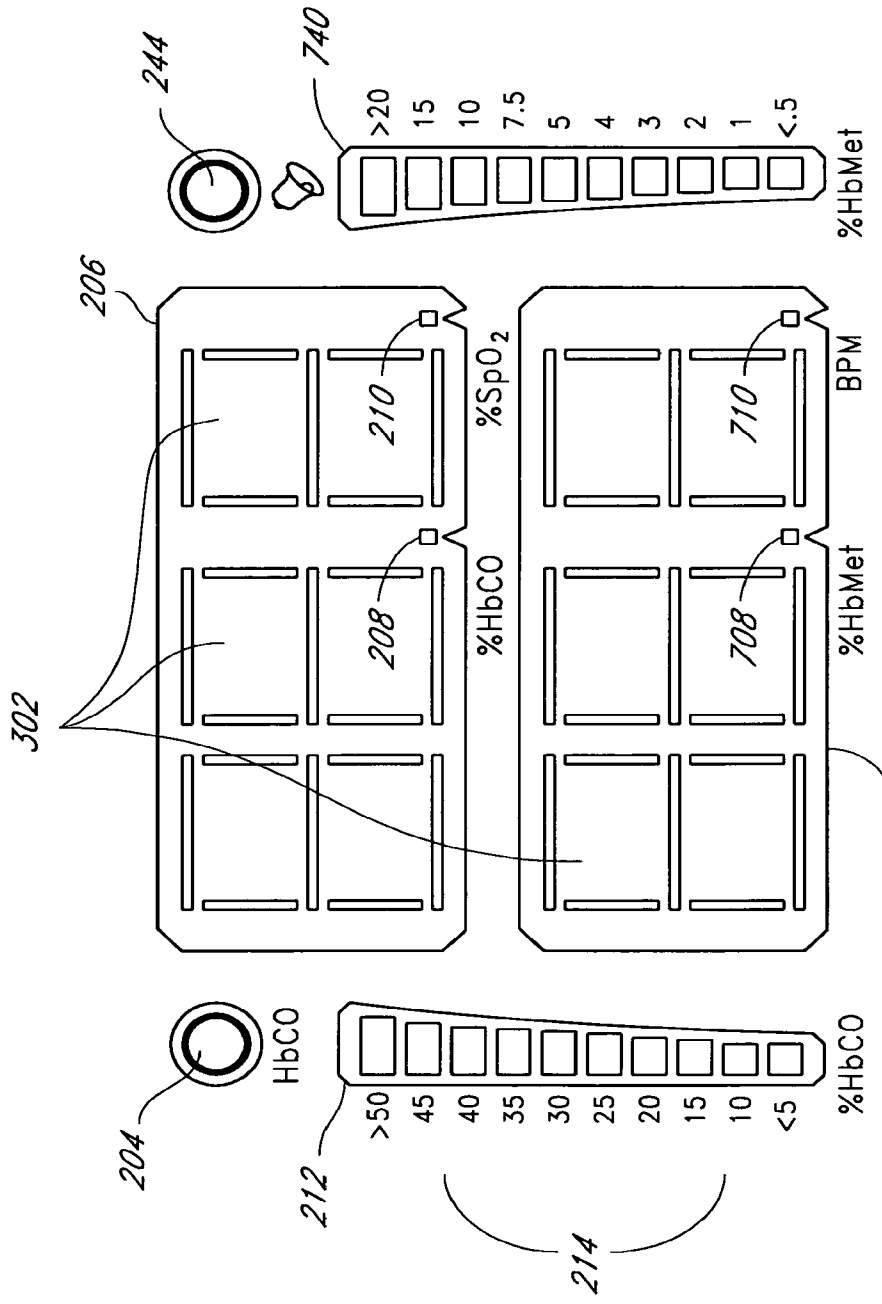

244
740
>20
15
10
7.5
5
4
3
2
1
<.5
%HbMet
206
210
%SpO2
BPM
710
208
%HbCO
708
%HbMet
302
706
204
HbCO
212
>50
45
40
35
30
25
20
15
10
<5
%HbCO
214

FIG. 8

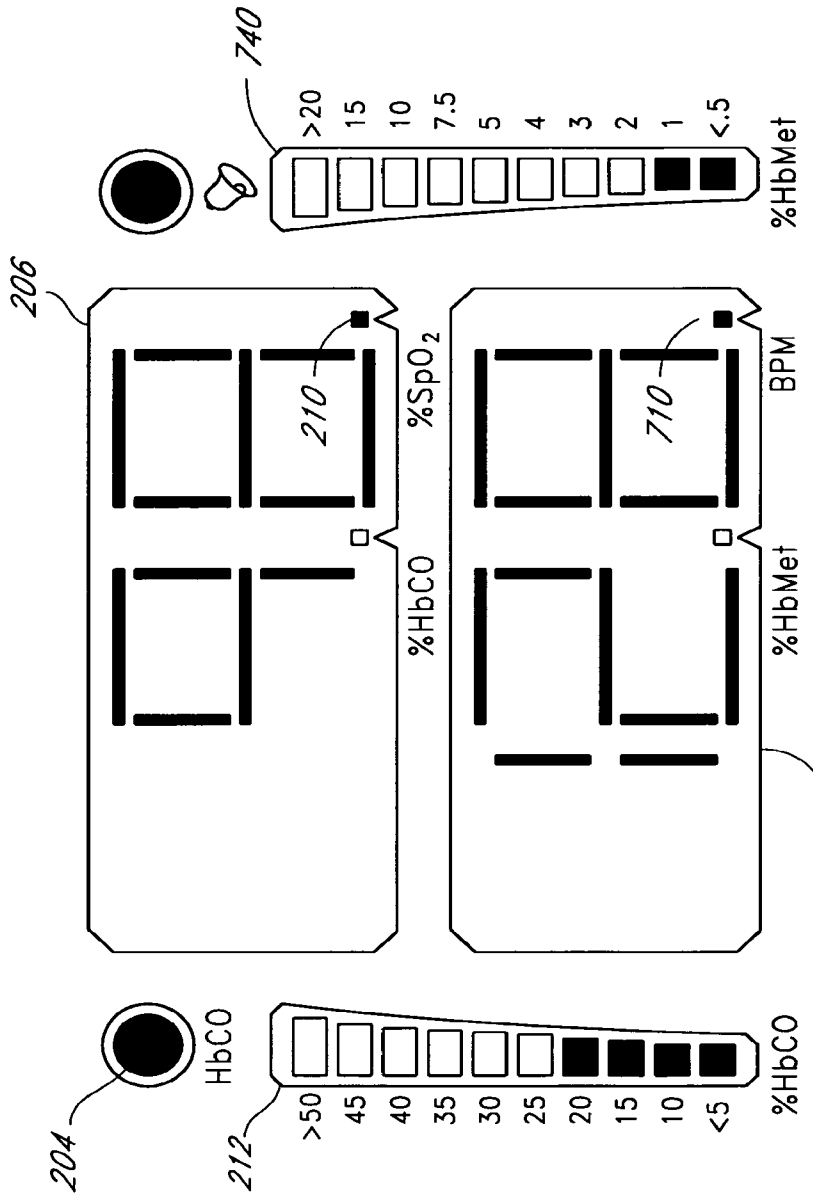

740
>20
15
10
7.5
5
4
3
2
1
<.5
%HbMet
206
210
%SpO2
%HbCO
710
BPM
%HbMet
706
204
HbCO
212
>50
45
40
35
30
25
20
15
10
<5
%HbCO

FIG. 9

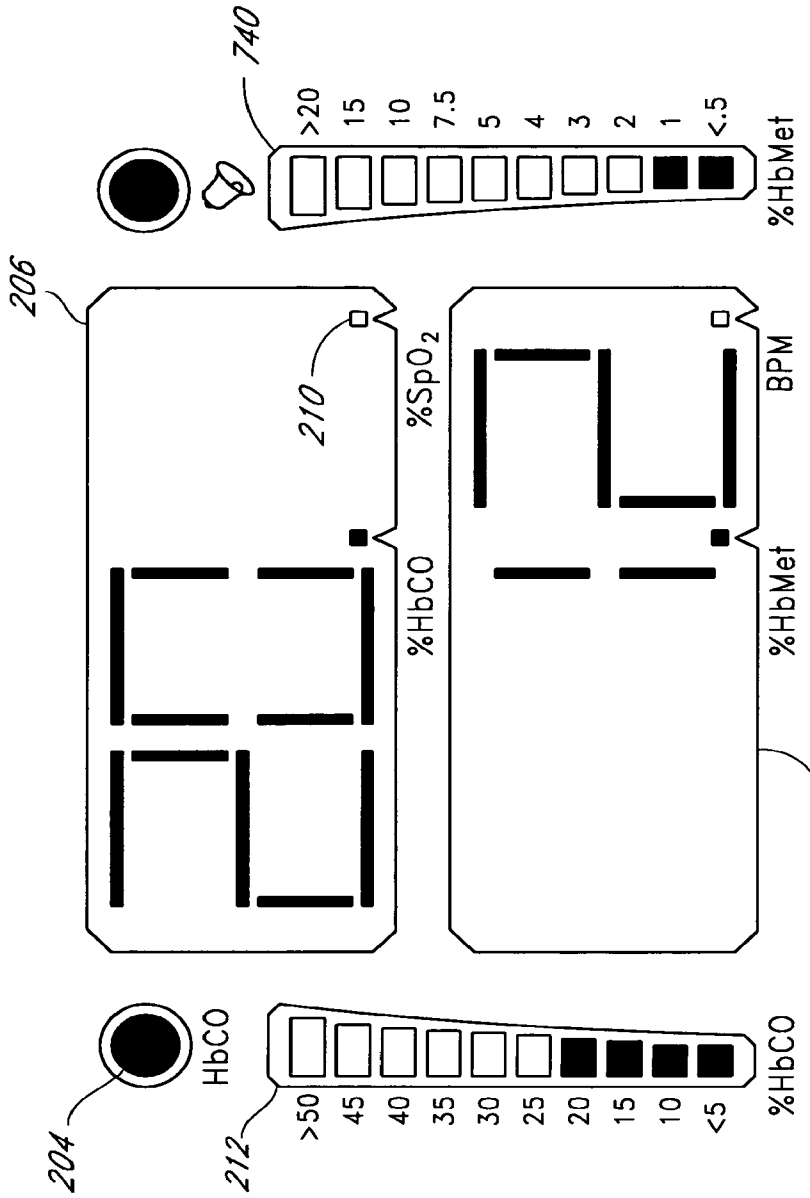

740
>20
15
10
7.5
5
4
3
2
1
<.5
%HbMet
206
210
%SpO2
%HbCO
BPM
%HbMet
706
204
HbCO
212
>50
45
40
35
30
25
20
15
10
<5
%HbCO

FIG. 10

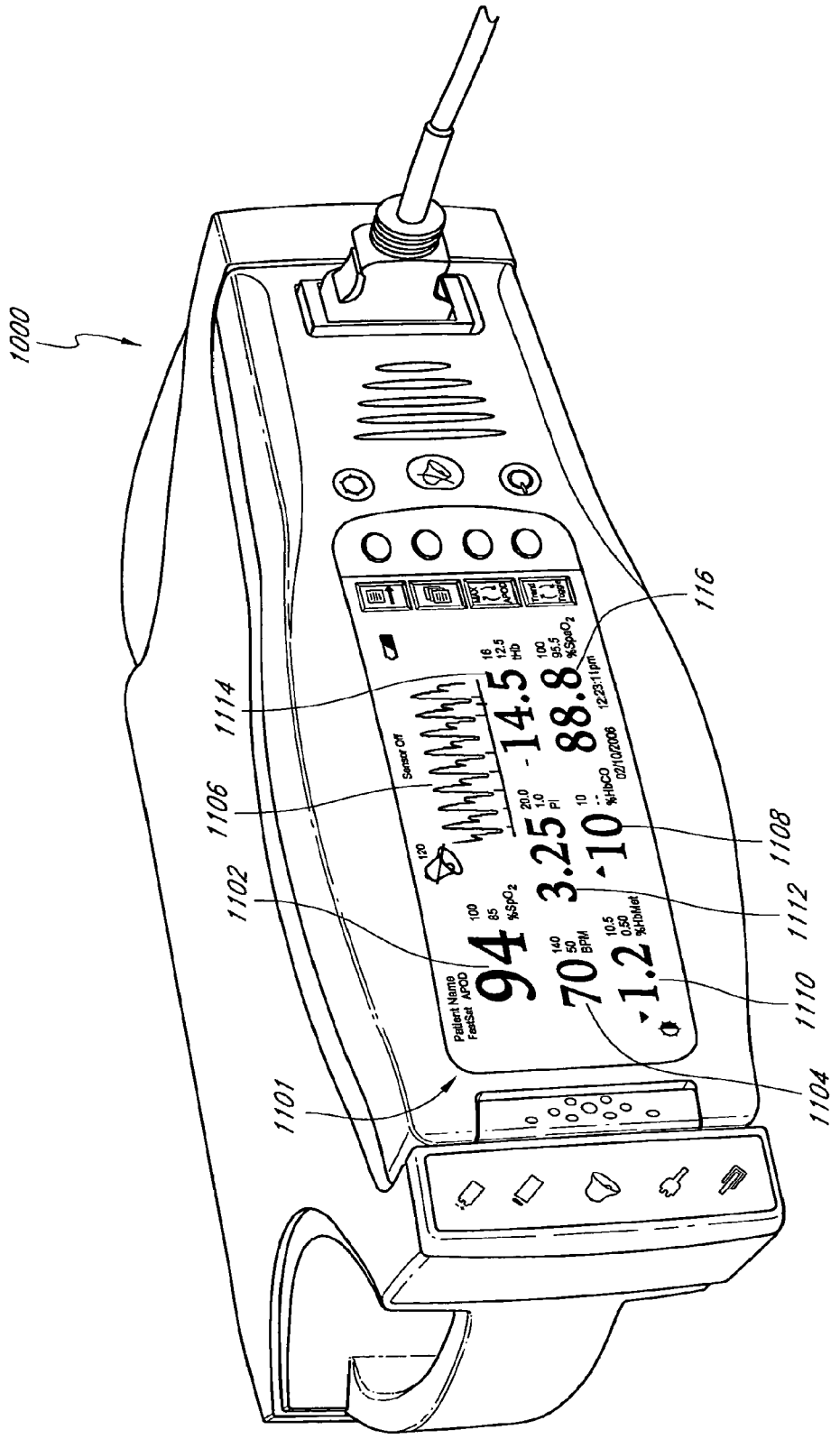

1000
1101
1102
1104
1106
1108
1110
1112
1114
116
Patient Name
FastSat APOD
94
%SpO2
70
BPM
3.25
PI
-10
%HbCO
-1.2
%HbMet
14.5
Hb
88.8
%SpaO2
Sensor Off
02/10/2006
12:23:11pm

FIG. 11A

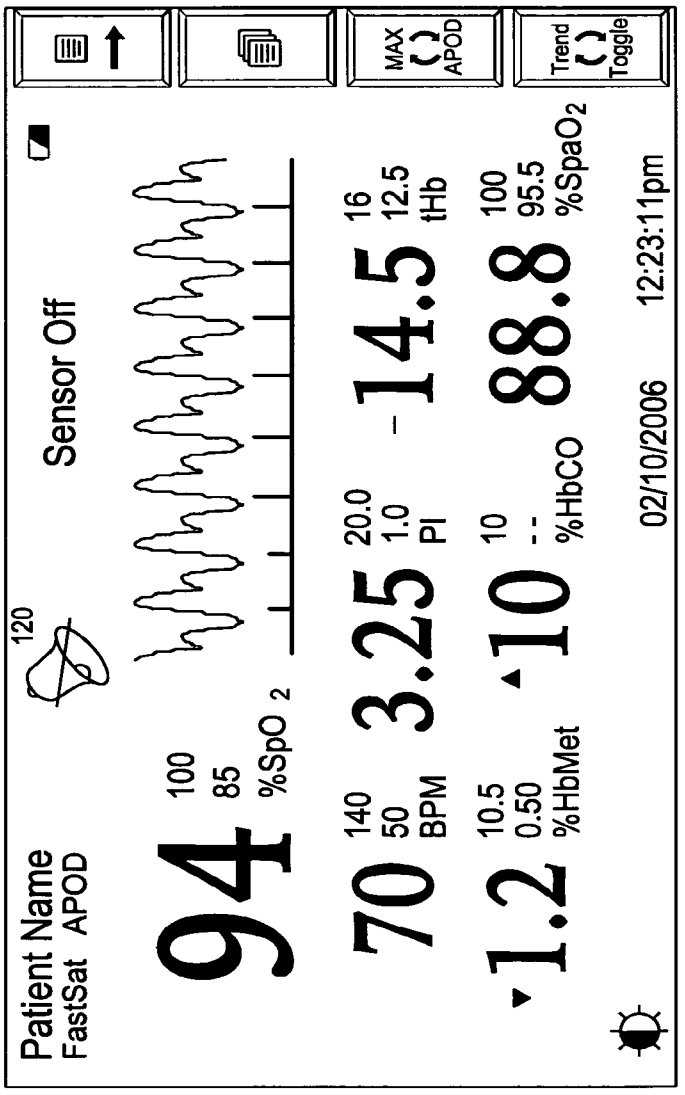

Patient Name
FastSat APOD
120
Sensor Off
MAX APOD
Trend Toggle
94
100
85
%SpO 2
70
140
50
BPM
3.25
20.0
1.0
PI
-14.5
16
12.5
tHb
1.2
10.5
0.50
%HbMet
10
--
%HbCO
88.8
100
95.5
%SpaO2
02/10/2006
12:23:11pm

FIG. 11B

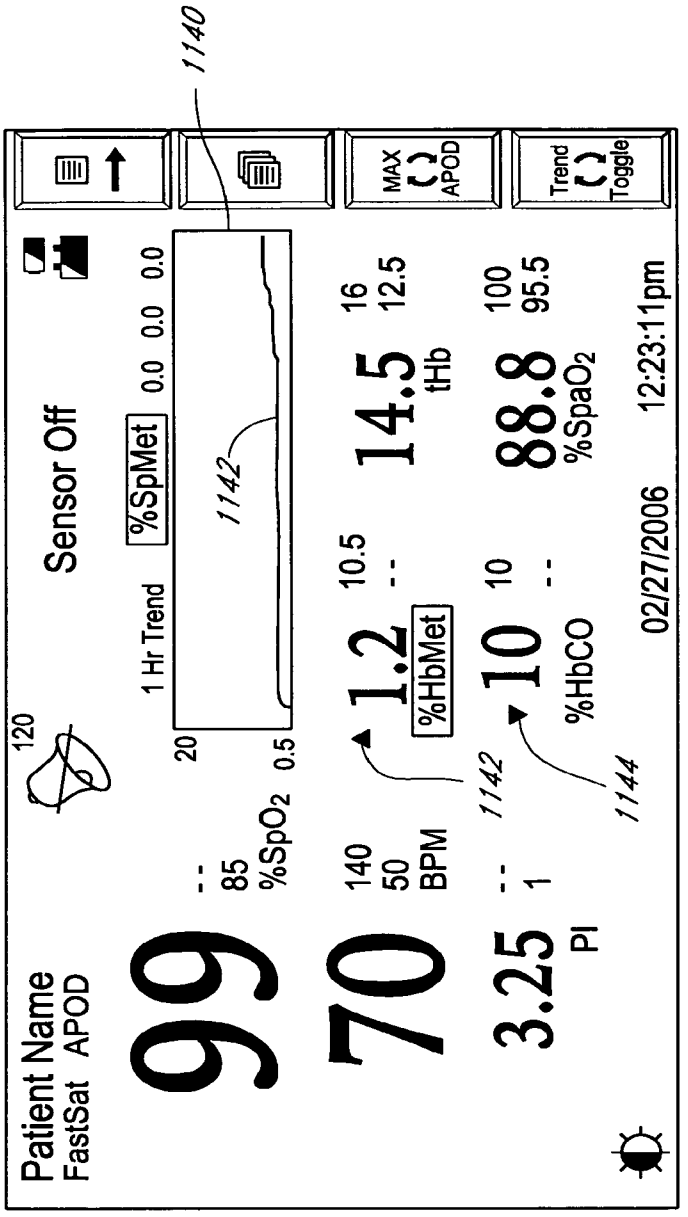

1140
120
Patient Name
FastSat APOD
Sensor Off
MAX APOD
Trend Toggle
1 Hr Trend
%SpMet
0.0 0.0 0.0
1142
99
-- 85 %SpO2
20 0.5
70
140 50 BPM
1.2
%HbMet
10.5 --
14.5
tHb
16 12.5
3.25
-- 1 PI
1142
10
%HbCO
10 --
1144
88.8
%SpaO2
100 95.5
02/27/2006 12:23:11pm

FIG. 11C

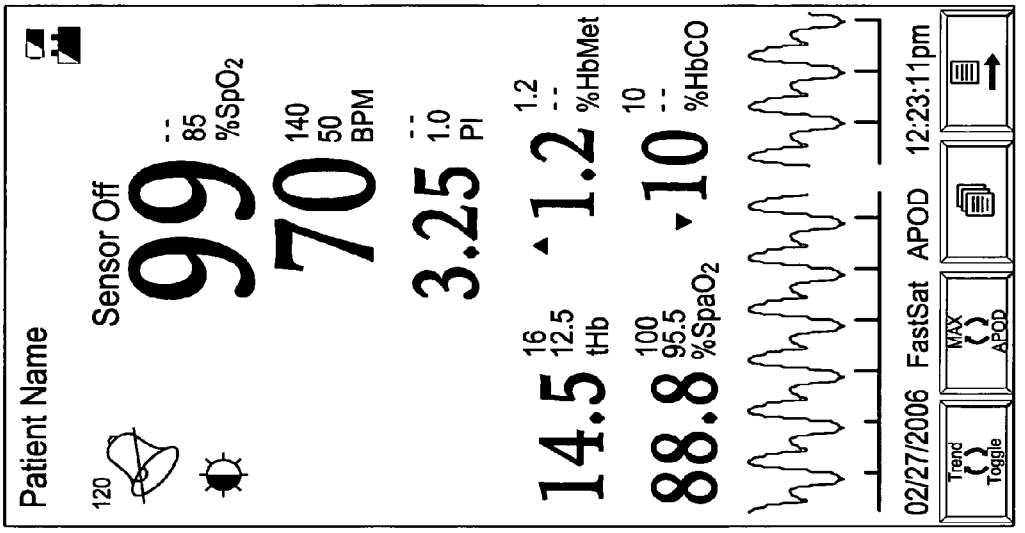

Patient Name
120
Sensor Off
99
85
%SpO2
70
140
50
BPM
3.25
1.0
PI
14.5
16
12.5
tHb
1.2
1.2
%HbMet
88.8
100
95.5
%SpaO2
10
10
%HbCO
02/27/2006
FastSat
APOD
12:23:11pm
Trend
Toggle
MAX
APOD

FIG. 11D

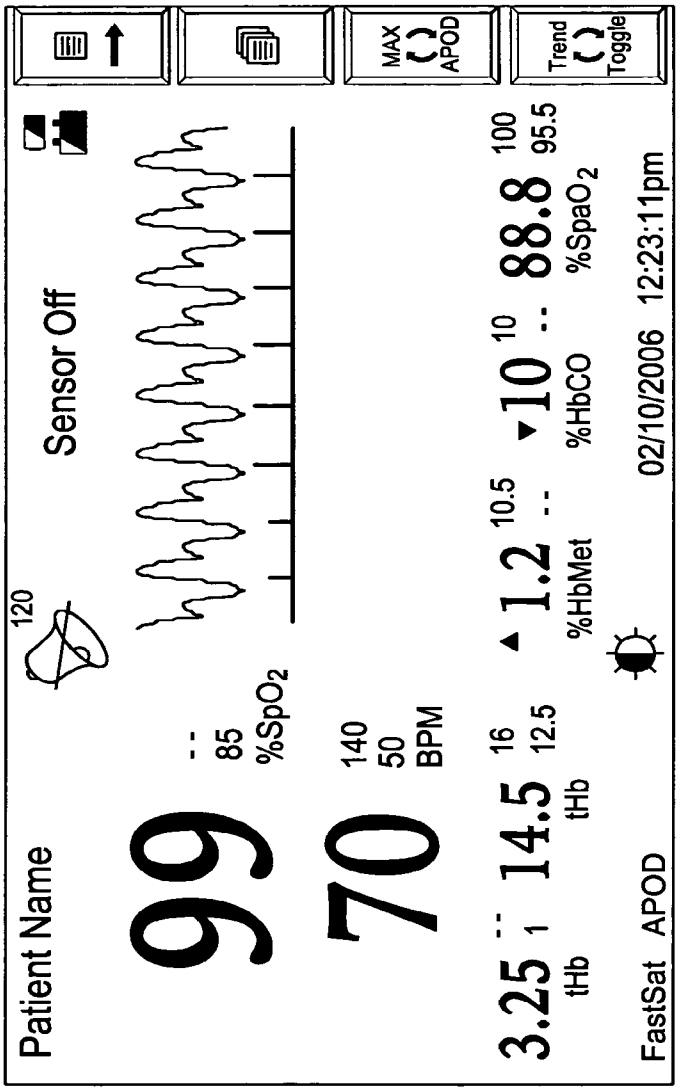

Patient Name
Sensor Off
MAX APOD
Trend Toggle
99
%SpO2
85
--
70
BPM
140
50
120
3.25
tHb
14.5
tHb
16
12.5
1.2
%HbMet
10.5
--
10
%HbCO
10
--
88.8
%SpaO2
100
95.5
FastSat APOD
02/10/2006 12:23:11pm

FIG. 11E

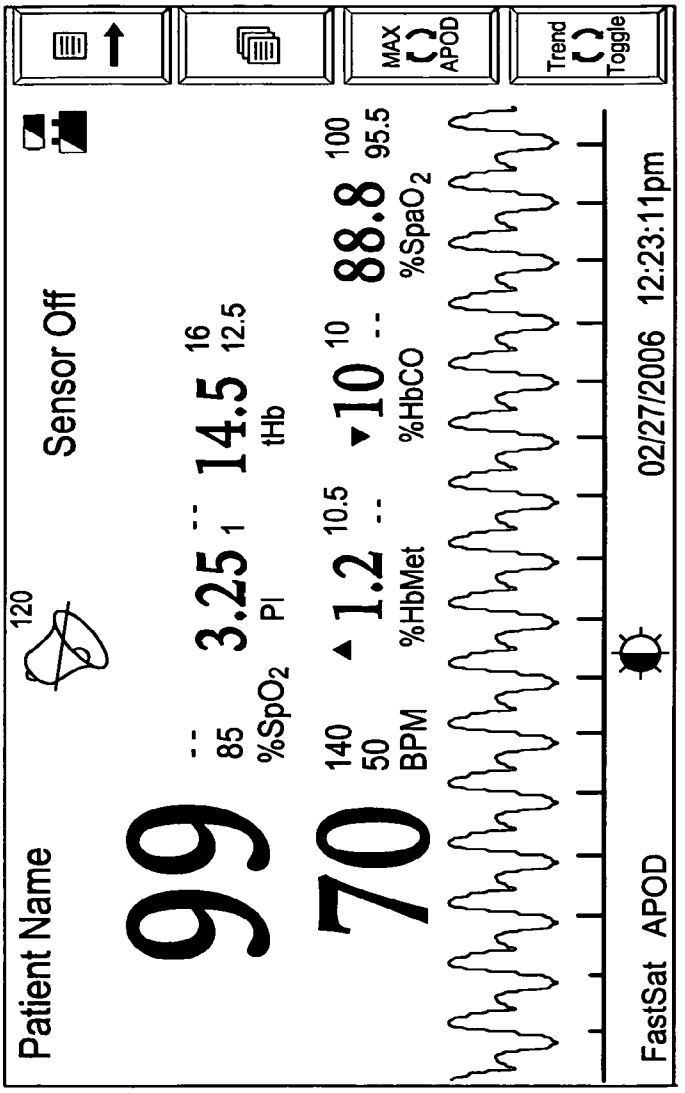

Patient Name
120
Sensor Off
MAX APOD
Trend Toggle
99
-- 85
%SpO2
3.25 -- 1
PI
14.5 16 12.5
tHb
70
140 50
BPM
1.2 10.5 --
%HbMet
10 10 --
%HbCO
88.8 100 95.5
%SpaO2
FastSat APOD
02/27/2006 12:23:11pm

FIG. 11F

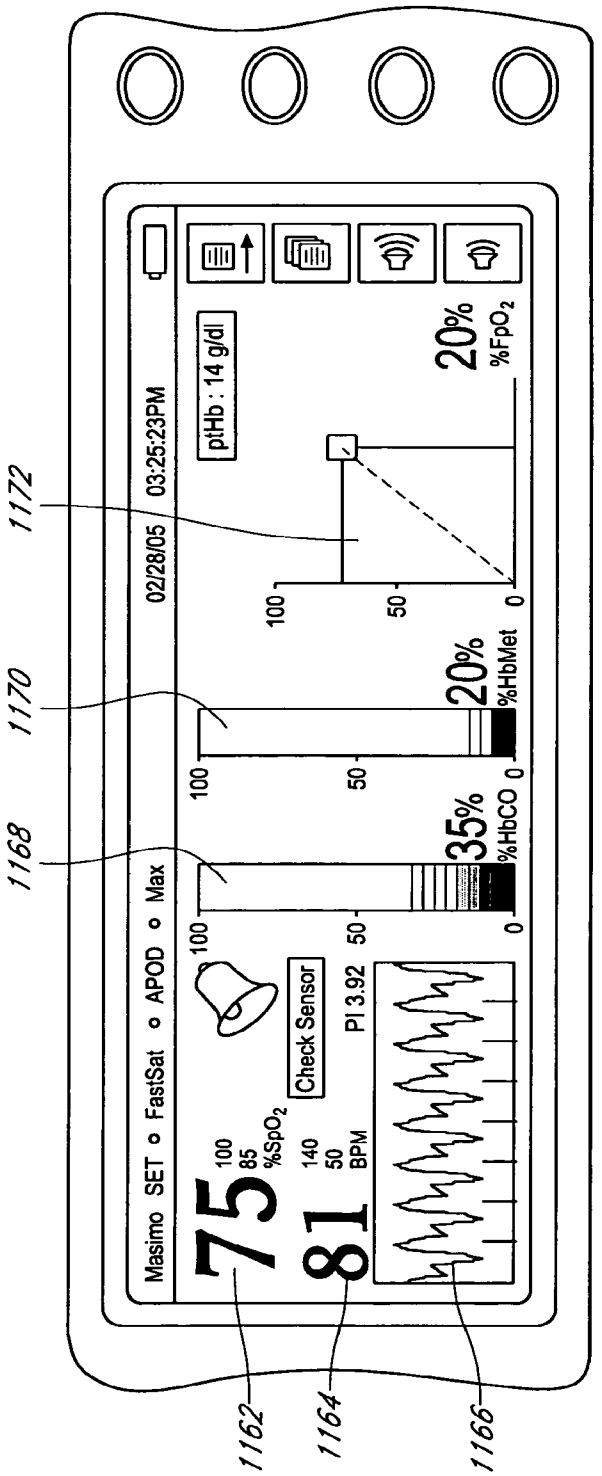

1172
1170
1168
1162
1164
1166
Masimo SET o FastSat o APOD o Max
02/28/05 03:25:23PM
ptHb : 14 g/dl
20% %FpO2
20% %HbMet
35% %HbCO
100
50
0
75
81
100 85 %SpO2
140 50 BPM
Check Sensor
PI 3.92

FIG. 11G

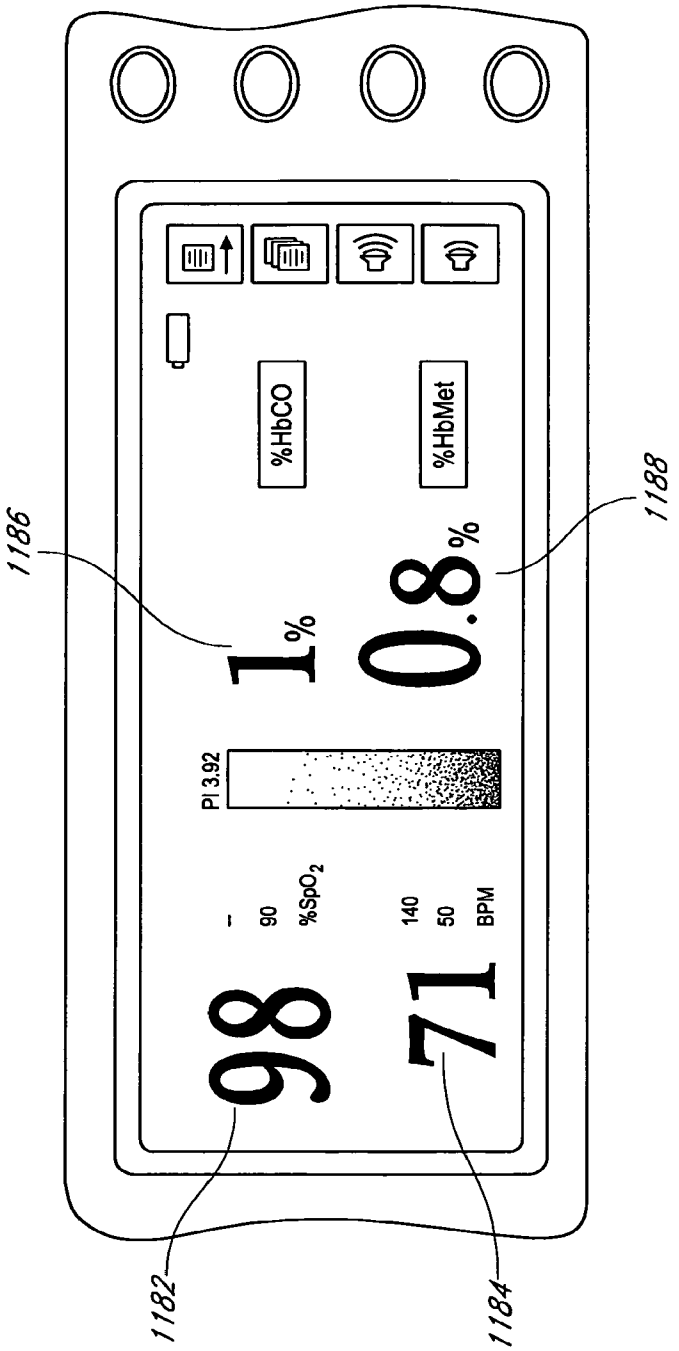

%HbCO
%HbMet
1%
0.8%
PI 3.92
98
%SpO2
90
–
71
BPM
50
140
1186
1188
1182
1184

FIG. 11H

NONINVASIVE MULTI-PARAMETER PATIENT MONITOR

PRIORITY CLAIM TO RELATED PROVISIONAL APPLICATIONS

The present application is a continuation of U.S. patent application Ser. No. 11/367,033, filed Mar. 1, 2006, which claims priority benefit under 35 U.S.C. §119(e) to U.S. Provisional Patent Application Ser. No. 60/657,596, filed Mar. 1, 2005, entitled "Multiple Wavelength Sensor," No. 60/657,281, filed Mar. 1, 2005, entitled "Physiological Parameter Confidence Measure," No. 60/657,268, filed Mar. 1, 2005, entitled "Configurable Physiological Measurement System," and No. 60/657,759, filed Mar. 1, 2005, entitled "Noninvasive Multi-Parameter Patient Monitor." The present application incorporates the foregoing disclosures herein by reference.

INCORPORATION BY REFERENCE OF RELATED UTILITY APPLICATIONS

The present application is related to the following copending U.S. utility applications:

	App. Sr. No.	Filing Date	Title	Atty Dock.
1	11/367,013	Mar. 1, 2006	Multiple Wavelength Sensor Emitters	MLR.002A
2	11/366,995	Mar. 1, 2006	Multiple Wavelength Sensor Equalization	MLR.003A
3	11/366,209	Mar. 1, 2006	Multiple Wavelength Sensor Substrate	MLR.004A
4	11/366,210	Mar. 1, 2006	Multiple Wavelength Sensor Interconnect	MLR.005A
5	11/366,833	Mar. 1, 2006	Multiple Wavelength Sensor Attachment	MLR.006A
6	11/366,997	Mar. 1, 2006	Multiple Wavelength Sensor Drivers	MLR.009A
7	11/367,034	Mar. 1, 2006	Physiological Parameter Confidence Measure	MLR.010A
8	11/367,036	Mar. 1, 2006	Configurable Physiological Measurement System	MLR.011A
9	11/367,033	Mar. 1, 2006	Noninvasive Multi-Parameter Patient Monitor	MLR.012A
10	11/367,014	Mar. 1, 2006	Noninvasive Multi-Parameter Patient Monitor	MLR.013A
11	11/366,208	Mar. 1, 2006	Noninvasive Multi-Parameter Patient Monitor	MLR.014A
12	13/412,428	Mar. 5, 2012	Noninvasive Multi-Parameter Patient Monitor	MLR.014C1
13	12/949,271	Nov. 18, 2010	Physiological Measurement System with Automatic Wavelength Adjustment	MLR.018A

The present application incorporates the foregoing disclosures herein by reference.

FIELD OF THE DISCLOSURE

The present disclosure relates to the field of noninvasive patient monitors. More specifically, the disclosure relates to monitors displaying measurements derived using signals from optical sensors.

BACKGROUND

Spectroscopy is a common technique for measuring the concentration of organic and some inorganic constituents of a solution. The theoretical basis of this technique is the Beer-Lambert law, which states that the concentration c_i of an absorbent in solution can be determined by the intensity of light transmitted through the solution, knowing the path-length d_λ, the intensity of the incident light $I_{0,\lambda}$, and the extinction coefficient $\epsilon_{i,\lambda}$ at a particular wavelength λ. In generalized form, the Beer-Lambert law is expressed as:

$$I_\lambda = I_{0,\lambda} e^{-d_\lambda \cdot \mu_{0,\lambda}} \tag{1}$$

$$\mu_{0,\lambda} = \sum_{i=1}^{n} \varepsilon_{i,\lambda} \cdot c_i \tag{2}$$

where $\mu_{0,\lambda}$ is the bulk absorption coefficient and represents the probability of absorption per unit length. The minimum number of discrete wavelengths that are required to solve Equations 1-2 are the number of significant absorbers that are present in the solution.

A practical application of this technique is pulse oximetry, which utilizes a noninvasive sensor to measure oxygen saturation (SpO_2) and pulse rate. In general, the sensor has light emitting diodes (LEDs) that transmit optical radiation of red and infrared wavelengths into a tissue site and a detector that responds to the intensity of the optical radiation after absorption (e.g., by transmission or transreflectance) by pulsatile arterial blood flowing within the tissue site. Based on this response, a processor determines measurements for SpO_2, pulse rate, and can output representative plethysmographic waveforms. Thus, "pulse oximetry" as used herein encompasses its broad ordinary meaning known to one of skill in the art, which includes at least those noninvasive procedures for measuring parameters of circulating blood through spectroscopy. Moreover, "plethysmograph" as used herein (commonly referred to as "photoplethysmograph"), encompasses its broad ordinary meaning known to one of skill in the art, which includes at least data representative of a change in the absorption of particular wavelengths of light as a function of the changes in body tissue resulting from pulsing blood.

Pulse oximeters capable of reading through motion induced noise are available from Masimo Corporation ("Masimo") of Irvine, Calif. Moreover, portable and other oximeters capable of reading through motion induced noise are disclosed in at least U.S. Pat. Nos. 6,770,028, 6,658,276, 6,157,850, 6,002,952, and 5,769,785. Read which are owned by Masimo, and are incorporated by reference herein. Such reading through motion oximeters have gained rapid acceptance in a wide variety of medical applications, including surgical wards, intensive care and neonatal units, general wards, home care, physical training, and virtually all types of monitoring scenarios.

SUMMARY OF THE DISCLOSURE

Despite the success of read through motion oximeter systems, there is a need to provide patient monitors capable of displaying multiple physiological parameters, other than or in addition to SpO_2, plethysmograph waveforms, or pulse rates. For example, in accessing a patient's condition, caregivers often desire knowledge of other blood constituents, including for example, a percent value for arterial carbon monoxide saturation ("HbCO") or a percent value for methemogobin

saturation ("HbMet") or the like. For example, in an embodiment, the display advantageously displays one or more of the following: pulse rate, plethysmograph waveform data, perfusion index, values of blood constituents in body tissue, including for example, HbCO, HbMet, total hemoglobin ("Hbt"), arterial oxygen saturation ("SpO_2"), fractional arterial oxygen saturation ("$SpaO_2$"), or the like. In other embodiments, the monitor may advantageously and accurately determine values for one or more of HbO_2, Hb, blood glucose, water, the presence or absence of therapeutic drugs (aspirin, Dapson, nitrates, or the like) or abusive/recreational drugs (methamphetamine, alcohol, steroids, or the like), concentrations of carbon dioxide ("CO_2") or oxygen ("O"), ph levels, bilirubin, perfusion quality, signal quality or the like. Accordingly, the present disclosure includes a multi-parameter patient monitor capable of determining one or more of the foregoing parameters, other than or in addition to, SpO_2, plethysmograph waveforms, or perfusion quality index.

In an embodiment, the display of a noninvasive multi-parameter patient monitor advantageously includes a plurality of display modes enabling more parameter data to be displayed than the available physical display area or real estate. In an embodiment, a user may cycle different parameter values through an area of the display common to both parameters even when one parameter is shifted, through, for example, actuation of a user input key. The patient monitor may also display different parameters as color-coded. For example, when the following measured parameters are within "normal" ranges, SpO_2 may be displayed red, pulse rate (BPM) may be displayed green, HbCO may be displayed orange, HbMet may be displayed blue, or the like. In an embodiment, measured values of SpO_2 may be displayed in white, BPM may be displayed in yellow green or aquamarine, PI™ may be displayed in violet, Hbt may be displayed in grass green, HbMet may be displayed in blue or light blue, HbCO may be displayed in orange, and $SpaO_2$ may be displayed in electric blue.

Moreover, parameter trend data may also be displayed using the same or similar color coding, especially when multiple trends are displayed on one or more display graphs. In addition, more coarse or gross parameter indications may be displayed for quick reference to indicate to a caregiver whether any of a variety of monitored parameters, such as, for example, SpO_2, HbCO or HbMet is within acceptable ranges. The monitor may advantageously include additional display information, such as, for example, parametric displays where one parameter is displayed as a function of another, three dimensional displays (for example, extending a parametric display along time or an additional parameter), directional indicators predicting where a parameter is likely heading or reporting a general direction a parameters has been trending, or the like.

In addition to the foregoing, caregivers often desire to more closely monitor parameters that are close to, approaching, or beyond normal safe thresholds. In an embodiment, the patient monitor provides an indication that the caregiver should change display modes to view more critical monitored parameters. In alternative embodiments, the patient monitor automatically changes display modes to show parameters moving closer to or beyond normal thresholds.

In an embodiment, the patient monitor includes an audible or visual indication of a type of sensor communicating with the monitor. For example, the monitor may determine how many wavelengths a particular attached sensor will emit through communication with memory devices associated with the attached sensor or cable.

Additional embodiments include audio or visual alarms for each of multiple monitored parameters, combinations of parameters, an indication of perfusion in the tissue of the measurement site, an indication of the confidence the signal processing has in its output measurements, or the like.

For purposes of summarization, certain aspects, advantages and novel features are described herein. Of course, it is to be understood that not necessarily all such aspects, advantages or features need to be present in any particular embodiment.

BRIEF DESCRIPTION OF THE DRAWINGS

The drawings and the associated descriptions are provided to illustrate embodiments of the disclosure and not to limit the scope of the claims.

FIG. **1** illustrates a block diagram of an exemplary embodiment of a patient monitoring system including a sensor and a multi-parameter patient monitor.

FIG. **2** illustrates a top elevation view of an exemplary handheld noninvasive multi-parameter patient monitor capable of displaying at least HbCO, such as, for example, the patient monitor of FIG. **1**.

FIG. **3** illustrates an exemplary display of the patient monitor of FIG. **2**.

FIG. **4** illustrates the display of FIG. **3** showing measured values of SpO_2, BPM, perfusion, and type of sensor according to an exemplary embodiment of the patient monitor of FIG. **1**.

FIG. **5** illustrates the display of FIG. **3** showing measured values of HbCO, perfusion, and type of sensor according to an exemplary embodiment of the patient monitor of FIG. **1**.

FIG. **6** illustrates the display of FIG. **3** showing measured values of SpO_2, HbCO, BPM, perfusion, and type of sensor, according to an exemplary embodiment of the patient monitor of FIG. **1**.

FIG. **7** illustrates a top elevation view of an exemplary handheld noninvasive multi-parameter patient monitor capable of displaying at least HbCO and HbMet, such as, for example, the patient monitor of FIG. **1**.

FIG. **8** illustrates an exemplary display of the patient monitor of FIG. **7**.

FIG. **9** illustrates the display of FIG. **8** showing measured values of SpO_2, BPM, HbCO, HbMet, and type of sensor according to an exemplary embodiment of the patient monitor of FIG. **1**.

FIG. **10** illustrates the display of FIG. **8** showing measured values of HbCO, HbMet, and type of sensor according to an exemplary embodiment of the patient monitor of FIG. **1**.

FIG. **11**A illustrates a perspective view of an exemplary noninvasive multi-parameter patient monitor such as, for example, the patient monitor of FIG. **1**.

FIGS. **11**B-**11**H illustrate display screens of the patient monitor of FIG. **11**A.

DETAILED DESCRIPTION OF PREFERRED AND ALTERNATIVE EMBODIMENTS

Embodiments of the present disclosure include a portable or other multi-parameter patient monitor capable of determining multiple physiological parameters from one or more signals output from one or more light sensitive detectors capable of detecting light attenuated by body tissue carrying pulsing blood. For example, in an embodiment, the monitor advantageously and accurately determines a wide variety of physiological parameters or other calculations as discussed above.

In an embodiment, the display of patient monitor advantageously includes a plurality of display modes enabling more parameter data to be displayed than the available physical display real estate. For example, the patient monitor may include one or more user input keys capable of toggling through measurement data. In an embodiment, the displays include mode indicators providing caregivers easily identifiable visual queues, such as LED's, text, icons, or other indicia providing readily identifiable queues as to which parameter is being displayed. In an embodiment, the display may shift, may be parameter color-coded, or the like to further ensure quick comprehension of which measured parameter is the displayed parameter. For example, in an embodiment, the monitor displays SpO_2 in white, pulse rate (BPM) in green, HbCO in orange, and HbMet in blue when the respective measured parameter is within a "normal" range.

In an embodiment, the patient monitor provides an indication that the caregiver should change display modes to view more critical or time sensitive measured parameters, specific caregiver selected parameters, or the like. For example, the patient monitor may advantageously sound audio or visual alarms that alert the caregiver to particular one or more of worsening parameters, parameters changing in a predetermined pattern or rate, parameters stabilizing below user defined or safe thresholds, caregiver selected parameters, or the like. The monitor may also use alerts that provide audio or visual indications of the severity of the condition, severity of the change, or the like. In alternative embodiments, the patient monitor may automatically change display modes when a particular parameter crosses one or more thresholds. For example, a patient monitor may be displaying a first parameter, such as a plethysmograph, and upon determining measurements indicating that HBMet is trending toward an alarm condition, the monitor may automatically switch from displaying the first parameter to the alarming parameter, or in this case, a trend of the alarming parameter.

In an embodiment, a switch is provided to allow a user to switch displays to view an alarming measurement. In an embodiment, during an alarm condition, a parameter display may switch to a trend graph in the same or different color, line weight, flash, flash rate, intensity, size, or the like.

The patient monitor may also include one or more displays capable of displaying trend data for any one or more of the monitored or derived patient parameters. For example, the trend data may be displayed in graph form, may include multiple trend lines, each representing a different monitored or derived patient parameter. Moreover, each trend line may be color-coded to facilitate quick comprehension of which trend line represents which measured parameter. However, an artisan will recognize from the disclosure herein a large number of identification techniques including color-coding, identifying text, or the like. Additionally, user input may toggle displayed trend data, may select which parameters to display simultaneously, or the like.

In an embodiment, the patient monitor includes an audible or visual indication of a type of sensor communicating with the monitor. For example, the patient monitor may provide a particular audio or visual indication, such as a beep, LED activation, graphic activation, text messages, voice messages, or the like, to indicate communication with or connection to an approved sensor, patient cable, combination, or the like. In an embodiment, the indication may change based on the manufacturer, type of sensor recognized or not recognized, type of patient, type of physiological parameters measurable with the attached sensor, or the like. Additional embodiments include an indication of perfusion in the tissue of the measurement site and an indication of the confidence the signal processing has in its output measurements or input signal quality.

To facilitate an understanding of the disclosure, the remainder of the description references exemplary embodiments illustrated in the drawings. Moreover, in this application, reference is made to many blood parameters. Some references that have common shorthand designations are referenced through such shorthand designations. For example, as used herein, HbCO designates carboxyhemoglobin, HbMet designates methemoglobin, and Hbt designates total hemoglobin. Other shorthand designations such as COHb, MetHb, and tHb are also common in the art for these same constituents. These constituents are generally reported herein in terms of a percentage, often referred to as saturation, relative concentration or fractional saturation. Total hemoglobin is generally reported as a concentration in g/dL. The use of the particular shorthand designators presented in this application does not restrict the term to any particular manner in which the designated constituent is reported.

FIG. **1** illustrates a block diagram of an exemplary embodiment of a patient monitoring system **100**. As shown in FIG. **1**, the system **100** includes a patient monitor **102** comprising a processing board **104** and a host instrument **108**. The processing board **104** communicates with a sensor **106** to receive one or more intensity signal(s) indicative of one or more parameters of tissue of a patient. The processing board **104** also communicates with a host instrument **108** to display determined values calculated using the one or more intensity signals. According to an embodiment, the board **104** comprises processing circuitry arranged on one or more printed circuit boards capable of installation into the monitor **102**, or capable of being distributed as some or all of one or more OEM components for a wide variety of host instruments monitoring a wide variety of patient information. In an embodiment, the processing board **102** comprises a sensor interface **110**, a digital signal processor and signal extractor ("DSP" or "processor") **112**, and an instrument manager **114**. In general, the sensor interface **110** converts digital control signals into analog drive signals capable of driving sensor emitters, and converts composite analog intensity signal(s) from light sensitive detectors into digital data.

In an embodiment, the sensor interface **110** manages communication with external computing devices. For example, in an embodiment, a multipurpose sensor port (or input/output port) is capable of connecting to the sensor **106** or alternatively connecting to a computing device, such as a personal computer, a PDA, additional monitoring equipment or networks, or the like. When connected to the computing device, the processing board **104** may upload various stored data for, for example, off-line analysis and diagnosis. The stored data may comprise trend data for any one or more of the measured parameter data, plethysmograph waveform data acoustic sound waveform, or the like. Moreover, the processing board **104** may advantageously download from the computing device various upgrades or executable programs, may perform diagnosis on the hardware or software of the monitor **102**. In addition, the processing board **104** may advantageously be used to view and examine patient data, including raw data, at or away from a monitoring site, through data uploads/downloads, or network connections, combinations, or the like, such as for customer support purposes including software maintenance, customer technical support, and the like. Upgradable sensor ports are disclosed in copending U.S. application Ser. No. 10/898,680, filed on Jul. 23, 2004, titled "Multipurpose Sensor Port," incorporated by reference herein.

As shown in FIG. **1**, the digital data is output to the DSP **112**. According to an embodiment, the DSP **112** comprises a processing device based on the Super Harvard ARChitecture ("SHARC"), such as those commercially available from Analog Devices. However, a skilled artisan will recognize from the disclosure herein that the DSP **112** can comprise a wide variety of data and/or signal processors capable of executing programs for determining physiological parameters from input data. In particular, the DSP **112** includes program instructions capable of receiving multiple channels of data related to one or more intensity signals representative of the absorption (from transmissive or reflective sensor systems) of a plurality of wavelengths of emitted light by body tissue. In an embodiment, the DSP **112** accepts data related to the absorption of eight (8) wavelengths of light, although an artisan will recognize from the disclosure herein that the data can be related to the absorption of two (2) to sixteen (16) or more wavelengths.

FIG. **1** also shows the processing board **104** including the instrument manager **114**. According to an embodiment, the instrument manager **114** may comprise one or more microcontrollers controlling system management, including, for example, communications of calculated parameter data and the like to the host instrument **108**. The instrument manager **114** may also act as a watchdog circuit by, for example, monitoring the activity of the DSP **112** and resetting it when appropriate.

The sensor **106** may comprise a reusable clip-type sensor, a disposable adhesive-type sensor, a combination sensor having reusable and disposable components, or the like. Moreover, an artisan will recognize from the disclosure herein that the sensor **106** can also comprise mechanical structures, adhesive or other tape structures, Velcro wraps or combination structures specialized for the type of patient, type of monitoring, type of monitor, or the like. In an embodiment, the sensor **106** provides data to the board **104** and vice versa through, for example, a patient cable. An artisan will also recognize from the disclosure herein that such communication can be wireless, over public or private networks or computing systems or devices, or the like.

As shown in FIG. **1**, the sensor **106** includes a plurality of emitters **116** irradiating the body tissue **118** with differing wavelengths of light, and one or more detectors **120** capable of detecting the light after attenuation by the tissue **118**. In an embodiment, the emitters **116** comprise a matrix of eight (8) emission devices mounted on a flexible substrate, the emission devices being capable of emitting eight (8) differing wavelengths of light. In other embodiments, the emitters **116** may comprise twelve (12) or sixteen (16) emitters, although other numbers of emitters are contemplated, including two (2) or more emitters. As shown in FIG. **1**, the sensor **106** may include other electrical components such as, for example, a memory device **122** comprising an EPROM, EEPROM, ROM, RAM, microcontroller, combinations of the same, or the like. In an embodiment, other sensor components may include a temperature determination device **123** or other mechanisms for, for example, determining real-time emission wavelengths of the emitters **116**.

The memory **122** may advantageous store some or all of a wide variety data and information, including, for example, information on the type or operation of the sensor **106**; type or identification of sensor buyer or distributor or groups of buyer or distributors, sensor manufacturer information, sensor characteristics including the number of emitting devices, the number of emission wavelengths, data relating to emission centroids, data relating to a change in emission characteristics based on varying temperature, history of the sensor temperature, current, or voltage, emitter specifications, emitter drive requirements, demodulation data, calculation mode data, the parameters for which the sensor is capable of supplying sufficient measurement data (e.g., HpCO, HpMet, HbT, or the like), calibration or parameter coefficient data, software such as scripts, executable code, or the like, sensor electronic elements, whether the sensor is a disposable, reusable, multisite, partially reusable, partially disposable sensor, whether it is an adhesive or non-adhesive sensor, whether the sensor is a reflectance, transmittance, or transreflectance sensor, whether the sensor is a finger, hand, foot, forehead, or ear sensor, whether the sensor is a stereo sensor or a two-headed sensor, sensor life data indicating whether some or all sensor components have expired and should be replaced, encryption information, keys, indexes to keys or hash functions, or the like, monitor or algorithm upgrade instructions or data, some or all of parameter equations, information about the patient, age, sex, medications, and other information that may be useful for the accuracy or alarm settings and sensitivities, trend history, alarm history, or the like. In an embodiment, the monitor may advantageously store data on the memory device, including, for example, measured trending data for any number of parameters for any number of patients, or the like, sensor use or expiration calculations, sensor history, or the like.

FIG. **1** also shows the patient monitor **102** including the host instrument **108**. In an embodiment, the host instrument **108** communicates with the board **104** to receive signals indicative of the physiological parameter information calculated by the DSP **112**. The host instrument **108** preferably includes one or more display devices **124** capable of displaying indicia representative of the calculated physiological parameters of the tissue **118** at the measurement site. In an embodiment, the host instrument **108** may advantageously comprise a handheld housing capable of displaying one or more of a pulse rate, plethysmograph data, perfusion quality such as a perfusion quality index ("PI™"), signal or measurement quality ("SQ"), values of blood constituents in body tissue, including for example, SpO_2, HbCO, HbMet, Hbt, or the like. In other embodiments, the host instrument **108** is capable of displaying values for one or more of Hbt, Hb, blood glucose, bilirubin, or the like. The host instrument **108** may be capable of storing or displaying historical or trending data related to one or more of the measured values, combinations of the measured values, plethysmograph data, or the like. The host instrument **108** also includes an audio indicator **126** and user input device **128**, such as, for example, a keypad, touch screen, pointing device, voice recognition device, or the like.

In still additional embodiments, the host instrument **108** includes audio or visual alarms that alert caregivers that one or more physiological parameters are falling below predetermined safe thresholds. The host instrument **108** may include indications of the confidence a caregiver should have in the displayed data. In a further embodiment, the host instrument **108** may advantageously include circuitry capable of determining the expiration or overuse of components of the sensor **106**, including, for example, reusable elements, disposable elements, or combinations of the same.

Although described in terms of certain embodiments, other embodiments or combination of embodiments will be apparent to those of ordinary skill in the art from the disclosure herein. For example, the monitor **102** may comprise one or more monitoring systems monitoring parameters, such as, for example, vital signs, blood pressure, ECG or EKG, respiration, glucose, bilirubin, or the like. Such systems may combine other information with intensity-derived information to

influence diagnosis or device operation. Moreover, the monitor **102** may advantageously include an audio system, preferably comprising a high quality audio processor and high quality speakers to provide for voiced alarms, messaging, or the like. In an embodiment, the monitor **102** may advantageously include an audio out jack, conventional audio jacks, headphone jacks, or the like, such that any of the display information disclosed herein may be audiblized for a listener. For example, the monitor **102** may include an audible transducer input (such as a microphone, piezoelectric sensor, or the like) for collecting one or more of heart sounds, lung sounds, trachea sounds, or other body sounds and such sounds may be reproduced through the audio system and output from the monitor **102**. Also, wired or wireless communications (such as Bluetooth or WiFi, including IEEE 801.11a, b, or g), mobile communications, combinations of the same, or the like, may be used to transmit the audio output to other audio transducers separate from the monitor **102**.

For example, patterns or changes in the continuous noninvasive monitoring of intensity-derived information may cause the activation of other vital sign measurement devices, such as, for example, blood pressure cuffs.

FIG. **2** illustrates a perspective view of an exemplary handheld noninvasive multi-parameter patient monitor **200**, such as, for example, the patient monitor **102** of FIG. **2**. Patient monitors **200** exhibiting combinations of many of the features described herein are advantageously commercially available from Masimo under the brand name "Rad 57c." As shown in FIG. **1**, the monitor **200** includes a patient cable connector **202** capable of mechanical mating with a patient cable to establish communication between the board **104** and the sensor **106**. In an embodiment, the connector **202** comprises a multipurpose cable connector such as that disclosed in the incorporated U.S. application Ser. No. 10/898,680, titled "Multipurpose Sensor Port," disclosing communication between the board **104** and an external computing device.

The monitor **202** also comprises a HbCO indicator **204** advantageously providing a visual queue that a HbCO capable sensor is properly connected through the connector **202**. For example, the HbCO indicator **204** may advantageously activate when a sensor is connected that communicates sufficient information to determine HbCO, such as, for example, a sensor capable of emitting sufficient different wavelengths of light, a sensor storing sufficient data on the memory **122**, a sensor having appropriate encryption data or key, combinations of the same, or the like. For example, in an embodiment, the processor **112** may receive information from a memory **122** indicating a number of available LED wavelengths for the attached sensor. Based on the number of wavelengths, or other information stored on the memory **122**, the processor **112** may determine whether an HbCO-ready sensor has been attached to the monitor **200**. An artisan will also recognize from the disclosure herein that the HbCO indicator **204** may advantageously comprise a HbMet indicator, Hbt indicator, or the like, which activates to a predetermined color associated with a parameter, or any color, or deactivates the same, to convey a type of attached sensor. Moreover, the artisan will recognize from the disclosure herein other parameters that may use other sensor components and the monitor **200** may include indicators capable of indicating communication with those types of sensors.

In an embodiment, the monitor **200** may also audibly indicate the type of sensor connected. For example, the monitor **200** may emit predetermined number or frequency of beeps associated with recognition of a particular sensor, a particular manufacturer, failure to recognize the sensor, or the like. Moreover, the sensor type may be indicative of the componentry, such as, for example, whether the sensor produces sufficient data for the determination of HbCO, HbMet, Hbt and SpO_2, SpO_2 only, SpO_2 and HbMet, any combination of the foregoing or other parameters, or the like. Additionally, the sensor type may be indicative of specific sensors designed for a type of patient, type of patient tissue, or the like. In other embodiments, the monitor **200** may announce the type of connector through speaker **236**.

An artisan will also recognize from the disclosure herein that other mechanical (such as keys), electrical, or combination devices may inform the monitor **202** of the type of attached sensor. In an embodiment, the processor **112** also may select to drive less emitters that are currently available, such as, for example, in the presence of low noise and when power consumption is an issue.

The monitor **202** also comprises a multi-mode display **206** capable of displaying, for example, measurements of SpO_2 and HbCO (or alternatively, HbMet). In an embodiment, the display **206** has insufficient space or display real estate to display the many parameters capable of being measured by the monitor **200**. Thus, the multi-mode display **206** may advantageously cycle through two or more measured parameters in an area common to both parameters even when shifted. In such embodiments, the monitor **200** may also advantageously include parameter indicators **208**, **210**, providing additional visual queues as to which parameter is currently displayed. In an embodiment, the display may also cycle colors, flash rates, or other audio or visual queues providing readily identifiable information as to which measured parameter is displayed. For example, when the multi-mode display **206** displays measured values of SpO_2 that are normal, the numbers may advantageously appear in green, while normal measured values of HbCO may advantageously appear in orange, and normal measured values of HbMet may appear in blue. Moreover, in an embodiment, the display **206** flashes at a predefined rate when searching for saturation and at another predefined rate when a signal quality is below a predetermined threshold.

The monitor **202** also comprises a HbCO bar **212** where in an embodiment a plurality of LED's activate from a bottom toward a top such that the bar "fills" to a level proportional to the measured value. For example, the bar **212** is lowest when the dangers from carbon monoxide poisoning are the least, and highest when the dangers are the greatest. The bar **212** includes indicia **214** that provide an indication of the severity of carbon monoxide saturation in a patient's blood. As shown in FIG. **2**, the bar **212** and the indicia **214** continuously indicate the concentration of HbCO in about 5% increments. The indicia **214** indicate a measurement of HbCO saturation percentage between about 0 and about 50% with a granularity of about 5%. However, an artisan will also recognize from the disclosure herein a wide variety of ranges and granularities could be used, the indicia **214** could be electronically displayed in order to straightforwardly increase or decrease resolution, or the like. For example, HbCO may advantageously be displayed with greater resolution than ±about %5 in a lower portion of the scale. For example, an HbCO bar may advantageously include a scale of about <3%, about 6%, about 9%, about 12%, about 15%, about 20%, about 25%, about 30%, about 35%, and about >40%.

As is known in the art, carbon monoxide in the blood can lead to serious medical issues. For example and depending upon the particular physiology of a patient, about 10% carbon monoxide saturation can lead to headaches, about 20% can lead to throbbing headaches, or dyspnea on exertion, about 30% can lead to impaired judgment, nausea, dizziness and/or vomiting, visual disturbance, or fatigue, about 40% can lead

to confusion and syncope, and about 50% and above can lead to comas, seizures, respiratory failure and even death.

In an embodiment, the bar **212** is the same or similar color as the multi-mode display **206** when displaying HbCO. In other embodiments, the bar **212** is lowest and green when the dangers from carbon monoxide poisoning are the least, and highest and red when the dangers are the greatest. In an embodiment, as HbCO increases, the entire bar **212** may advantageously change color, such as, for example, from green to red, to provide a clear indication of deepening severity of the condition. In other embodiments, the bar **212** may advantageously blink or flash, an audio alarm may beep or provide a continuation or rise in pitch or volume, or the like to alert a caregiver of deepening severity. Moreover, straightforward to complex alarm rules may be implemented to reduce false alarms based on, for example, knowledge of the physiological limitations on the rate of change in HbCO or the like.

Additionally, the monitor **200** may be capable of storing and outputting historical parameter data, display trend traces or data, or the like. Although the foregoing bar **212** has been described in terms of certain preferred embodiments, other embodiments will be apparent to those of ordinary skill in the art from the disclosure herein.

FIG. **2** also shows the monitor **200** including a pulse display **216** displaying measured pulse rate in beats per minute ("BPM"). In an embodiment, the display **212** flashes when searching for a pulse. The pulse display **216** advantageously displays measured pulse rates from about zero (0) to about two hundred and forty (240) BPM. Moreover, when the measured pulse rates are considered normal, the pulse display **216** is advantageously green. Similar to other displays associated with the monitor **200**, the pulse display **216** may employ a variety of color changes, audio alarms, or combinations of the same to indicate measured BPM below predetermined safe thresholds. In an embodiment, the pulse rate display **216** displays the measured pulse rate during the display of SpO_2 and displays message data during the display of other parameters. For example, during the display of HbCO, the display **216** may advantageously display the term "CO." In an embodiment, the display of the message data may be in the same or similar color as the other displays. For example, in an embodiment, the multi-mode display **206**, the bar **212**, and the pulse display **216** may all display data or messages in orange when the multi-mode display **206** displays measured HbCO values.

FIG. **2** also illustrates the monitor **200** comprising user input keys **218**, including a HbCO button **220**, mode/enter button **222**, next button **224**, power on/off button **226**, up/down button **228**, and alarm silence button **230**. In an embodiment, activation of the HbCO button **220** toggles the measured value displayed in the multi-mode display **206**. For example, activation of the HbCO button **220** toggles the multi-mode display **206** from displaying measured values of SpO_2 to HbCO for about ten (10) seconds. Activation of the mode/enter button **222** or the next button **224** during the ten (10) second period returns the multi-mode display **206** back to SpO_2. A skilled artisan will also recognize that activation of the HbCO button **220** may advantageously toggle through a plurality of measured values, and that such values may be displayed for short segments and then return to SpO_2, may remain displayed until further activation of the button **220**, or the like.

Activation of the mode/enter button **222** cycles through various setup menus allowing a caregiver to select or activate certain entries within the menu setup system, including alarm threshold customizations, or the like. Activation of the next button **224** can move through setup options within the menu setup system and in an embodiment is not active during normal patient monitoring. For example, a caregiver may activate the mode/enter button **222** and the next button **224** to specify high and low alarm thresholds for one or more of the measured parameters, to specify device sensitivity, trend settings, display customizations, color code parameters, or the like. In an embodiment, the high alarm setting for SpO_2 can range from about two percent (2%) to about one hundred percent (100%) with a granularity of about one percent (1%). The low alarm setting for SpO_2 can range from about one percent (1%) to about one hundred percent (100%) with a granularity of about one percent (1%). Moreover, the high alarm setting for pulse rate can range from about thirty (30) BPM to about two hundred and forty (240) BPM with a granularity of about five (5) BPM. The low alarm setting for pulse rate can range from about twenty five (25) BPM to about two hundred and thirty five (235) BPM with a granularity of about five (5) BPM. Other high and low ranges for other measured parameters will be apparent to one of ordinary skill in the art from the disclosure herein.

In a further embodiment, a caregiver may activate the mode/enter button **222** and the next button **224** to specify device sensitivity, such as, for example, device averaging times, probe off detection, whether to enable fast saturation calculations, or the like. Various embodiments of fast saturation calculations are disclosed in U.S. patent application Ser. No. 10/213,270, filed Aug. 5, 2002, titled "Variable Indication Estimator" and incorporated by reference herein. Using the menus, a caregiver may also advantageously enter appropriate information governing trend collection on one or more of the measured parameters, input signals, or the like.

FIG. **2** also shows the power on/off button **226**. Activation of the power on/off button **226** activates and deactivates the monitor **200**. In an embodiment, press-and-hold activation for about two (2) seconds shuts the monitor **200** off. In an additional embodiment, activation of the on/off button **226** advantageously initiates detection of a type of attached sensor. For example, activation of the on/off button **226** may advantageously cause the monitor **200** to read information from a memory on an attached sensor and determine whether sufficient wavelengths exist on the sensor to determine one or more the physiological parameters discussed in the foregoing.

An artisan will recognize from the disclosure herein that the on/off button **226** may advantageously cause an electronic determination of whether to operate in at powers consisted with the U.S. (60 Hz) or another nationality (50 Hz). In an embodiment, such automatic determination and switching is removed from the monitor **200** in order to reduce a likelihood of problematic interfering crosstalk caused by such power switching devices.

Activation of the up/down button **228** may advantageously adjust the volume of the pulse beep tone. Additionally, activation of the up/down button **228** within the menu setup system, causes the selection of values with various menu options.

Moreover, activation of the alarm silence button **230** temporarily silences audio alarms for a predetermined period, such as, for example, about one hundred and twenty (120) seconds. A second activation of the alarm silence button **230** mutes (suspends) the alarm indefinitely, while a third activation returns the monitor **200** to standard alarm monitoring. FIG. **2** also shows the alarm silence button **230** includes an alarm silenced indicator **232**. The alarm silenced indicator **232** may advantageously flash to indicate one or more alarms are temporarily silenced, may illuminate solid to indicate the

alarms have been muted, or the like. Moreover, an artisan will recognize from the disclosure herein a wide variety of alarm silencing methodologies.

The monitor **202** also includes a battery level indicator **234** indicating remaining battery life. In the illustrated embodiment, four LED's indicate the status of the battery by incrementally deactivating to indicate proportionally decreasing battery life. In an embodiment, the four LED's may also change color as the battery charge decreases, and the final LED may begin to flash to indicate that the caregiver should replace the batteries.

FIG. **2** also shows the monitor **202** including an audio transducer or speaker **236**. The speaker **236** advantageously provides audible indications of alarm conditions, pulse tone and feedback for key-presses, or the like. Moreover, the monitor **202** includes a low signal quality indicator ("SQ" or "SIQ™") **238**. The signal IQ indicator **238** activates to inform a caregiver that a measured value of the quality of the incoming signal is below predetermined threshold values. For example, in an embodiment, the measured value for signal IQ is at least partially based on an evaluation of the plethysmograph data's correspondence to predetermined models or characteristics of physiological signals. In an embodiment, the signal IQ indicator **238** output may be associated with the displayed parameter. For example, the output may be associated with one threshold for the display of SpO_2 and another for the display of other parameter data.

The monitor **202** also comprises a perfusion quality index ("PI™") bar **240** (which quantifies the measure of perfusion of the patient) where in an embodiment a plurality of LED's activate from a bottom toward a top such that the bar "fills" to a level proportional to the measured value. In one embodiment, the PI™ bar **240** shows a static value of perfusion for a given time period, such as, for example, one or more pulses. In another embodiment, or functional setting, the PI™ bar **240** may advantageously pulse with a pulse rate, may hold the last reading and optionally fade until the next reading, may indicate historical readings through colors or fades, or the like. Additionally, the PI™ bar **240** may advantageously change colors, flash, increasingly flash, or the like to indicate worsening measured values of perfusion.

The PI™ bar **240** can be used to simply indicate inappropriate occlusion due, for example, to improper attachment of the sensor **106**. The PI™ bar **240** can also be used as a diagnostic tool during low perfusion for the accurate prediction of illness severity, especially in neonates. Moreover, the rate of change in the PI™ bar **240** can be indicative of blood loss, sleep arousal, sever hypertension, pain management, the presence or absence of drugs, or the like. According to one embodiment, the PI™ bar **240** values may comprise a measurement of the signal strength of the arterial pulse as a percentage of the total signal received. For example, in one preferred embodiment, the alternating portion of at least one intensity signal from the sensor **106** may advantageously be divided by the static portion of the signal. For example, an infrared intensity signal may advantageously be used as it is less subjective to noise.

In an embodiment, a measurement below about 1.25% may indicate medical situations in need of caregiver attention, specifically in monitored neonates. Because of the relevance of about 1.25%, the PI™ bar **240** may advantageously include level indicia **242** where the indicia **242** swap sides of the PI™ bar **240**, thus highlighting any readings below about that threshold. Moreover, behavior of the PI™ bar **240**, as discussed above, may advantageously draw attention to monitored values below such a threshold.

As discussed above, the monitor **200** may include output functionality that outputs, for example, trend perfusion data, such that a caregiver can monitor measured values of perfusion over time. Alternatively or additionally, the monitor **200** may display historical trace data on an appropriate display indicating the measured values of perfusion over time. In an embodiment, the trend data is uploaded to an external computing device through, for example, the multipurpose sensor connector **202** or other input output systems such as USB, serial or parallel ports or the like.

The monitor **200** also includes an alarm indicator **244** capable of providing visual queues of the status of one or more of the measured parameters. For example, the alarm indicator **244** may advantageously be green when all of the measured parameters are within normal conditions, may gradually fade to red, may flash, increasing flash, or the like, as one or more of the measured values approaches or passes predetermined thresholds. In an embodiment, the alarm indicator **244** activates when any parameter falls below an associated threshold, thereby advantageously informing a caregiver that perhaps a nondisplayed parameters is at an alarm condition. In another embodiment, the alarm indicator **244** may indicate the status of the parameter displayed on the multi-mode display **206**. In an embodiment, the speaker **236** may sound in conjunction with and/or in addition to the indicator **244**. Moreover, in an embodiment, an alarming parameter may automatically be displayed, may be emphasized, flashed, colored, combinations of the same or the like to draw a user's attention to the alarming parameter.

Although the foregoing invention has been described in terms of certain preferred embodiments, other embodiments will be apparent to those of ordinary skill in the art from the disclosure herein.

FIG. **3** illustrates an exemplary display of the patient monitor **200**. As shown in FIG. **3**, the display includes the multi-mode display **206**, the pulse rate display **216**, parameter indicators **208**, **210**, the HbCO bar **212** and indicator **204**, the PI™ bar **240**, and the alarm indicator **244**. In an embodiment, the multi-mode display **206** and the pulse rate display **216** each comprise a plurality of seven segment displays **302** capable of displaying alpha-numeric information. As disclosed in the foregoing, the exemplary display may advantageously include color-coded parameter displays. Moreover, the exemplary display may include color progressions, flashing, flashing progressions, audible alarms, audible progressions, or the like, indicating worsening measured values of physiological data. In addition, in an embodiment, some or all of the displays may flash at a first rate to indicate attempts to acquire data when actual measured values are unavailable. Moreover, some or all of the display may flash at a second rate to indicate low signal quality where confidence is decreasing that the measured values reflect actual physiological conditions.

FIG. **4** illustrates the display of FIG. **3** showing measured values of SpO_2, BPM, perfusion, and type of sensor, according to an exemplary embodiment of the patient monitor of FIG. **1**. As shown in FIG. **4**, the multi-mode display **206** is displaying a percentage value of SpO_2, and the pulse rate display **216** is displaying a pulse rate in beats per minute. Accordingly, the parameter indicator **210** is activated to confirm the display of measured values of SpO_2. As disclosed in the foregoing, in an embodiment, the multi-mode display **206** is red, indicating blood oxygen measurements while the pulse rate display **216** is green, indicating normal values of a patient's pulse.

FIG. **4** also shows the PI™ bar **240** almost fully activated, representing good perfusion. In addition, the HbCO indicator **204** is showing communication with a sensor producing

insufficient data to determine measured values of additional parameters, such as, HbCO. In an embodiment, such sensors may comprise sensors capable of emitting light at about two (2) different wavelengths, may comprise sensors with insufficient data stored on a memory associated therewith, or the like.

FIG. **5** illustrates the display of FIG. **3** showing measured values of HbCO, perfusion, and type of sensor, according to an exemplary embodiment of the patient monitor of FIG. **1**. As shown in FIG. **5**, the multi-mode display **206** is displaying a percentage value of HbCO, and the pulse rate display **216** is displaying an appropriate message indicating the HbCO measurement, such as, for example, "CO". Also, the multi-mode display **206** has shifted the data to the left to quickly and efficiently indicate that the displayed parameter is other than SpO_2. Accordingly, the parameter indicator **208** is also activated to confirm the display of measured values of HbCO. As disclosed in the foregoing, in an embodiment, the multi-mode display **206** and pulse rate display message **216** are orange.

FIG. **5** also shows the PI™ bar **240** almost fully activated, representing good perfusion. In addition, the activation of the HbCO indicator **204** represents communication with a sensor capable of producing sufficient data to determine measured values of HbCO. In an embodiment, such sensors may comprise sensors capable of emitting light at about eight (8) or more different wavelengths; however, such sensors may comprise about two (2) or more different wavelengths. Moreover, such sensors may have appropriate data stored on a memory associated therewith, or the like. FIG. **5** also shows the HbCO measurement being about 20% (as illustrated on the HbCO bar **212** and multi-mode display **206**) thereby indicating a potentially dangerous situation that if exacerbated, will become quite problematic. Therefore, the alarm indicator **244** is also activated, and in some embodiments, the speaker **236** as well.

FIG. **6** illustrates the display of FIG. **3** showing measured values of SpO_2, HbCO, BPM, perfusion, and type of sensor, according to an exemplary embodiment of the patient monitor of FIG. **1**. In contrast to FIG. **4**, FIG. **6** shows that the monitor **200** is communicating with a sensor capable of producing sufficient data to determine measured values of HbCO, even though the displayed values are that of SpO_2 and BPM. Thus, FIG. **6** shows the activation of the HbCO indicator **204**, and the continuous monitoring of HbCO by the HbCO bar **212**. FIG. **6** also shows a high value of HbCO, and therefore, the indication of an alarm condition by activation of the alarm indicator **244**. In an embodiment, upon determination of an alarm condition on a nondisplayed parameter, the monitor **200** may advantageously provide an alarm indication through speaker and alarm indicator activation, automatic toggle to the nondisplayed parameter on the multi-mode display **206** for a defined or undefined time, or the like.

FIG. **7** illustrates a top elevation view of an exemplary handheld noninvasive multi-parameter patient monitor **700** capable of displaying at least HbCO and HbMet, such as, for example, the patient monitor of FIG. **1**. Patient monitors exhibiting combinations of many of the features described herein are advantageously commercially available from Masimo under the brand name "Rad 57 cm." As shown in FIG. **7**, the monitor **700** comprises a monitor similar to monitor **200** disclosed with reference to FIG. **2**. Moreover, monitor **700** further includes a multi-mode display **706** capable of displaying, for example, measurements of HbMet and BPM. In an embodiment, the display **706** has insufficient space or display real estate to display the many parameters capable of being measured by the monitor **700**. Thus, the multi-mode display **706** may advantageously cycle through two or more measured parameters. In such embodiments, the monitor **700** may also advantageously include parameter indicators **708**, **710**, providing additional visual queues as to which parameter is currently displayed. In an embodiment, the display **706** may also cycle colors, flash rates, or other audio or visual queues providing readily identifiable information as to which measured parameter is displayed. For example, when the multi-mode display **706** displays measured values of BPM that are normal, the numbers may advantageously appear in green, while normal measured values of HbMet may appear in blue. Moreover, in an embodiment, the display **706** may flash at a predefined rate when searching for saturation and at another predefined rate when a signal quality is below a predetermined threshold.

FIG. **7** also illustrates the monitor **700** comprising user input keys **718**, including an HbCO/HbMet button **220**. In an embodiment, activation of the HbCO/HbMet button **720** toggles the measured value displayed in the multi-mode display **706**. For example, activation of the HbCO/HbMet button **720** toggles the multi-mode display **206** from displaying measured values of SpO_2 and BPM, to HbCO and HbMet for about ten (10) seconds. Activation of the mode/enter button **222** or the next button **224** during the ten (10) second period returns the multi-mode display **706** back to SpO_2 and BPM. A skilled artisan will also recognize that activation of the HbCO/HbMet button **720** may advantageously toggle through a plurality of measured values, and that such values may be displayed for short segments and then return to SpO_2 and BPM, may remain displayed until further activation of the button **720**, or the like.

The monitor **700** also comprises a coarser indication of HbMet through an HbMet bar **740**. In an embodiment, a plurality of LED's activate from a bottom toward a top such that the bar "fills" to a level proportional to the measured value, with increments at about 0.5%, about 1%, about 2%, about 3%, about 4%, about 5%, about 7.5%, about 10%, about 15% and greater than about 20%, although an artisan will recognize from the disclosure herein other useful delineations. Additionally, the HbMet bar **740** may advantageously change colors, flash, increasingly flash, or the like to indicate worsening measured values of perfusion.

Although disclosed with reference to the HbMet bar **740**, and artisan will recognize from the disclosure herein other coarse or even gross indications of HbMet, or any measured parameter. For example, a single LED may advantageously show green, yellow, and red, to indicate worsening coarse values of HbMet. Alternatively, a single LED may simply light to indicate an alarm or approaching alarm condition.

FIG. **8** illustrates an exemplary display of the patient monitor **700** of FIG. **7**. As shown in FIG. **8**, the display includes the multi-mode displays **206**, **706**, parameter indicators **208**, **210**, **708**, **710**, the HbCO bar **212** and indicator **204**, the HbMet bar **740**, and the alarm indicator **244**. In an embodiment, the multi-mode display **706** is similar to multi-mode display **206**, comprising a plurality of seven segment displays **302** capable of displaying alpha-numeric information, and capable of altering its display characteristics or aspects in a wide variety of configurations discussed with reference to the display **206**.

FIG. **9** illustrates the display of FIG. **8** showing measured values of SpO_2, BPM, HbCO, HbMet, and type of sensor according to an exemplary embodiment of the patient monitor of FIG. **1**. FIG. **9** also shows the HbMet bar **740** near the bottom and corresponding to about 1%, representing acceptable HbMet, while the HbCO bar **212** hovers at a dangerous near 20%. In addition, the HbCO indicator **204** is showing communication with a sensor producing sufficient data to determine measured values of additional parameters, such as,

HbMet, HbCO or the like. In an embodiment, such sensors may comprise sensors capable of emitting light of more than two (2) different wavelengths, preferably more than four (4) different wavelengths, and more preferably eight (8) or more different wavelengths.

FIG. **10** illustrates the display of FIG. **8** showing measured values of HbCO, HbMet, and type of sensor according to an exemplary embodiment of the patient monitor of FIG. **1**. As shown in FIG. **10**, the multi-mode display **706** is displaying a percentage value of HbMet that is shifted using the parameter indicator **708**. The data has been advantageously shifted to the left to quickly and efficiently indicate that the displayed parameter is other than BPM. Accordingly, the parameter indicator **708** is also activated to confirm the display of measured values of HbMet. As disclosed in the foregoing, in an embodiment, the multi-mode display **706** is blue.

FIG. **10** also shows the HbMet bar **740** nearly empty, representing acceptable HbMet. In addition, the activation of the HbCO indicator **204** represents communication with a sensor capable of producing sufficient data to determine measured values of HbCO. In an embodiment, such sensors may have appropriate data stored on a memory associated therewith, or the like. FIG. **10** also shows the HbCO measurement being about 20% (as illustrated on the HbCO bar **212** and multi-mode display **206**) thereby indicating a potentially dangerous situation that if exacerbated, will become quite problematic. Therefore, the alarm indicator **244** is also activated, and in some embodiments, the speaker **236** as well.

FIG. **11**A illustrates a perspective view of an exemplary noninvasive multi-parameter patient monitor **1100**, such as, for example, the patient monitor of FIG. **1**. Moreover, FIGS. **11**B-**11**E illustrate exemplary display screens of the patient monitor of FIG. **11**A. As shown in FIGS. **11**A-**11**B, an embodiment of the monitor **1100** includes a display **1101** showing a plurality of parameter data. For example, the display may advantageously comprise a CRT or an LCD display including circuitry similar to that available on oximeters commercially available from Masimo Corporation of Irvine, Calif. sold under the name Radical™, and disclosed in the U.S. patents referenced above and incorporated above. However, an artisan will recognize from the disclosure herein many commercially available display components capable of displaying multiple parameter data along with the ability to display graphical data such as plethysmographs, trend traces, and the like.

In an embodiment, the display includes a measured value of SpO_2 **1102**, a measured value of pulse rate **1104** in BPM, a plethysmograph **1106**, a measured value of HbCO **1108**, a measured value of HbMet **1110**, a measured value of a perfusion quality **1112**, a measured value of Hbt **1114**, and a derived value of fractional saturation "$SpaO_2$" **116**. In an embodiment, $SpaO_2$ comprises HbO_2 expressed as a percentage of the four main hemoglobin species, i.e., HbO_2, Hb, HbCO, and HbMet.

In an embodiment, one or more of the foregoing parameter includes trending or prediction indicators **1118** showing the current trend or prediction for that corresponding parameter. In an embodiment, the indicators **1118** may advantageously comprise an up arrow, a down arrow, and a hyphen bar to indicate up trending/prediction, down trending/prediction, or neutral trending/prediction.

FIG. **11**C illustrates an exemplary display screen showing trend graph **1140** including trend line **1142** for HbMet. In an embodiment, the trend line **1142** may be advantageously colored for quick straightforward recognition of the trending parameter, may be associated with any one or more of the foregoing alarm attributes, may include trending lines for other parameters, or the like. The display screen also shows trending directional indicators **1142**, **1144** for many of the displayed physiological parameters. In an embodiment, the directional indicators **1142**, **1144** may advantageously comprises arrows showing the recent trend, predicted trend, user-customizable trend, combinations thereof, or the like for the associated parameters. In an embodiment, the directional indicators **1142**, **1144** comprises an up arrow indicating a rising trend/predicted trend, a middle bar indicating a somewhat stable trend/predicted trend, and a down arrow indicating a lowering trend/predicted trend. An artisan will recognize a wide variety of other directional indicators **1142**, **1144** from the disclosure herein.

FIG. **11**D shows an exemplary display screen in vertical format. Such vertical format could be user actuated or based on a gravity switch. FIGS. **11**E-**11**F illustrate additional displays of various physiological parameters similar to those discussed in the foregoing. being As shown in FIG. **11**G, the display includes a measured value of SpO_2 **1162**, a measured value of pulse rate **1164** in BPM, a plethysmograph **1166**, a HbCO bar **1168**, and a HbMet bar **1170**. In an embodiment, the HbCO bar **1168** and HbMet bar **1170** may advantageously behave the same or similarly to the HbCO bar **212** and HbMet bar **712**. Moreover, similar bars may advantageously display any of the physiological parameters discussed herein using display indicia appropriate to that parameter. For example, a SpO_2 or $SpaO_2$ bar may advantageously range from about 0% to about 100%, and more preferably range from about 50% to about 100%, while a Hbt bar may advantageously range from about 0 to about 30.

Moreover, similar to the disclosure above, the measured value of SpO_2 **1162** may advantageously toggle to measured values of HbCO, HbMet, Hbt, or the like based on, for example, actuation of user input keys, or the like.

In addition to the foregoing, the display may also include graphical data showing one or more color-coded or other identifying indicia for traces of trend data. Moreover, other graphical presentations may advantageously provide readily identifiable indications of monitored parameters or combinations of monitored parameters of the patient. For example, in an embodiment, the display includes a $SpaO_2$ graph **1172**. The $SpaO_2$ graph **1172** plots SpO_2 as a function of other blood analytes (1-$SpaO_2$), where $SpaO_2$ comprises HbO_2 expressed as a percentage of the four main hemoglobin species, i.e., HbO_2, Hb, HbCO, and HbMet. Thus, as shown in FIG. **11**C, as the slope of the displayed line or arrow increases, the caregiver can readily note that the majority of hemoglobin carriers are being used to carry oxygen, and not, for example, harmful carbon monoxide. On the other hand, as the slope decreases, the caregiver can readily and advantageously note that the number of hemoglobin species available to carry oxygen is decreasing, regardless of the current value of SpO_2. Moreover, the length of the arrow or line also provides an indication of wellness, e.g., the higher the line the more oxygen saturation, the lower the line, the more likely there may be desaturation event, or the like.

Thus, the $SpaO_2$ graph **1172** provides the caregiver with the ability to recognize that even though the measured value of SpO_2 may be within acceptable ranges, there are potentially an unacceptable number of hemoglobin carriers unavailable for carrying oxygen, and that other potential problems may exist, such as, for example, harmful carbon monoxide levels, or the like. In an embodiment, various alarm conditions may cause the graph **1172** to change color, flash, or any combination of alarm indications discussed in the forgoing. Moreover, FIG. **11**I illustrates yet an additional display of the foregoing parameters.

An embodiment may also include the monitor **1100** advantageously defining regions of wellness/severity of the monitored patient. For example, because the graph **1172** comprises two dimensions, the monitor **1100** may advantageously define regions where the patient's measured physiological parameters are considered acceptable, regions where the patient is considered at risk, regions where the patient is critical, and the like. For example, one region of acceptability may include a high SpO_2 and a low 1-$SpaO_2$, another region of risk may include a high SpO_2 and a high 1-$SpaO_2$, and another critical region may include a low SpO_2 and a high 1-$SpaO_2$. Moreover, an artisan will recognize from the disclosure herein that different parameters may also be combined to provide readily identifiable indications of patient wellness.

In addition to or as an alternative to the two dimensional $SpaO_2$ graph **1172**, the monitor **1100** may also include a three dimensional graph, such as, for example, extending the graph **1172** along the variable of time. In this embodiment, the forgoing regions advantageously become three dimensional surfaces of wellness. Moreover, trend data may also be advantageously added to the surface to provide a history of when particular monitored parameters dipped in and out of various surfaces of wellness, risk, criticality, or the like. Such trend data could be color-coded, text identified, or the like. An artisan will also recognize that such surfaces may be dynamic. For example, measurements of HbCO>about 5 may dictate that trend data showing SpO_2<about 90% should be considered critical; however, measurements of HbCO<about 5 may dictate only SpO_2<about 85% would be critical. Again, an artisan will recognize from the disclosure herein other parameter combinations to create a wide variety of wellness/critical regions or surfaces that provide readily available visual or audio indications of patient well being, trigger specific alarms, or the like.

Moreover, the monitor **1100** may advantageously employ enlargement or reorganization of parameter data based on, for example, the severity of the measurement. For example, the monitor **1100** may display values for HbCO in a small portion of the screen or in the background, and when HbCO begins to approach abnormal levels, the small portion may advantageously grown as severity increases, even in some embodiments to dominate the display. Such visual alarming can be combined with audio alarms such as announcements, alarms, rising frequencies, or the like, and other visual alarms such as flashing, coloration, or the like to assist a caregiver in noticing the increasing severity of a monitored parameter. In an embodiment, a location of the display of an alarming value is changed to be displayed in a larger display area, such as **1102**, so as to be readily noticeable and its display values readily ascertainable.

Although the foregoing invention has been described in terms of certain preferred embodiments, other embodiments will be apparent to those of ordinary skill in the art from the disclosure herein. For example, the monitor **100** may advantageously be adapted to monitor or be included in a monitor capable of measuring physiological parameters other than those determined through absorption spectroscopy, such as, for example, blood pressure, ECG, EKG, respiratory rates, volumes, inputs for blood pressure sensors, acoustical sensors, and the like. Moreover, the monitor **100** may be adapted for wireless communication to and from the sensor **106**, and/or to and from other monitoring devices, such as, for example, multi-parameter or legacy monitoring devices.

Also, other combinations, omissions, substitutions and modifications will be apparent to the skilled artisan in view of the disclosure herein. Accordingly, the present invention is not intended to be limited by the reaction of the preferred embodiments, but is to be defined by reference to the appended claims.

Additionally, all publications, patents, and patent applications mentioned in this specification are herein incorporated by reference to the same extent as if each individual publication, patent, or patent application was specifically and individually indicated to be incorporated by reference.

What is claimed is:

1. A method of graphically displaying a plurality of physiological measurements on a single display, the method comprising:

obtaining a first physiological measurement;

obtaining a second physiological measurement;

displaying an indication of the first physiological measurement on a first display area;

displaying an indication of the second physiological measurement on the first display area, wherein the first display area alternates between displaying the indication of the first physiological measurement and the indication of the second physiological measurement;

automatically switching between the indication of the first physiological measurement and the indication of the second physiological measurement without human intervention when a trend of either the first physiological measurement or the second physiological measurement indicate an alarm condition.

2. The method of claim **1**, wherein the first physiological measurement is one of carbon monoxide saturation, methemoglobin saturation, total hemoglobin, oxygen saturation, and fractional oxygen saturation.

3. The method of claim **1**, wherein the second physiological measurement is one of carbon monoxide saturation, methemoglobin saturation, total hemoglobin, oxygen saturation, and fractional oxygen saturation.

4. The method of claim **1**, further comprising switching between the indication of the first physiological measurement and the indication of the second physiological measurement based on a user activated input.

5. The method of claim **1**, wherein the indication of the first physiological measurement is an indication of the trend of the first physiological measurement.

6. The method of claim **1**, further comprising changing a color of the displayed indication of the physiological measurement based on a severity of the alarm condition.

7. The method of claim **1**, further comprising changing a size of the indication of the first physiological measurement based on a severity of the alarm condition.

8. A physiological measurement and display system comprising:

a physiological sensor including a plurality of light emitting elements and a detector, the physiological sensor configured to measure and indication of at least two physiological parameters of a patient;

one or more processors configured to determine at least two physiological parameter measurements using the measured indication from the physiological sensor;

a display, the display including a first display area, at least a portion of each of the at least two physiological parameter measurements are alternatively displayed in the same display area, wherein the physiological parameter displayed switches from a first parameter to a second parameter when a trend of the second parameter indicates a worsening condition of the patient.

9. The system of claim **8**, wherein the at least two physiological measurements comprise one or more of carbon mon-

oxide saturation, methemoglobin saturation, total hemoglobin, oxygen saturation, and fractional oxygen saturation.

10. The system of claim **8**, wherein a color of the displayed physiological parameter measurement is changed based on a severity of the worsening condition of the patient.

11. The system of claim **8**, wherein a size of the displayed physiological parameter measurement is changed based on a severity of the worsening condition of the patient.

12. A physiological parameter display system capable of receiving and displaying measurements, the system comprising:

a display configured to display a plurality of indications of physiological measurements of a patient; and

at least one processor configured to alternate displaying at least two different measurement indications of physiological parameters in the same display area of the display, the at least one processor configured to switch from displaying a first measurement indication to displaying a second measurement indication when the second measurement indication indicates a worsening state of a patient under measurement.

13. The system of claim **12**, wherein the plurality of indications of physiological measurements of a patient comprise one or more of carbon monoxide saturation, methemoglobin saturation, total hemoglobin, oxygen saturation, and fractional oxygen saturation.

14. The system of claim **12**, wherein a color of the displayed measurement indication is changed based on a severity of the worsening condition of the patient.

15. The system of claim **12**, wherein a size of the displayed measurement indication is changed based on a severity of the worsening condition of the patient.

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