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(54) **PULSE OXIMETRY SYSTEM WITH AN INTEGRATED PULSE WIDTH MODULATOR**

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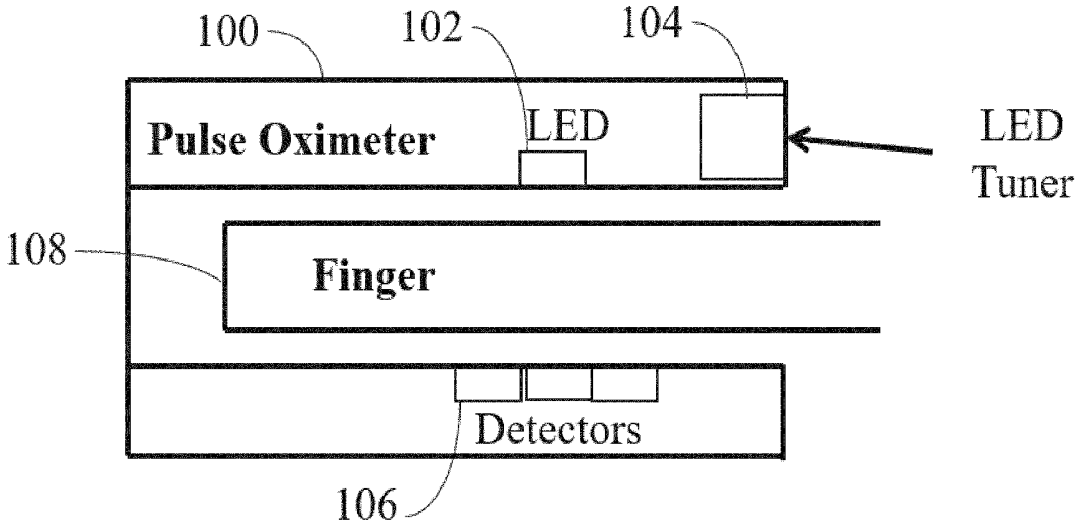
(57) **ABSTRACT**

A system and method comprising a pulse oximeter with a pulse width modulator that periodically tests the en wavelengths emitted at the pulse width's upper and lower limits in order to ensure that the median pulse width is emitting the wavelength specified by the manufacturer. The system comprises a pulse oximeter that has LED emitter(s), photodetectors, a pulse width modulator and memory. The specifications database contains data relating to the wavelength specified by the manufacturer. The calibration software will periodically test the LED to ensure the correct wavelength is being emitted by the LED in order to detect the proper constituents in the patient's blood. The testing is conducted whenever the pulse oximeter is energized and then again at a specified interval until power is disconnected from the pulse oximeter. Each test includes increasing the pulse width until an error is detected, recording the upper limit of the pulse width and the corresponding wavelength before an error occurred. Then performing the same test by decreasing the pulse width until an error is detected. The wavelength emitter at the median pulse width is then calculated and compared to the manufacturer's specification. If they do not match the calibration software adjusts the pulse width until the manufacturer's specification is achieved.



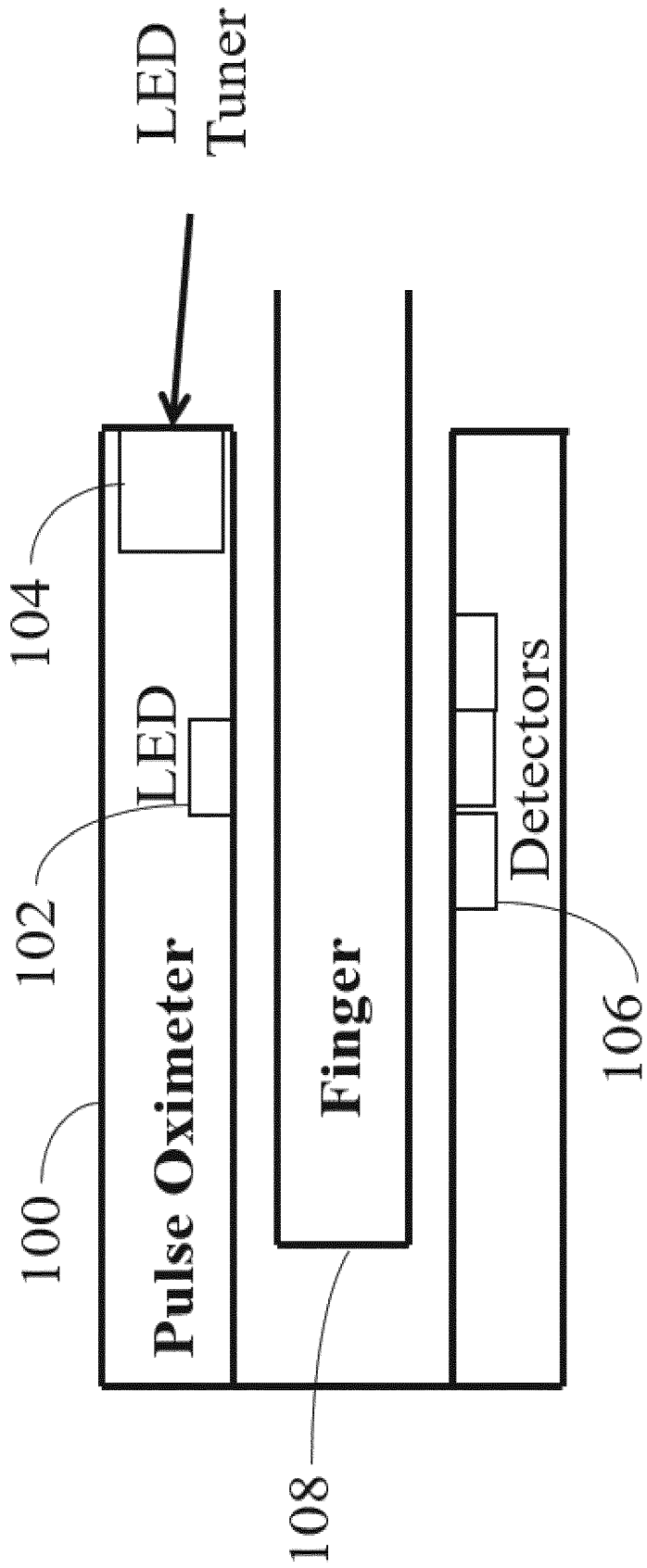

LED Tuner
104
LED
102
Pulse Oximeter
100
Finger
108
Detectors
106

FIG. 1

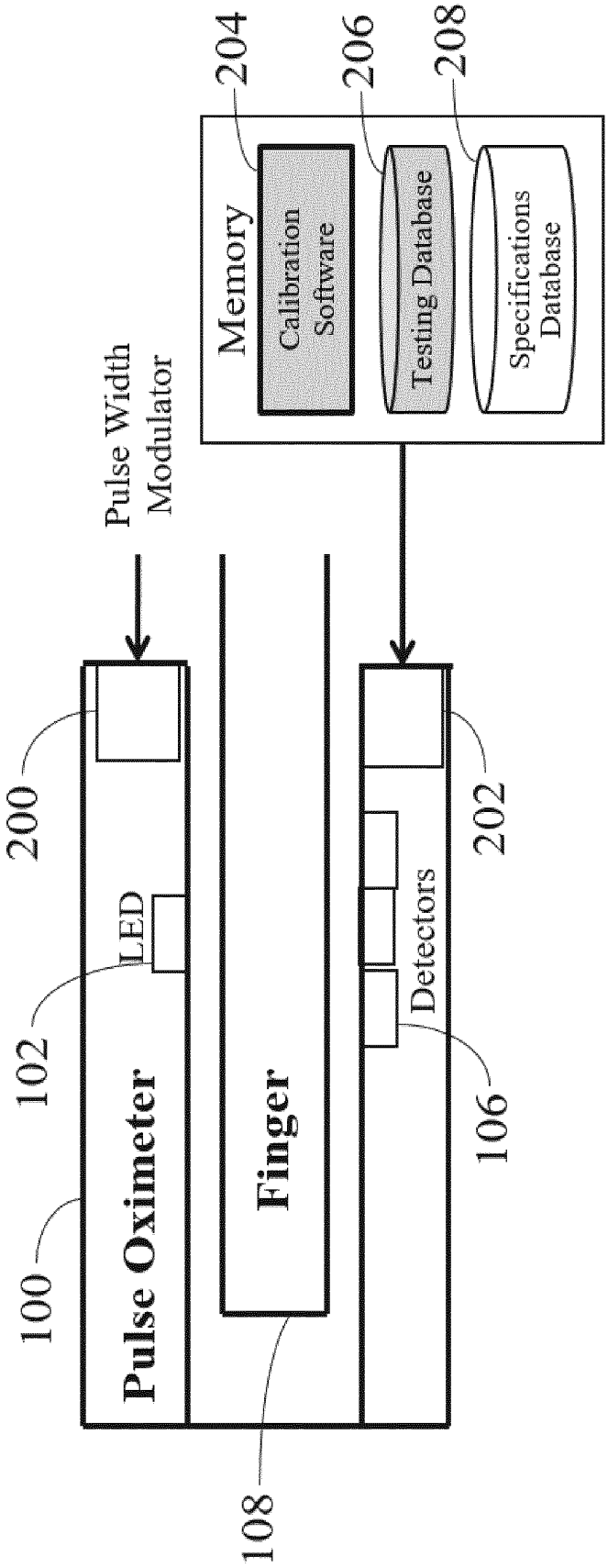

204
206
208
Memory
Calibration Software
Testing Database
Specifications Database
Pulse Width Modulator
200
LED
102
100
Pulse Oximeter
Finger
Detectors
202
106
108

FIG. 2

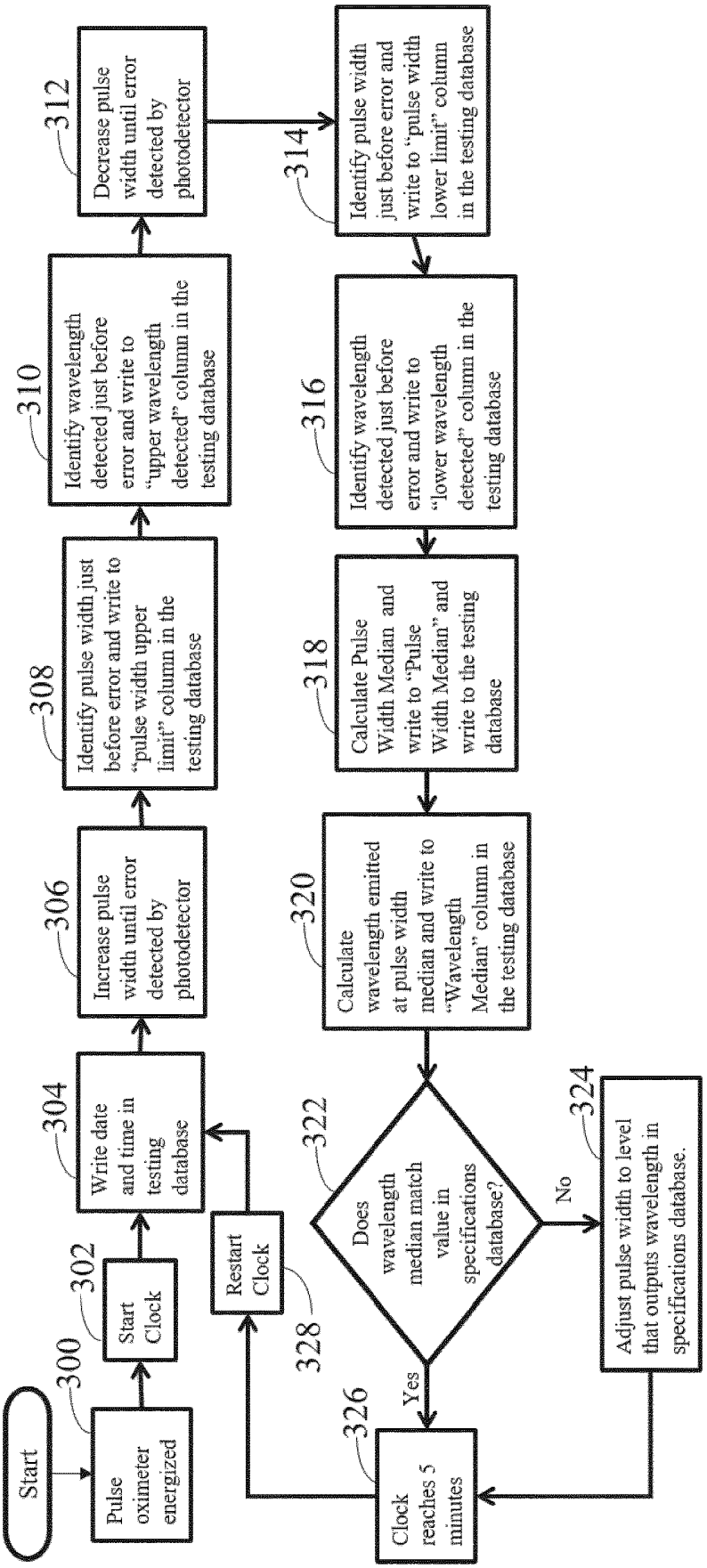
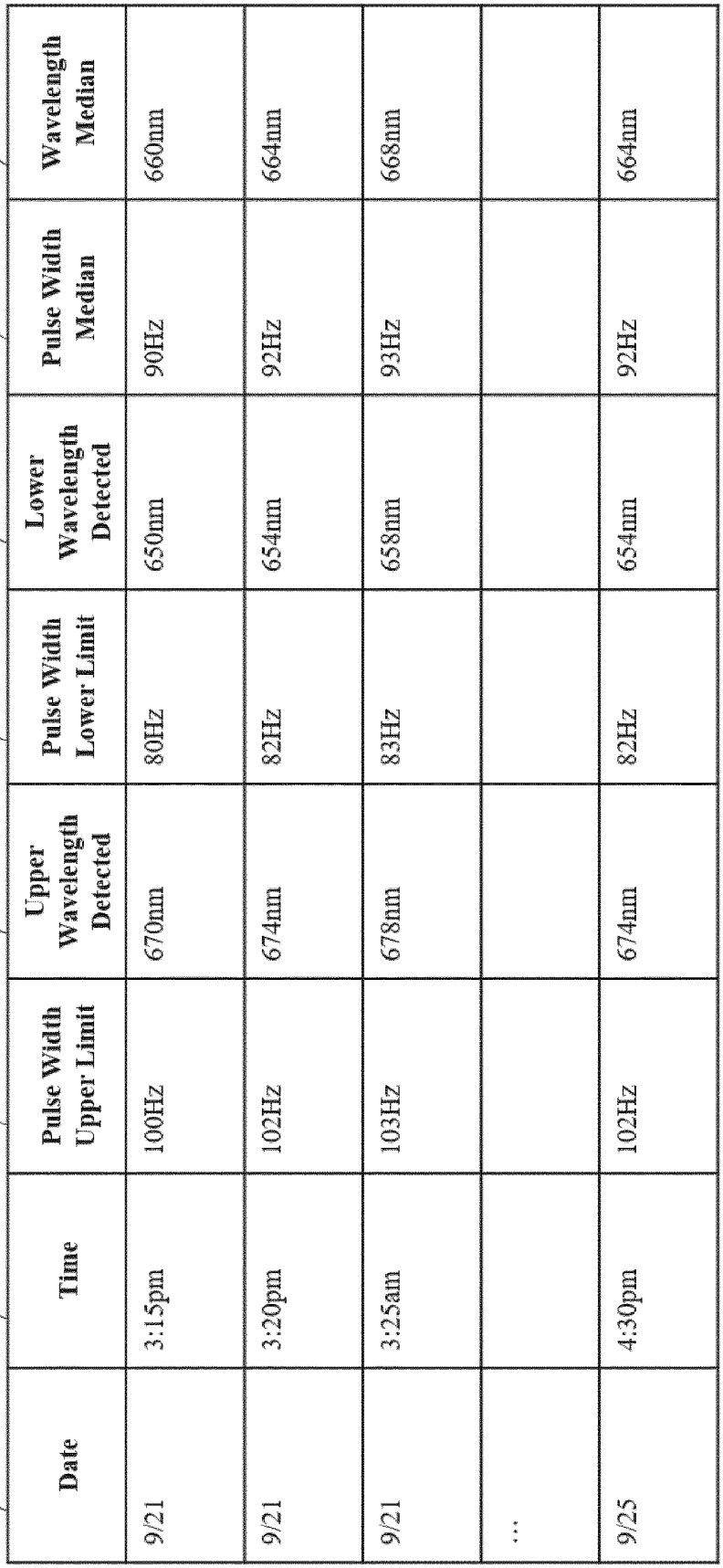

Start
300
Pulse oximeter energized
302
Start Clock
304
Write date and time in testing database
306
Increase pulse width until error detected by photodetector
308
Identify pulse width just before error and write to "pulse width upper limit" column in the testing database
310
Identify wavelength detected just before error and write to "upper wavelength detected" column in the testing database
312
Decrease pulse width until error detected by photodetector
314
Identify pulse width just before error and write to "pulse width lower limit" column in the testing database
316
Identify wavelength detected just before error and write to "lower wavelength detected" column in the testing database
318
Calculate Pulse Width Median and write to "Pulse Width Median" and write to the testing database
320
Calculate wavelength emitted at pulse width median and write to "Wavelength Median" column in the testing database
322
Does wavelength median match value in specifications database?
324
No
Adjust pulse width to level that outputs wavelength in specifications database.
326
Yes
Clock reaches 5 minutes
328
Restart Clock

FIG. 3



400 Date	402 Time	404 Pulse Width Upper Limit	406 Upper Wavelength Detected	408 Pulse Width Lower Limit	410 Lower Wavelength Detected	412 Pulse Width Median	414 Wavelength Median
9/21	3:15pm	100Hz	670nm	80Hz	650nm	90Hz	660nm
9/21	3:20pm	102Hz	674nm	82Hz	654nm	92Hz	664nm
9/21	3:25am	103Hz	678nm	83Hz	658nm	93Hz	668nm
...							
9/25	4:30pm	102Hz	674nm	82Hz	654nm	92Hz	664nm

FIG. 4

PULSE OXIMETRY SYSTEM WITH AN INTEGRATED PULSE WIDTH MODULATOR

BACKGROUND OF THE INVENTION

[0001] The present invention is directed to a system and method for calibrating pulse oximetry pulse width and wavelength parameters using pulse width modulation. U.S. Pat. No. 5,784,151 discloses a system that comprises a pulse width modulation (PWM) module **39** which is operated by CPU. This patent discloses an apparatus for testing a pulsed light oximeter and a light sensing means for producing an electrical pulse signal representative of light flashes emitted by the oximeter, each light flash emitted having one of a plurality of predefined wavelengths. U.S. Pat. No. 5,577,500 discloses a pulse width modulator and a means to control the peak-to-peak values of both the red and infrared signals so that they extend across most of the range of the A/D converter to give maximum resolution. U.S. patent application number 2005/0187450 discloses a pulse oximeter comprising a controller for generating a pulse width modulator (PWM) drive signal to said LED and a system configured to determine if a forward voltage of said LED is within a predetermined range using a measurement of said current and said PWM signal.

SUMMARY OF THE CLAIMED INVENTION

[0002] The present invention relates to pulse oximeters with a pulse width modulator that periodically tests the wavelengths emitted at the pulse width's upper and lower limits in order to ensure that the median pulse width is emitting the wavelength which has been specified. In one embodiment the wavelength is specified by the manufacturer of the pulse oximeter. The system comprises a pulse oximeter that has LED emitter(s), photodetectors, a pulse width modulator and memory. On the memory is calibration software, a testing database and a specifications database. The specifications database contains data relating to the wavelength specified by, for example, the manufacturer. The calibration software will periodically test the LED to ensure the correct wavelength is being emitted by the LED in order to detect the proper constituents in the patient's blood. The testing is conducted whenever the pulse oximeter is energized and then again at a specified interval until power is disconnected from the pulse oximeter. Each test consists of increasing the pulse width until an error is detected, recording the upper limit of the pulse width and the corresponding wavelength before an error occurred. Then performing the same test by decreasing the pulse width until an error is detected. The wavelength emitter at the median pulse width is then calculated and compared to the given, or desired, specification. If they do not match the calibration software adjusts the pulse width until the desired specification is achieved.

BRIEF DESCRIPTION OF THE DRAWINGS

[0003] The accompanying drawings, which are included to provide a further understanding of the invention, are incorporated herein to illustrate embodiments of the invention. Along with the description, they also serve to explain the principle of the invention. In the drawings:

[0004] FIG. **1** illustrates a pulse oximetry system according to the present invention comprising an LED tuner integrated into a pulse oximeter.

[0005] FIG. **2** illustrates a pulse oximeter system comprising a pulse width modulator and a memory according to a preferred embodiment of the invention.

[0006] FIG. **3** is a flowchart illustrating a process according to a preferred embodiment of the invention.

[0007] FIG. **4** illustrates a database comprising various parameters used for adjusting the pulse width and wavelength according to a preferred embodiment of the present invention.

DETAILED DESCRIPTION OF THE EMBODIMENTS

[0008] The following are definitions of terms as used in the various embodiments of the present invention.

[0009] The term "database" as used herein refers to a collection of data and information organized in such a way as to allow the data and information to be stored, retrieved, updated, and manipulated and to allow them to be presented into one or more formats such as in table form or to be grouped into text, numbers, images, and audio data. The database typically resides in computer memory that includes various types of volatile and non-volatile computer memory. "Database" as used herein also refers to conventional databases that may reside locally or that may be accessed from a remote location, e.g., remote network servers. The term "database" as used herein may also refer to a segment or portion of a larger database, which in this case forms a type of database within a database. Memory wherein the database resides may include high-speed random access memory or non-volatile memory such as magnetic disk storage devices, optical storage devices, and flash memory. Memory where the database resides may also comprise one or more software for processing and organizing data received by and stored into the database.

[0010] The present invention is directed to a system comprising a pulse oximeter that has LED emitter(s), photodetectors, a pulse width modulator, and memory. On the memory is calibration software, a testing database and a specifications database. The specifications database includes data specifying the wavelength specified by the manufacturer (e.g., 660 nm). The calibration software periodically tests the LED to ensure that the specified wavelength is being emitted by the LED in order to ensure accurate pulse oximetry measurements. The testing is conducted when the pulse oximeter is enabled to take measurements, and preferably at specified intervals (e.g., every 5 minutes) until power is disconnected from the pulse oximeter. Each calibration test comprises increasing the pulse width until an error is detected, recording the upper limit of the pulse width and the corresponding mean wavelength before an error is detected. Then, the calibration test is perform again this time by decreasing the pulse width until an error is detected. The median pulse width is calculated and compared to the manufacturer's specification. If they do not match, the calibration software adjusts the pulse width until the manufacturer's specification is matched.

[0011] In a preferred embodiment, the wavelength emitted by an LED in a pulse oximeter is tuned in order to detect a second variable. A pulse modulation software is used to regulate the pulse width. Because the pulse width can change over time due to factors such as LED degradation, constantly calibrating the mean wavelength for a range of

pulse width values, the system of the present invention can ensure that the LED is outputting 660 nm, instead of 664 or 657 nm, for example.

[0012] In one embodiment of the present invention, the median wavelength is measured to be 970 nm, which is the wavelength corresponding to O2 bound to iron. If the PWM is modulated around a reference value and the LED is presently outputting 964 to 974 nm, which are all being absorbed but at 963 nm the system gets an error reading and at 975 nm, the system detects another error reading, the median and range that does not give rise to an error reading can thus be calculated. After, e.g., 2 hours from the time the pulse oximetry measurement was initiated, the LED's median wavelength was observed to drift and it is outputting, at the same PWM, say 962 nm, this means the signal being measured at that wavelength is incorrect. So, every now and then while performing "ranging," it is found that, prior to the detection of the error, the median wavelength has moved up to 975 nm (or the PWM has moved up), we know get 969 to 980 nm as the range where 975 is the median. This means the median PWM should be changed to match the median reading of O2 attached to the iron. This allows the necessary correction to be applied to the PWM signal, which was initially believed to still be at the reference value but was in fact no longer corresponds to the median wavelength, e.g., the PWM for 970 nm is really the PWM for 962 nm.

[0013] FIG. **1** shows a preferred embodiment of the invention that integrates an LED tuner **104** into a pulse oximeter **100**. In the figure, the patient's finger **108** is inside the pulse oximeter between the LED **102** and light detectors **106**.

[0014] FIG. **2** shows a pulse oximeter **100**, LED **102**, with a PWM (pulse width modulator) **200**, detectors **106** and memory **202** wherein the calibration software **204**, testing database **206**, and specifications database **208** reside.

[0015] FIG. **3** is a flowchart that illustrates a preferred embodiment of the present invention. Here, the software module is triggered when the pulse oximeter is connected to a power source (step **300**). The software starts a clock (step **302**) and writes the date and time in the testing database (step **304**). The pulse width is then increased until an error is detected by the photodetector (step **306**). The highest pulse width achieved before the error occurred and the corresponding wavelength emitted are recorded in the "pulse width upper limit" (step **308**) and "upper wavelength detect" columns (step **310**) in the testing database. The same process is then repeated in reverse to detect the lower limit of the pulse width before an error occurs (step **312**). Then recording the pulse width and corresponding wavelength emitted in the "pulse width lower limit" (step **314**) and "lower wavelength detect" (step **316**) columns in the testing database. The mean pulse width (step **318**) and the corresponding wavelength emitted (step **320**) is then calculated and the values are written to the "pulse width median" (step **318**) and "wavelength median" columns (step **320**) in the testing database. The wavelength emitted at the pulse width median in then compared to the manufacturer's specification in the specification database (step **322**). If the values match and the clock has reached a specified interval, such as 5 minutes, the clock is restarted and the testing process is repeated (step **326**). If the values do not match, the pulse width is adjusted to output the manufacturer's specified wavelength (step **324**). Once the clock reaches a specified interval, such as 5 minutes, the clock is restarted and the testing process begins again.

[0016] FIG. **4** shows a database according to a preferred embodiment of the invention, along with example data. The database comprises several columns of data corresponding to different parameters: "Date" **400**, "Time" **402**, "Pulse Width Upper Limit" **404**, "Upper Wavelength Detected" **406**, "Pulse Width Lower Limit" **408**, "Lower Wavelength Detected" **410**, "Pulse Width Median" **412**, and "Wavelength Median" **414**. The database is located in the memory in the pulse oximeter. The database is where the result of each test completed by the calibration software is stored into. The first two columns house the date **400** and time **402** of each test. The next two columns have the pulse width upper limit **404** achieved during the test before encountering an error and the corresponding wavelength emitted **406** at that pulse width upper limit. The next two columns have the pulse width lower limit **408** achieved during the test before encountering an error and the corresponding wavelength emitted **410** at that pulse width lower limit. The final two columns have the calculated median values for both pulse width **412** and wavelength between their upper and lower limits **414**.

[0017] The present invention is not intended to be restricted to the several exemplary embodiments of the invention described above. Other variations that may be envisioned by those skilled in the art are intended to fall within the disclosure.

1. A method for calibrating pulse width and median wavelength of a pulse oximetry system, the method comprising:

increasing a width of a pulse until an error reading is detected;

recording an upper limit of the pulse width and a corresponding mean wavelength before the error reading is detected;

decreasing the pulse width until another error reading is detected;

calculating a median pulse width;

comparing the calculated median pulse width with a given specification of the pulse oximetry system, wherein the comparison reveals a mismatch between the calculated median pulse width and the given specification; and

adjusting the pulse width using a calibration software until the given specification is matched.

2. The method of claim **1**, wherein the error reading detected is a photodetector error reading.

3. The method of claim **2**, wherein the photodetector error reading arises from a detected wavelength outside of the given specification.

4. The method of claim **2**, wherein the photodetector error reading arises from a substantially flat reading over a given specified wavelength range being detected.

5. The method of claim **1**, wherein the pulse is emitted by a light-emitting device (LED) of the pulse oximetry system.

6. The method of claim **1**, further comprising recording a lower limit of the pulse width and a corresponding mean wavelength before the other error reading is detected.

7. A system for calibrating pulse width and median wavelength of a pulse oximetry system, the system comprising:

a pulse width modulator that increases a width of a pulse until an error reading is detected and that decreases the pulse width until another error reading is detected;

memory that records an upper limit of the pulse width and a corresponding mean wavelength before the error reading is detected;

a processor that executes instructions stored in memory, wherein execution of the instruction by the processor:

calculates a median pulse width,

compares the calculated median pulse width with a given specification of the pulse oximetry system, wherein the comparison reveals a mismatch between the calculated median pulse width and the given specification, and

adjusts the pulse width using a calibration software until the given specification is matched.

8. The system of claim **7**, wherein the error reading detected is a photodetector error reading.

9. The system of claim **8**, wherein the photodetector error reading arises from a detected wavelength outside of the given specification.

10. The system of claim **8**, wherein the photodetector error reading arises from a substantially flat reading over a manufacturer specified wavelength range being detected.

11. The system of claim **7**, wherein the pulse is emitted by a light-emitting device (LED) of the pulse oximetry system.

12. The system of claim **7**, wherein memory further records a lower limit of the pulse width and a corresponding mean wavelength before the other error reading is detected.

13. A non-transitory computer-readable storage medium, having embodied thereon a program executable by a processor to perform a method for calibrating pulse width and median wavelength of a pulse oximetry system, the method comprising:

increasing a width of a pulse until an error reading is detected;

recording an upper limit of the pulse width and a corresponding mean wavelength before the reading error is detected;

decreasing the pulse width until another error reading is detected;

calculating a median pulse width;

comparing the calculated median pulse width with a given specification of the pulse oximetry system, wherein the comparison reveals a mismatch between the calculated median pulse width and the given specification; and

adjusting the pulse width using a calibration software until the given specification is matched.

* * * * *

专利名称(译)	具有集成脉冲宽度调制器的脉搏血氧仪系统		
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申请(专利权)人(译)	皇家飞利浦N.V.		
当前申请(专利权)人(译)	皇家飞利浦N.V.		
[标]发明人	CRONIN JOHN DANDREA MICHAEL		
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外部链接	Espacenet USPTO		

摘要(译)

一种系统和方法，包括脉冲血氧计，脉冲宽度调制器周期性地测试在脉冲宽度的上限和下限发射的en波长，以确保中值脉冲宽度发射制造商规定的波长。该系统包括脉冲血氧计，其具有LED发射器，光电探测器，脉冲宽度调制器和存储器。规格数据库包含与制造商指定的波长有关的数据。校准软件将定期测试LED，以确保LED发出正确的波长，以便检测患者血液中的正确成分。每当脉搏血氧仪通电时进行测试，然后再以指定的间隔进行测试，直到电源与脉搏血氧仪断开。每个测试包括增加脉冲宽度直到检测到错误，记录错误发生前脉冲宽度的上限和相应的波长。然后通过减小脉冲宽度执行相同的测试，直到检测到错误。然后计算中值脉冲宽度的波长发射器并与制造商的规格进行比较。如果它们不匹配，校准软件会调整脉冲宽度，直到达到制造商的规格。