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(54) **ROBUST FRACTIONAL SATURATION DETERMINATION**

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See application file for complete search history.

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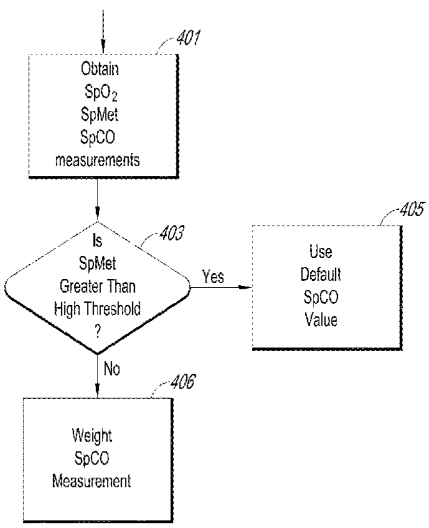
(57) **ABSTRACT**

The present disclosure describes the derivation and measurement of a fractional oxygen saturation measurement. In one embodiment, a system includes an optical sensor and a processor. The optical sensor can emit light of multiple wavelengths directed at a measurement site of tissue of a patient, detect the light after attenuation by the tissue, and produce a signal representative of the detected light after attenuation. The processor can receive the signal representative of the detected light after attenuation and determine, using the signal, a fractional oxygen saturation measurement based on two or more different measures of fractional oxygen saturation.

20 Claims, 7 Drawing Sheets



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2014/0194766	A1	7/2014	Al-Ali et al.
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2014/0330098	A1	11/2014	Merritt et al.
2014/0330099	A1	11/2014	Al-Ali et al.
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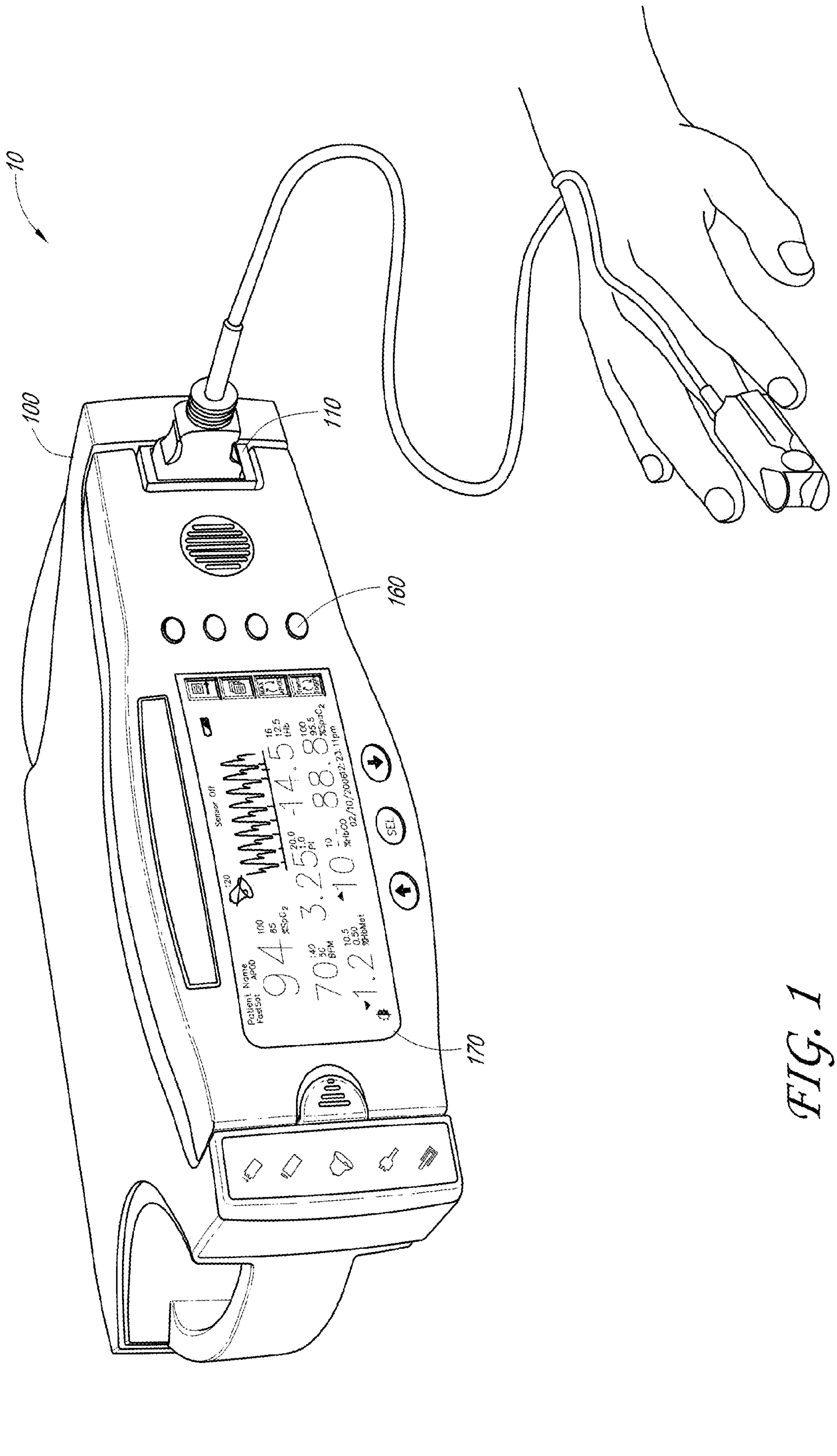

FIG. 1

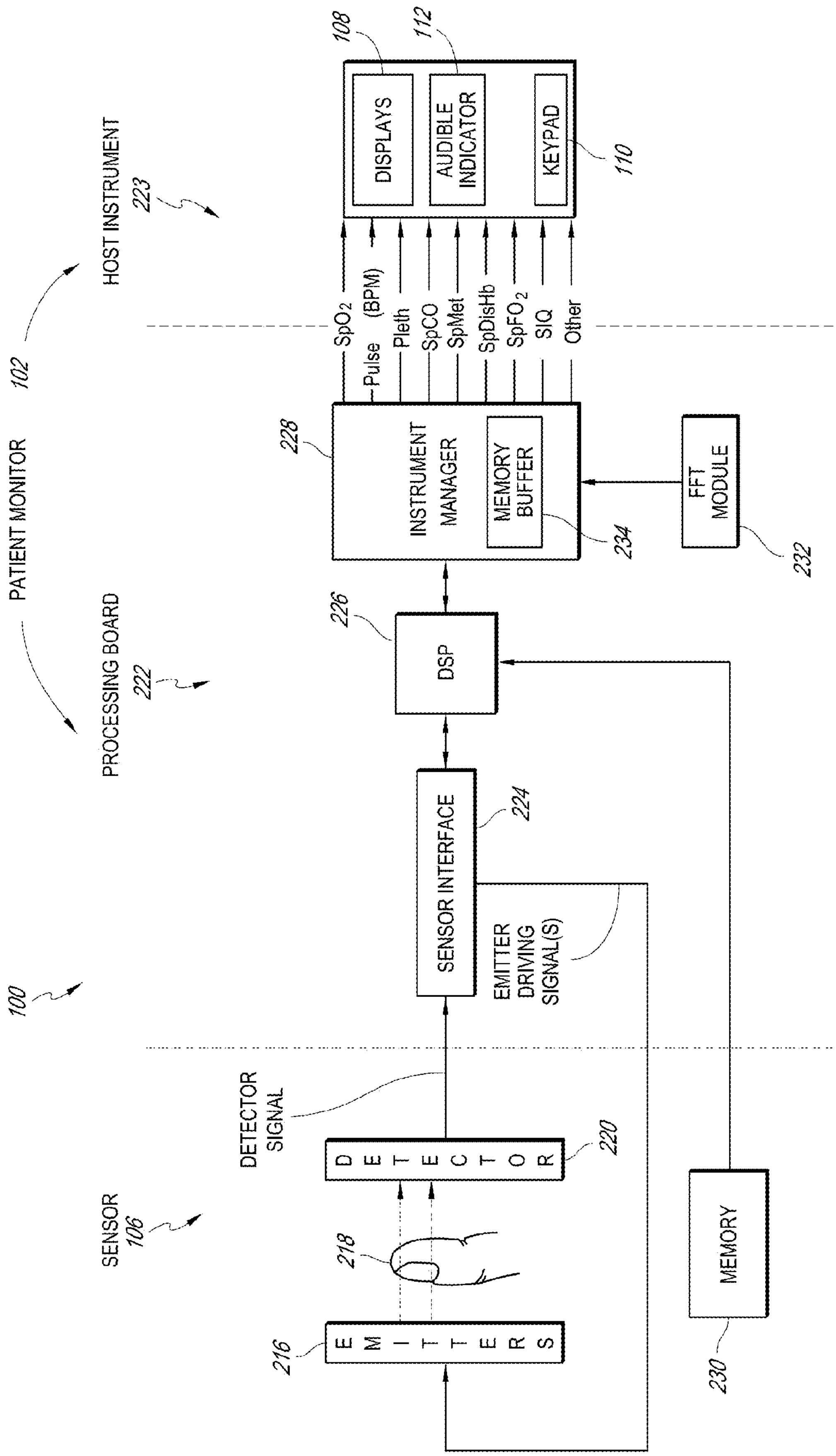
100
102
PATIENT MONITOR
PROCESSING BOARD
222
HOST INSTRUMENT
223
SENSOR
106
216
EMITTERS
218
220
DETECTOR
DETECTOR SIGNAL
SENSOR INTERFACE
224
EMITTER DRIVING SIGNAL(S)
DSP
226
INSTRUMENT MANAGER
228
MEMORY BUFFER
234
FFT MODULE
232
MEMORY
230
SpO2
Pulse (BPM)
Pleth
SpCO
SpMet
SpDisHb
SpFO2
SIQ
Other
DISPLAYS
108
AUDIBLE INDICATOR
112
KEYPAD
110

FIG. 2

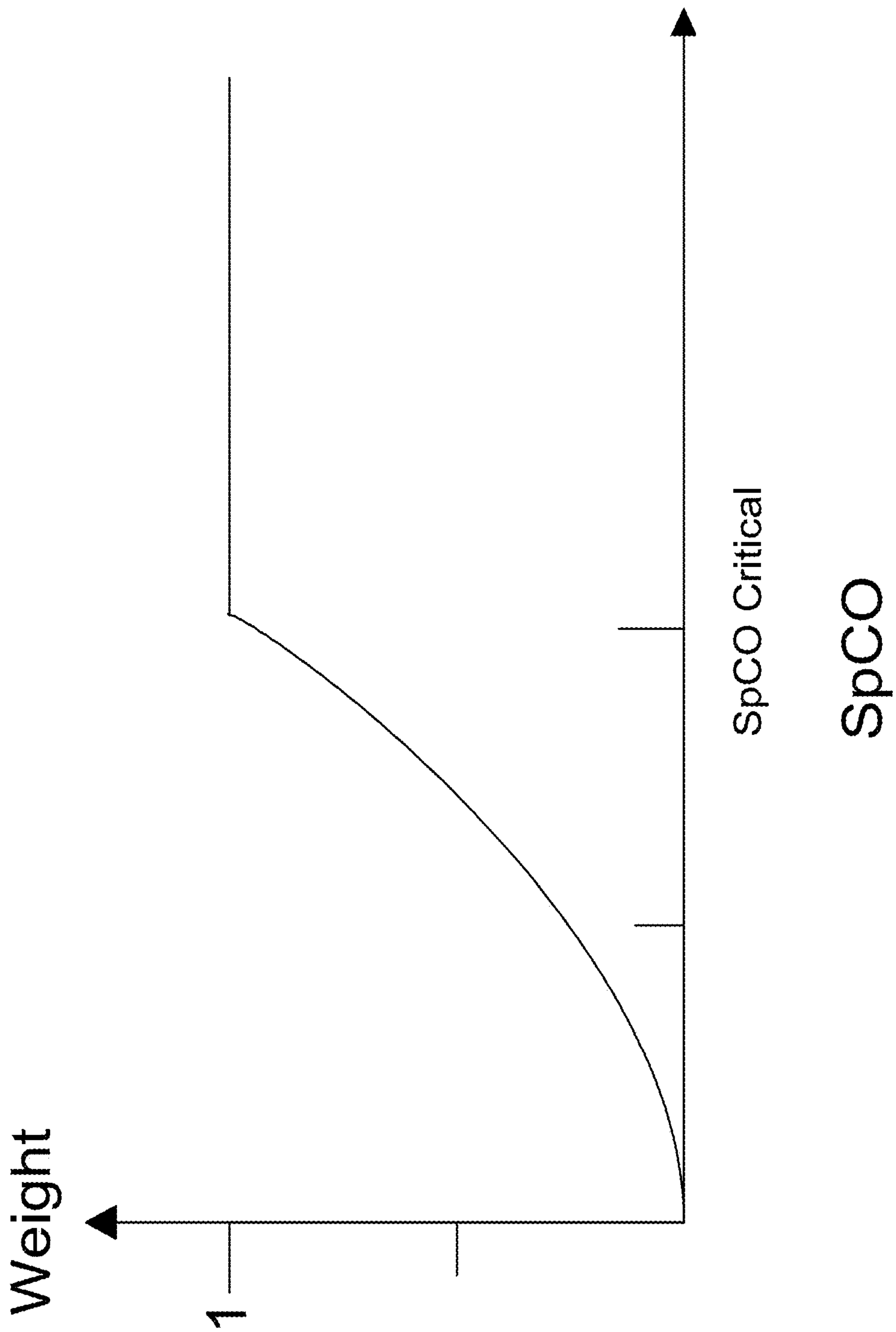

FIG. 3

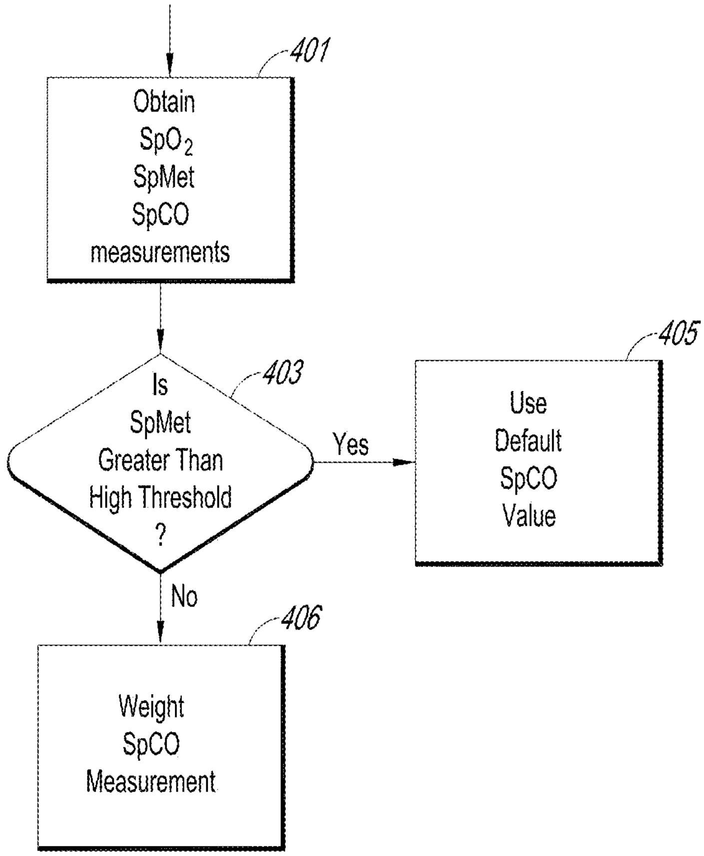
401
Obtain
SpO_2
SpMet
SpCO
measurements
403
Is
SpMet
Greater Than
High Threshold
?
Yes
405
Use
Default
SpCO
Value
No
406
Weight
SpCO
Measurement

FIG. 4A

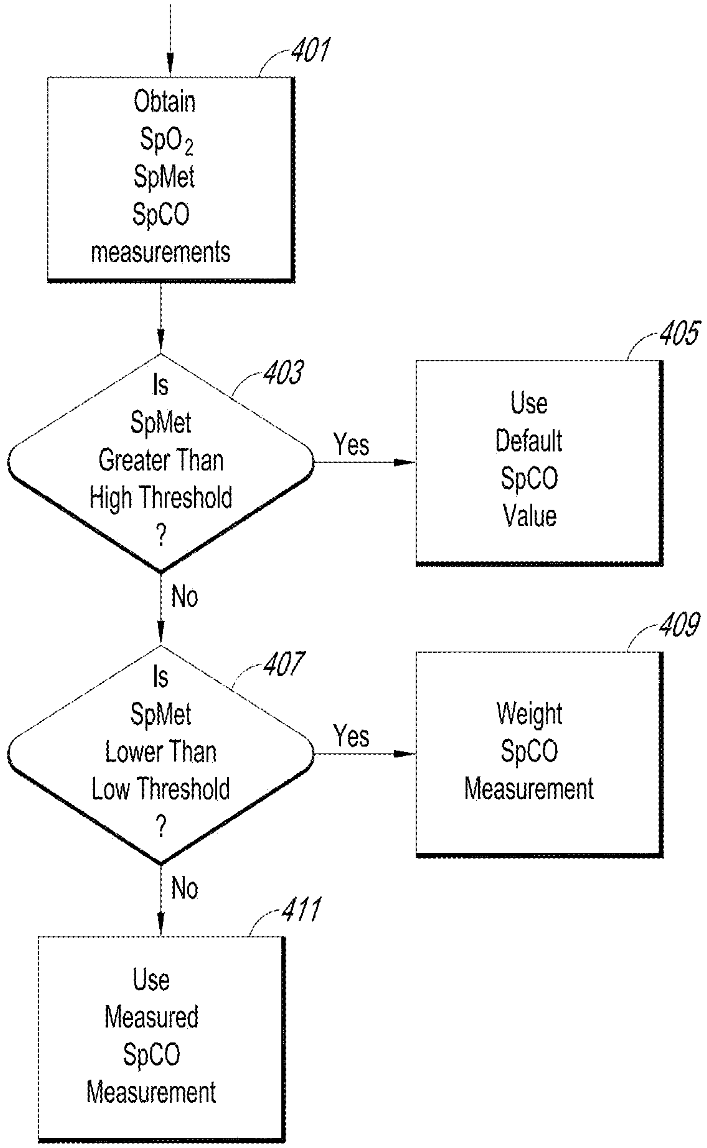
401
Obtain
SpO_2
SpMet
SpCO
measurements
403
Is
SpMet
Greater Than
High Threshold
?
Yes
405
Use
Default
SpCO
Value
No
407
Is
SpMet
Lower Than
Low Threshold
?
Yes
409
Weight
SpCO
Measurement
No
411
Use
Measured
SpCO
Measurement

FIG. 4B

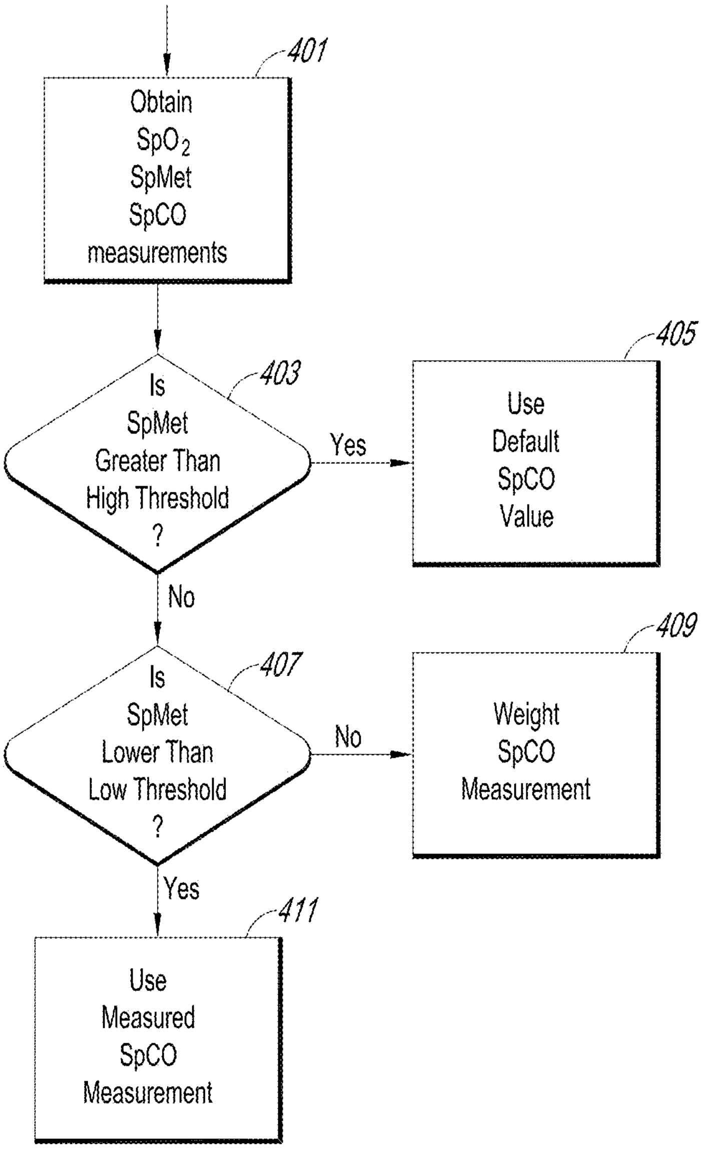
401
Obtain
SpO_2
SpMet
SpCO
measurements
403
Is
SpMet
Greater Than
High Threshold
?
Yes
405
Use
Default
SpCO
Value
No
407
Is
SpMet
Lower Than
Low Threshold
?
No
409
Weight
SpCO
Measurement
Yes
411
Use
Measured
SpCO
Measurement

FIG. 4C

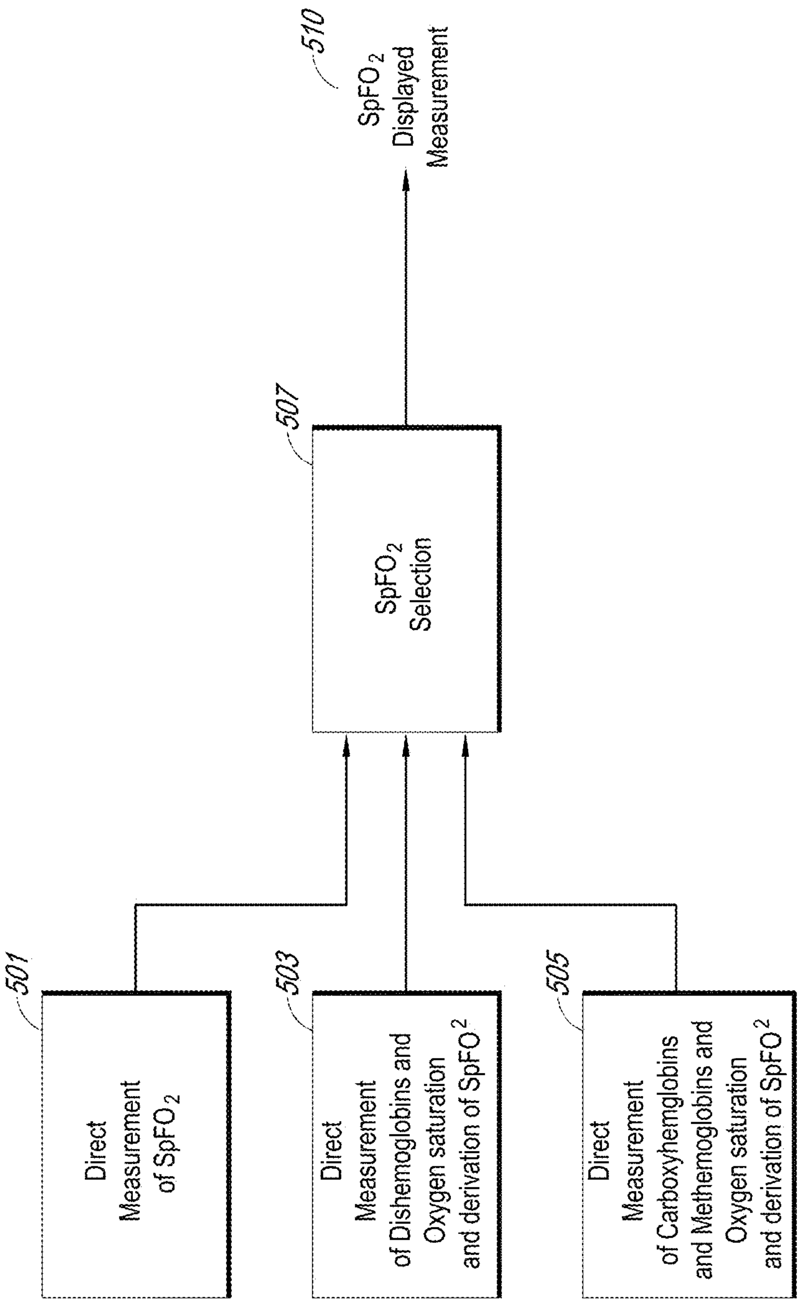
510
$SpFO_2$ Displayed Measurement
507
$SpFO_2$ Selection
501
Direct Measurement of $SpFO_2$
503
Direct Measurement of Dishemoglobins and Oxygen saturation and derivation of $SpFO^2$
505
Direct Measurement of Carboxyhemglobins and Methemoglobins and Oxygen saturation and derivation of $SpFO^2$

FIG. 5

ROBUST FRACTIONAL SATURATION DETERMINATION

PRIORITY CLAIM TO RELATED APPLICATIONS

The present application is a continuation of U.S. patent application Ser. No. 13/791,633, filed Mar. 8, 2013, entitled "Robust Fractional Saturation Determination," which is a continuation-in-part of U.S. patent application Ser. No. 13/650,730, filed Oct. 12, 2012, entitled "Robust Fractional Saturation Determination," which claims priority benefit under 35 U.S.C. § 119(e) of U.S. Provisional Application Ser. No. 61/703,688, filed Sep. 20, 2012, entitled "Robust Fractional Saturation Determination," and U.S. Provisional Application Ser. No. 61/547,001, filed Oct. 13, 2011, entitled "Robust Fractional Saturation Determination;" the disclosures of which are incorporated herein by reference.

FIELD OF THE DISCLOSURE

The present disclosure relates to the field of non-invasive optical based physiological measurements.

BACKGROUND

Pulse oximeters are well known and accepted for use in clinical environments. Pulse oximeters measure the relative percentage of oxygen carrying hemoglobin molecules in the blood. This measurement is commonly referred to as oxygen saturation or SpO_2. Pulse oximeters generally shine light of predetermined wavelengths at a measurement site on the patient and measure the attenuation of the light by the tissue using a detector. Some Pulse oximeters also include additional capabilities to measure other blood analyte levels in addition to oxygen saturation. Non-invasive measurement devices capable of measuring multiple physiological parameters, including oxygen saturation, methemoglobin levels and carboxyhemoglobin levels, are available from Masimo Corporation of Irvine Calif.

SUMMARY

Oxygen saturation provides a measure of the percentage of oxygenated hemoglobin to non-oxygenated hemoglobin. However, oxygen saturation does not take into account dishemoglobins including methemoglobin or carboxyhemoglobin that may affect the actual number of total hemoglobin molecules carrying oxygen. This is a serious problem when, for example, a patient with elevated dishemoglobins measures a high oxygen saturation measurement. Although the oxygen saturation measurement may be high, the patient may be in need of oxygen therapy because the patient's total capacity to carry oxygen is lowered by the effects of the dishemogobins. Thus, despite a high oxygen saturation measurement, the patient may need additional oxygen.

Embodiments of the present disclosure provide a measurement of fractional oxygen saturation that takes into account dishemoglobins, such as, for example, carboxyhemoglobin and methemoglobin and provides a care giver with a more accurate picture of the patient's blood analyte.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** illustrates an embodiment of a physiological measurement device according to an embodiment.

FIG. **2** illustrates a schematic diagram of an embodiment of a physiological measurement device according to an embodiment.

FIG. **3** illustrates a chart for weighting a carboxyhemoglobin measurement when methemoglobin is low.

FIGS. **4**A-C illustrate flowcharts detailing rules for determining carboxyhemglobin measurements in view of methemoglobin measurements.

FIG. **5** illustrates a fractional oxygen saturation determination system for determining fraction oxygen saturation from a plurality of different fraction oxygen saturation measurements.

DETAILED DESCRIPTION

FIG. **1** illustrates an embodiment of a physiological measurement system **10** configured to determine a fractional oxygen saturation measurement. The system **10** includes a patient monitor **100** and optical sensor **200**. The Monitor **100** includes a display screen **170**, various user inputs **160** and sensor port **110**. The sensor **200** includes emitters for emitting light of a plurality of wavelengths and a detector which detects light attenuated by tissue and generates a signal representative of the detected light. In operation, the patient monitor **100** sends drive signals to sensor **200** that turn the emitters on and off. The detector detects the light produced by the emitters after attenuation by the tissue. The detector generates a signal representative of the detected light and communicates the signal to the patient monitor **100**. The patient monitor **100** includes a processor and other signal processing circuitry for processing the signal and determining physiological measurements from the signal. Greater detail of the patient measurement system **10** is disclosed in U.S. Pat. No. 7,764,982 entitled "Multiple Wavelength Sensor Emitters," the contents of which is expressly incorporated herein in its entirety.

FIG. **2** illustrates details of an embodiment of a physiological measurement system **100** in a schematic form. Typically a sensor **106** includes energy emitters **216** located on one side of a patient monitoring site **218** and one or more detectors **220** located generally opposite. The patient monitoring site **218** is usually a patient's finger (as pictured), toe, ear lobe, or the like. Energy emitters **216**, such as LEDs, emit particular wavelengths of energy through the flesh of a patient at the monitoring site **218**, which attenuates the energy. The detector(s) **220** then detect the attenuated energy and send representative signals to the patient monitor **102**. In an embodiment, 8 LEDs are used. In an embodiment 10 LEDs are used. In an embodiment, the LEDs have nominal wavelengths of about 620 nm, 630 nm, 650 nm, 660 nm, 730 nm, 805 nm, 905 nm, 1170 nm, 970 nm, 1270-1300 nm. Of course other nominal wavelengths in the same general range can be used as will be appreciated by a person of skill in the art.

In an embodiment, the patient monitor **102** includes processing board **222** and a host instrument **223**. The processing board **222** includes a sensor interface **224**, a digital signal processor (DSP) **226**, and an instrument manager **228**.

The host instrument typically includes one or more displays **108**, control buttons **110**, a speaker **112** for audio messages, and a wireless signal broadcaster. Control buttons **110** may comprise a keypad, a full keyboard, a track wheel, and the like. Additionally embodiments of a patient monitor **102** can include buttons, switches, toggles, check boxes, and the like implemented in software and actuated by a mouse, trackball, touch screen, or other input device.

The sensor interface **224** receives the signals from the sensor **106** detector(s) **220** and passes the signals to the DSP **226** for processing into representations of physiological parameters. These are then passed to the instrument manager **228**, which may further process the parameters for display by the host instrument **223**. In some embodiments, the DSP **226** also communicates with a memory **230** located on the sensor **106**; such memory typically contains information related to the properties of the sensor that may be useful in processing the signals, such as, for example, emitter **216** energy wavelengths. The elements of processing board **222** provide processing of the sensor **106** signals. Tracking medical signals is difficult because the signals may include various anomalies that do not reflect an actual changing patient parameter. Strictly displaying raw signals or even translations of raw signals could lead to inaccurate readings or unwarranted alarm states. The processing board **222** processing generally helps to detect truly changing conditions from limited duration anomalies. The host instrument **223** then is able to display one or more physiological parameters according to instructions from the instrument manager **228**, and caregivers can be more confident in the reliability of the readings. Among the various parameters that can be display are $Sp0_2$ (Oxygen Saturation), SpMet (Methemoglobin), SpCO (Carboxyhemoglobin), a combined dishemoglobin measurement (referred to herein as SpDisHb), and directly measured or derived Fractional Oxygen Saturation, referred to herein as $SpF0_2$ or $SpFrac0_2$ among other parameters including those illustrated in FIG. **2**.

In an embodiment, a direct measurement of fractional oxygen saturation is obtained from the plethysmograph data using DSP **226**. The measurement is based on empirically obtained data which is correlated with gold standard invasive measurements of fractional oxygen saturation which is used to obtain a calibration curve.

In another embodiment, a direct measurement of dishemoglobins are obtained. The dishemoglobin measurement is also obtained from the plethysmograph data using DSP **226**. The measurement is based on empirically obtained data which is correlated with gold standard invasive measurements of dishemoglobins which is used to obtain a calibration curve. The dishemoglobin measurement is then used in conjunction with the oxygen saturation measurement as described below in order to obtain a fraction oxygen saturation measurement.

In yet another embodiment, a direct measurement of carboxyhemoglobin and methemoglobin is obtained and used to determine a fractional oxygen saturation measurement as described below.

In an embodiment, two or more of the above described processes for obtaining a fractional oxygen saturation measurement are used at the same time in order to obtain a more accurate measurement of oxygen saturation. For example, the various fractional oxygen saturation measurements can be compared or averaged. In an embodiment, signal confidence is determined for each measurement and used to determine which measurement determination is the best determination to use. In an embodiment, when signal confidence is low, the carboxyhemoglobin and methemoglobin measurements are used to determine a fraction saturation measurement. In an embodiment, when the signal confidence is high, a direct measurement of either the dishemoglobin or of the fraction oxygen saturation itself is used.

In an embodiment, the determination of fractional oxygen saturation begins with the understanding that hemoglobin in the blood falls into one of three categories. The three categories are: oxygenated hemoglobin, deoxygenated hemoglobin and dishemoglobins. Dishemoglobins include, for example, methemoglobin and carboxyhemoglobin. There may be additional categories of hemoglobin depending on patient conditions and inhaled toxins, however, for purposes of this fractional saturation measurement, it is assumed that these conditions are rare and/or negligible and are accounted for in the dishemoglobin measurement. Next, it is assumed that the relative fraction measured of these three categories of hemoglobin will add up to unity. This can be expressed mathematically as follows:

$$fRHb+fO2Hb+fDisHb=1 \quad (1)$$

where fRHb, fO2Hb and fDisHb represent the fraction of the total amount of available hemoglobin that is in each hemoglobin state, deoxygenated hemoblogin, oxygenated hemoglobin and dishemoglobins. In an embodiment, the dishemolgobin measurement can be mathematically represented as:

$$fDisHb=fMetHb+fCOHb \quad (2)$$

Typical pulse oximeters measure an oxygen saturation measurement that is referred to as a functional oxygen saturation measurement or SaO2. Functional oxygen saturation is the percentage of oxygenated blood compared to total potential oxygen carrying capacity of the combined oxygenated and deoxygenated hemoglobin species. Functional oxygen saturation can be mathematically represented as follows:

$$SaO2 = \frac{fO_2Hb}{fRHb + fO_2Hb} * 100\% \quad (3)$$

True fractional oxygen saturation or $SpFO_2$, as defined herein, provides a measure of oxygenated hemoglobin compared to the total of all hemoglobin in the blood. This includes oxygenated hemoglobin and deoxygenated hemoglobin as well as dishemoglobins (including methemoglobin and carboxyhemoglobin, for example). In an embodiment, fraction oxygen saturation is measured directly from the plethysmograph. Fractional oxygen saturation can also be mathematically represented as follows:

$$SpFO2\ (\%) = \frac{fO_2Hb}{fRHb + fO_2Hb + fDisHb} * 100\% \quad (4)$$

Fractional oxygen saturation can be measured directly or derived from measurable parameters. As discussed above, typical pulse oximeters measure functional oxygen saturation. Some physiological measurement devices sold and marketed under the Rainbow® mark by Masimo Corp. of Irvine, Calif. are capable of measuring methemoglobin and carboxyhemoglobin in addition to functional oxygen saturation. Additionally, the dishemoglobins can be measured directly together as a single parameter combining methemoglobin and carboxyhemglobin as well as other dishemoglobins in order to avoid anomalies introduced by separate measurements. As described below, fractional oxygen saturation can be determined using measurements of SpO2, SpMet and SpCO. The following equations separate carboxyhemglobin and methemoglobin measurements, however, it is to be understood that the carboxyhemglobin and methemoglobin measurements need not be separate measurements but can be substituted for a single separate dishemoglobin measurement. Thus, for example, in equation

4 below, fMetHb+fCOHb can be substituted out for a single fDisHb (fractional dishemoglobin) measurement.

Equation 1 above can be mathematically rewritten as follows using a separate methemoglobin measurement and carboxyhemoglobin measurement instead of a single dishemoglobin measurement:

$$fRHb+fO_2Hb=1-fMetHb-fCOHb \quad 4$$

Equation 3 above can also be mathematically rewritten as follows so that the left side of the equation matches the left side of equation 4:

$$fRHb + fO_2Hb = \frac{fO_2Hb}{SaO2} * 100\% \quad 5$$

Equations 4 and 5 can be combined as follows:

$$\frac{fO_2Hb}{SaO2} * 100 = 1 - fMetHb - fCOHb \quad 6$$

Equation 6 can then be mathematically rewritten as follows:

$$fO_2Hb = \frac{(1 - fMetHb - fCOHb) * SaO2}{100} \quad 7$$

Equation 7 can be multiplied by 100 to express fO2Hb, fMetHb, and fCOHb as a percentage, leading to the final equation for fractional oxygen saturation:

$$O_2Hb = \frac{(100 - MetHb - COHb) * SaO2}{100} \quad 8$$

Finally, rewriting Equation 8 in terms of measurable parameters using a Masimo Rainbow patient monitor provides the following equation:

$$SpFO_2 = \frac{(100 - SpMet - SpCO) * SpO2}{100} \quad 9$$

Equation 9 above thus provides a calculated fractional saturation measurement that will give a patient care provider a more accurate indication of the physiological state of the patient.

One issue that arises with equation 9 is the accuracy of the various measurements involved. In particular, if one measurement is inaccurate, the accuracy of the fractional oxygen saturation measurement can be significantly affected. In order to minimize error in the fractional oxygen saturation measurement, the accuracy of the various measurements that form the fractional oxygen saturation measurement are determined. If one or more of the measurements are considered unreliable or inaccurate, weights or adjustments can be added in order to increase the reliability of the fractional oxygen saturation measurement.

In one embodiment, a rule based system is provided which analyzes the measurements based on various rules and adjusts parameter values in accordance with those rules. For example, if one parameter has a low confidence it can be down weighted in the determination of fractional oxygen saturation. Alternatively a confidence measure can be derived from the fractional oxygen measurement based on the confidence measure of SpO2, SpMet and SpCO. Many specific rules can be implanted to account for inaccuracies in the measurement.

In one embodiment, for example, high methemoglobin levels can impact the measurements of both carboxyhemoglobin and oxygen saturation. Thus, the present disclosure provides a rule based system for accounting for potential measurement inaccuracies during certain conditions.

In an embodiment, a more robust measurement of oxygen saturation is used. This measurement, referred to herein as Sp02_Robust, is determined using 2 or more wavelengths and a higher order polynomial fit. In an embodiment, 3 or more wavelengths can be used. In an embodiment, 5 wavelengths and a 3rd order polynomial equation are used to determine a more robust oxygen saturation measurement. Thus, equation 9 can be modified to:

$$SpFO_2 = \frac{(100 - SpMet - SpCO) * SpO2\_Robust}{100} \quad 10$$

In an embodiment, a correction to SpCO is provided. As methemoglobin levels increase, the measurement of SpCO can be affected. In order to compensate for this, the following set of rules can be used. If the SpMet measurement is greater than a critical threshold, for example, about 2.2%, then the SpCO measurement is considered unreliable. This is referred to throughout this disclosure as a high methemoglobin condition. In this situation, SpCO is set to a relatively average SpCO measurement. In an embodiment, this can be the population average. In an embodiment, SpCO is set to about 0.9%.

In one embodiment, if the SpMet measurement is below the high methemoglobin measurement threshold, then the SpCO measurement is weighted. This is referred to throughout this disclosure as a low methemoglobin condition. In an embodiment, the weighting provided to the SpCO measurement is directly related to the SpCO measurement. By way of example, the weighting scale depicted in FIG. **3** illustrates an embodiment of a weighting scheme for SpCO values. As depicted in FIG. **3**, the greater the SpCO measurement, the greater the weight provided. In an embodiment, the SpCO critical value is about 7% to about 8%. Other weighting schemes can also be used. For example, a purely linear, exponential, partially linear and partially non-linear weighting scales could be used as well. In an embodiment, the SpCO critical value can be higher or lower.

In one embodiment, if the SpMet measurement is less than a low methemoglobin measurement threshold, then the SpCO measurement is weighted as discussed above. In an embodiment, a low SpMet measurement is below about 1%. If the SpMet measurement is between a low methemoglobin value and a high methemoglobin value, then the measured parameters are used without adjustment.

FIG. **4**A illustrates an embodiment of a flow chart for determining whether a carboxyhemoglobin measurement needs to be adjusted. At step **401**, oxygen saturation, carboxyhemoglobin and methemoglobin measurements are obtained. In an embodiment, the oxygen saturation measurement is a robust oxygen saturation measurement. The process moves to step **403** where a determination is made as to whether the methemoglobin measurement is greater than a threshold. If the answer is yes, the at step **405**, a default carboxyhemglobin measurement value is used. If, at step

403, the answer is no, the process moves to step 406 where the carboxyhemoglobin measurement value is weighted as described above.

FIG. 4B illustrates another embodiment of a flow chart for determining whether a carboxyhemoglobin measurement needs to be adjusted. At step 401, oxygen saturation, carboxyhemoglobin and methemoglobin measurements are obtained. In an embodiment, the oxygen saturation measurement is a robust oxygen saturation measurement. The process moves to step 403 where a determination is made as to whether the methemoglobin measurement is greater than a threshold. If the answer is yes, the at step 405, a default carboxyhemglobin measurement value is used. If, at step 403, the answer is no, the process moves to step 407. At step 407, the determination is made as to whether the methemoglobin measurement is lower than a low threshold. If the answer is yes, then the carboxyhemoglobin measurement value is weighted as described above. If the answer is no at step 407, the process moves onto step 411 where the measured carboxyhemoglobin value is used in the above described process for determining a fractional oxygen saturation.

FIG. 4C illustrates another embodiment of a flow chart for determining whether a carboxyhemoglobin measurement needs to be adjusted. At step 401, oxygen saturation, carboxyhemoglobin and methemoglobin measurements are obtained. In an embodiment, the oxygen saturation measurement is a robust oxygen saturation measurement. The process moves to step 403 where a determination is made as to whether the methemoglobin measurement is greater than a threshold. If the answer is yes, the at step 405, a default carboxyhemglobin measurement value is used. If, at step 403, the answer is no, the process moves to step 407. At step 407, the determination is made as to whether the methemoglobin measurement is lower than a low threshold. If the answer is no, then the carboxyhemoglobin measurement value is weighted as described above. If the answer is yes at step 407, the process moves onto step 411 where the measured carboxyhemoglobin value is used in the above described process for determining a fractional oxygen saturation.

In an embodiment, a multivariate classifier is used to determine whether the SpMet and SpCO values should be categorized as either a high or low methemoglobin condition. The multivariate classifier determines clusters of classifications based on empirically obtained measurement data. The measurement under analysis is then compared with the multivariate classification information in order to determine into which classification, or cluster, the measurement should be placed. Once the measurement under analysis is classified into either a high or low methemoglobin condition, then the actions described above with respect to the high and low methemoglobin conditions respectively are taken.

FIG. 5 illustrates an embodiment of a system that calculates a plurality of fractional oxygen saturation measurements and then determines which of the measurements to use in a final measurement. As illustrated in FIG. 5, a direct measurement of fractional oxygen saturation is determined at module 501. At module 503, a derived measurement fractional oxygen saturation is determined from a measurement of oxygen saturation and a direct dishemoglobin measurement. At module 505, a derived measurement fractional oxygen saturation is determined from a measurement of carboxyhemoglobin and methemoglobin measurements as described above. $SpFO_2$ determination module 507 then determines a final fraction oxygen saturation measurement 510. In an embodiment, the determination module looks at a signal confidence value to determine which measurement to use. If the signal confidence is low, the determination module 507 will use one or both of the output of modules 503 and 505. If the signal confidence is high, the determination module 507 will use the output of module 501. In an embodiment, the determination module 507 is configured to use an average or weighted average of all three measurements. In an embodiment, only two measurements are used. In an embodiment, more than three different determinations of fraction oxygen saturation are used and the determination modules 507 then determines an appropriate output.

Although the foregoing has been described in terms of certain specific embodiments, other embodiments will be apparent to those of ordinary skill in the art from the disclosure herein. Moreover, the described embodiments have been presented by way of example only, and are not intended to limit the scope of the disclosure. Indeed, the novel methods and systems described herein may be embodied in a variety of other forms without departing from the spirit thereof. Accordingly, other combinations, omissions, substitutions, and modifications will be apparent to the skilled artisan in view of the disclosure herein. Thus, the present disclosure is not limited by the preferred embodiments, but is defined by reference to the appended claims. The accompanying claims and their equivalents are intended to cover forms or modifications as would fall within the scope and spirit of the disclosure.

The methods, steps, processes, calculations, computations or the like ("methods") provided herein are simplified examples that are generally performed by advanced processing devices, including complex signal processors, sensitive analog and digital signal preprocessing boards, optical/optoelectronic componentry, display drivers and devices, or similar electronic devices. An artisan will recognize from the disclosure herein that the various methods often must be performed at speeds that, as a practical matter, could never be performed entirely in a human mind. Rather, for many calculations providing real time or near real time solutions, outputs, measurements, criteria, estimates, display indicia, or the like, many of the foregoing processing devices perform tens to billions or more calculations per second. In addition, such processing devices may process electrical signals, infrared signals, wireless signals, or other electromagnetic wave signals that are incomprehensible to a human mind in their raw form and at the speeds communicated.

What is claimed is:

1. A patient monitoring system comprising:

an optical sensor configured to emit light of a plurality of wavelengths directed at a measurement site of tissue of a patient and detect the light after attenuation by the measurement site to produce a signal representative of the light after attenuation; and

a patient monitor comprising:

one or more hardware processors configured to:

determine a methemoglobin measurement and a carboxyhemoglobin measurement from the signal,

determine that the methemoglobin measurement is indicative of a low methemoglobin condition, and

in response to determining that the methemoglobin measurement is indicative of the low methemoglobin condition, change the carboxyhemoglobin measurement to a weighted carboxyhemoglobin measurement that is correlated to the carboxyhemoglobin measurement; and

a display configured to display a parameter value responsive to the carboxyhemoglobin measurement.

2. The patient monitoring system of claim 1, wherein the weighted carboxyhemoglobin measurement is weighted according to the methemoglobin measurement.

3. The patient monitoring system of claim 1, wherein when the methemoglobin measurement is within a range, the weighted carboxyhemoglobin measurement is weighted so that a weighting of the carboxyhemoglobin measurement increases as the methemoglobin measurement increases.

4. The patient monitoring system of claim 3, wherein the range extends from a low value to a high value, the high value being between 7% and 8%.

5. The patient monitoring system of claim 3, wherein when the methemoglobin measurement is within the range, the weighting varies with the methemoglobin measurement at least in part according to an exponential function.

6. The patient monitoring system of claim 3, wherein when the methemoglobin measurement is within the range, the weighting varies with the methemoglobin measurement at least in part according to a linear function.

7. The patient monitoring system of claim 1, wherein the parameter value is indicative of a fractional oxygen saturation.

8. The patient monitoring system of claim 1, wherein the parameter value equals the carboxyhemoglobin measurement.

9. The patient monitoring system of claim 1, wherein the one or more hardware processors is configured to:

determine that the methemoglobin measurement is unreliable, and

in response to determining that the methemoglobin measurement is unreliable, change the carboxyhemoglobin measurement to a default carboxyhemoglobin value.

10. The patient monitoring system of claim 9, wherein the one or more hardware processors is configured to:

determine that the methemoglobin measurement is indicative of the low methemoglobin condition from a comparison of the methemoglobin measurement to a first threshold, and

determine that the methemoglobin measurement is unreliable from a comparison of the methemoglobin measurement to a second threshold different from the first threshold.

11. The patient monitoring system of claim 10, wherein the first threshold is 1%.

12. The patient monitoring system of claim 10, wherein the second threshold is 2.2%.

13. The patient monitoring system of claim 12, wherein the default carboxyhemoglobin value is 0.9%.

14. The patient monitoring system of claim 1, wherein the signal is representative of the light of three or more wavelengths after attenuation, and the one or more hardware processors is configured to determine the methemoglobin measurement and the carboxyhemoglobin measurement from the light of three or more wavelengths after attenuation.

15. The patient monitoring system of claim 1, wherein the signal is representative of the light of five or more wavelengths after attenuation, and the one or more hardware processors is configured to determine the methemoglobin measurement and the carboxyhemoglobin measurement from the light of five or more wavelengths after attenuation.

16. A method of patient monitoring, the method comprising:

emitting light of a plurality of wavelengths directed at a measurement site of tissue of a patient;

detecting the light after attenuation by the measurement site to produce a signal representative of the light after attenuation;

determining, with one or more hardware processors, a first methemoglobin measurement and a first carboxyhemoglobin measurement from the signal;

determining, with the one or more hardware processors, that the first methemoglobin measurement is indicative of a low methemoglobin condition;

in response to determining that the first methemoglobin measurement is indicative of the low methemoglobin condition, changing, with the one or more hardware processors, the first carboxyhemoglobin measurement to a weighted carboxyhemoglobin measurement that is correlated to the first carboxyhemoglobin measurement; and

displaying, with a display, a first parameter value responsive to the first carboxyhemoglobin measurement.

17. The method of claim 16, wherein the weighted carboxyhemoglobin measurement is weighted according to the first methemoglobin measurement.

18. The method of claim 16, wherein when the first methemoglobin measurement is within a range, the weighted carboxyhemoglobin measurement is weighted so that a weighting of the first carboxyhemoglobin measurement increases as the first methemoglobin measurement increases.

19. The method of claim 16, further comprising:

determining, with the one or more hardware processors, a second methemoglobin measurement and a second carboxyhemoglobin measurement from the signal;

determining, with the one or more hardware processors, that the second methemoglobin measurement is unreliable;

in response to determining that the second methemoglobin measurement is unreliable, changing, with the one or more hardware processors, the second carboxyhemoglobin measurement to a default carboxyhemoglobin value; and

displaying, with the display, a second parameter value responsive to the second carboxyhemoglobin measurement.

20. The method of claim 16, wherein the first parameter value is indicative of a fractional oxygen saturation.

* * * * *

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当前申请(专利权)人(译)	Masimo公司		
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本公开描述了分数氧饱和度测量的推导和测量。在一个实施例中，一种系统包括光学传感器和处理器。光学传感器可以发射指向患者组织的测量部位的多个波长的光，在组织衰减之后检测光，并且在衰减之后产生表示检测到的光的信号。处理器可以在衰减之后接收表示检测到的光的信号，并且使用该信号基于分数氧饱和度的两个或更多个不同测量来确定分数氧饱和度测量。