US 20160143566A1

(19) **United States**

(12) **Patent Application Publication**

BALLAM et al.

(10) **Pub. No.: US 2016/0143566 A1**

(43) **Pub. Date: May 26, 2016**

(54) **CIRCUITRY TO ALLOW LOW CURRENT OPERATION OF A DEVICE CAPABLE OF DETERMINING A BLOOD PROPERTY**

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(21) Appl. No.: **14/549,167**

(22) Filed: **Nov. 20, 2014**

Publication Classification

(51) **Int. Cl.**

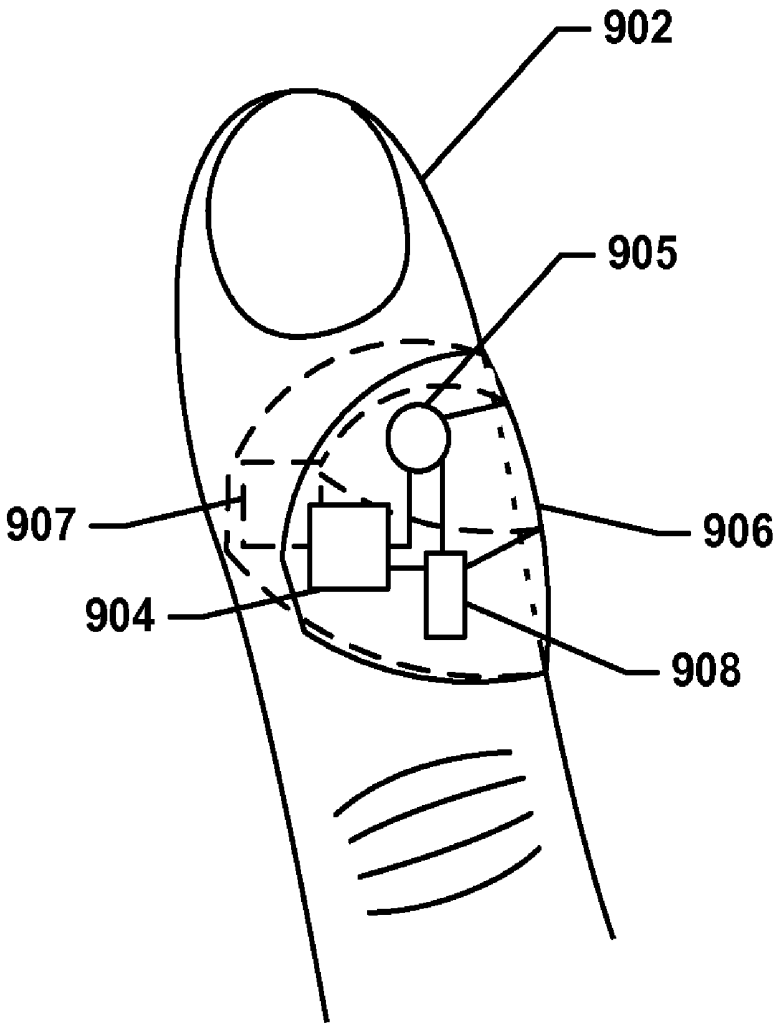
A61B 5/1455	(2006.01)
A61B 5/00	(2006.01)

(52) **U.S. Cl.**

CPC ***A61B 5/14552*** (2013.01); ***A61B 5/7278*** (2013.01); *A61B 2560/0214* (2013.01); *A61B 2562/0238* (2013.01); *A61B 2560/0412* (2013.01); *A61B 2562/164* (2013.01)

(57) **ABSTRACT**

Systems, methods, and devices of the various embodiments provide a device capable of determining a blood property based at least in part on the measurement of the amount of light received by a receiver circuit with a limited current capacity by charging a capacitor with a low voltage power supply and intermittently discharging the capacitor through a light emitting diode. In some embodiments the device may be a pulse oximeter capable of taking blood oxygen readings. In some embodiments the device may be a heart rate monitor to determine a heart rate based on an amount of light passed through tissue. The various embodiments may enable pulse oximeters and/or heart rate monitors to be incorporated into small unobtrusive body patches, while enabling the pulse oximeters to operate from a power output equivalent to that of a small coin cell battery or printed cell battery.



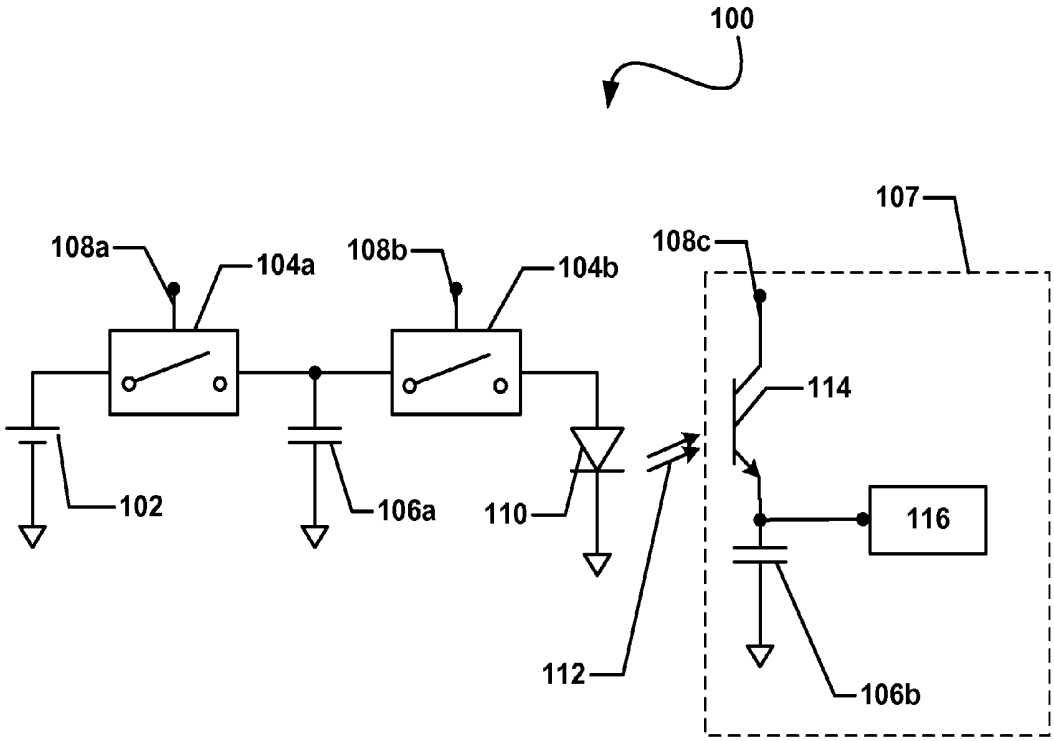


FIG. 1

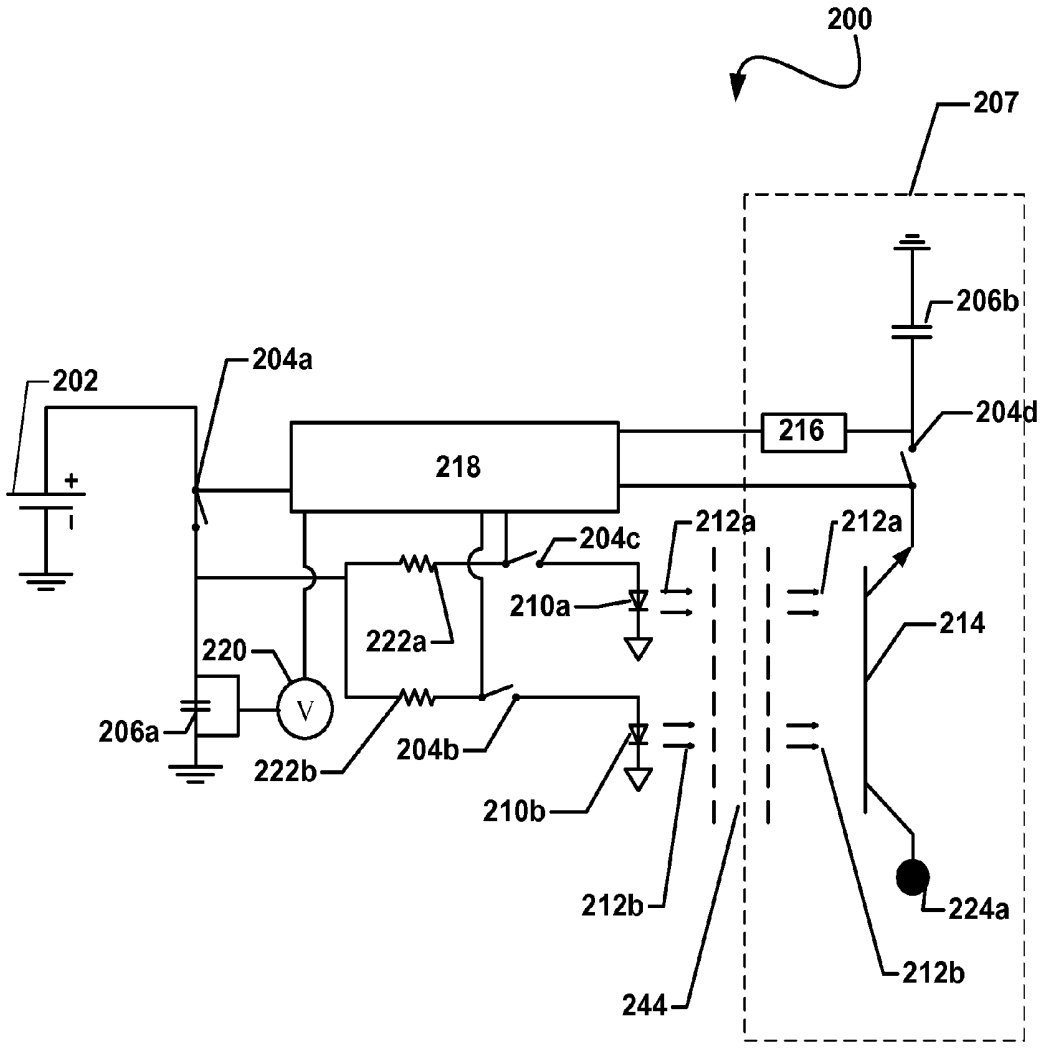

200
207
206b
204d
202
204a
216
218
204c
212a
212a
210a
214
220
222a
206a
V
204b
222b
210b
212b
224a
212b
244

FIG. 2

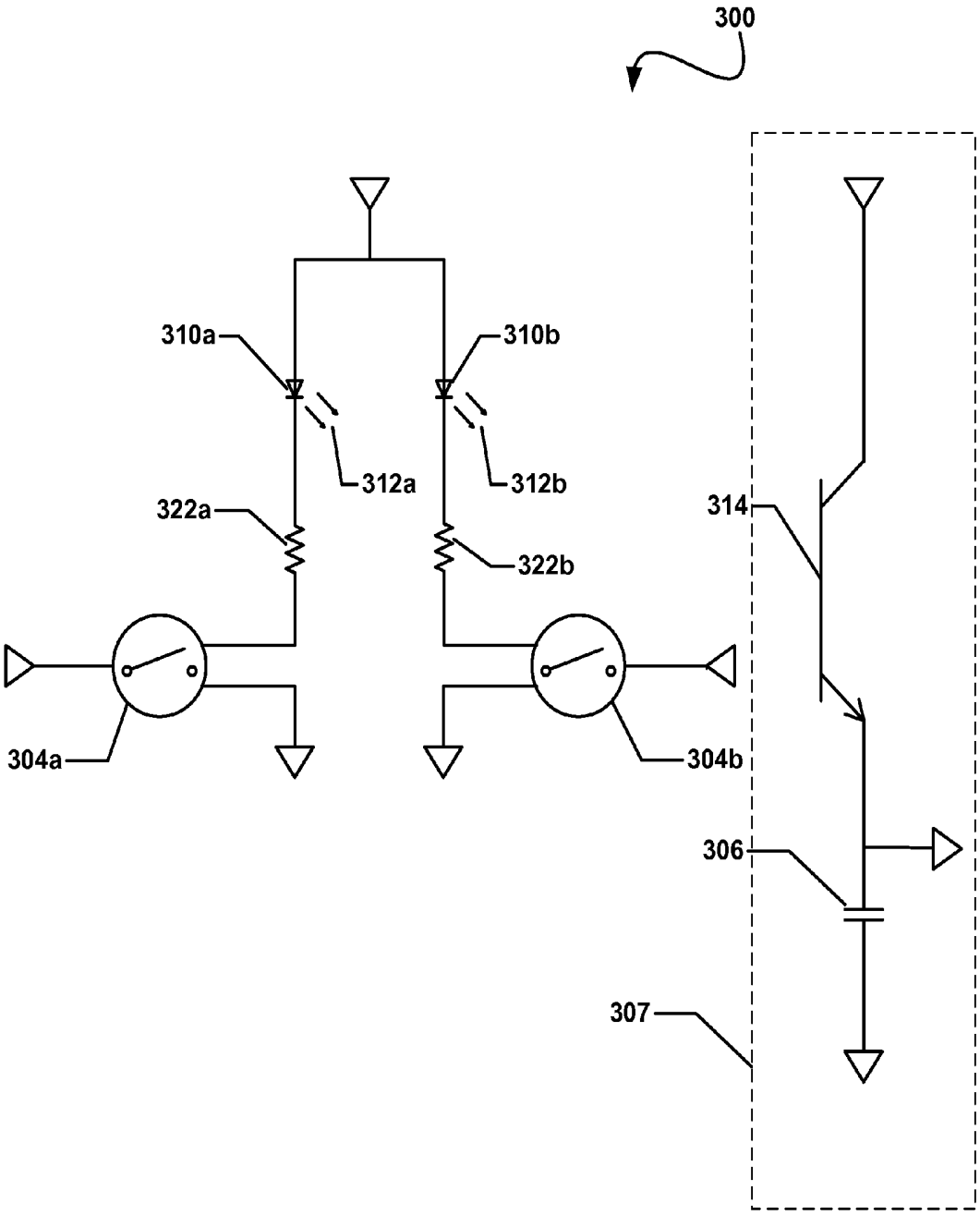


FIG. 3

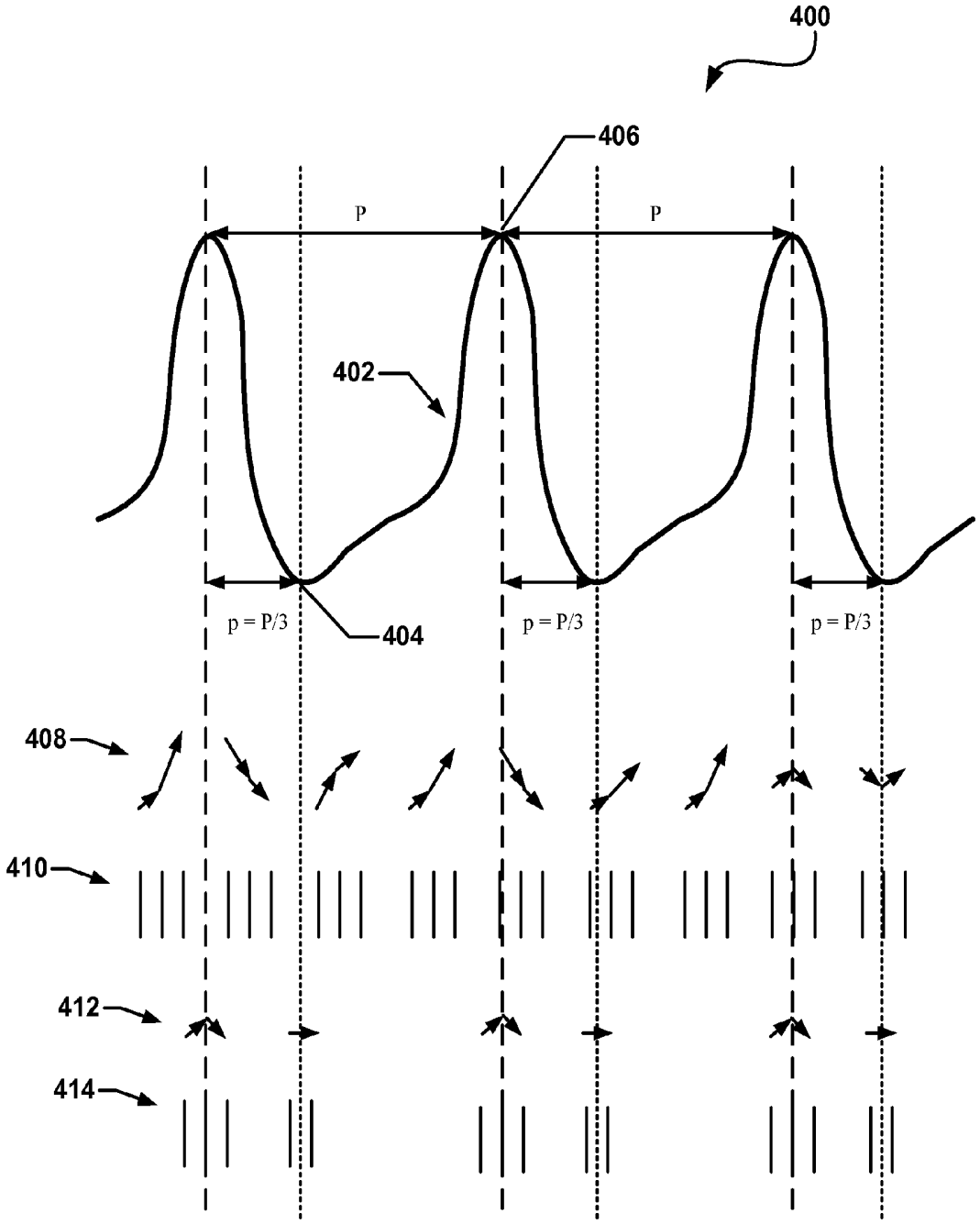


FIG. 4

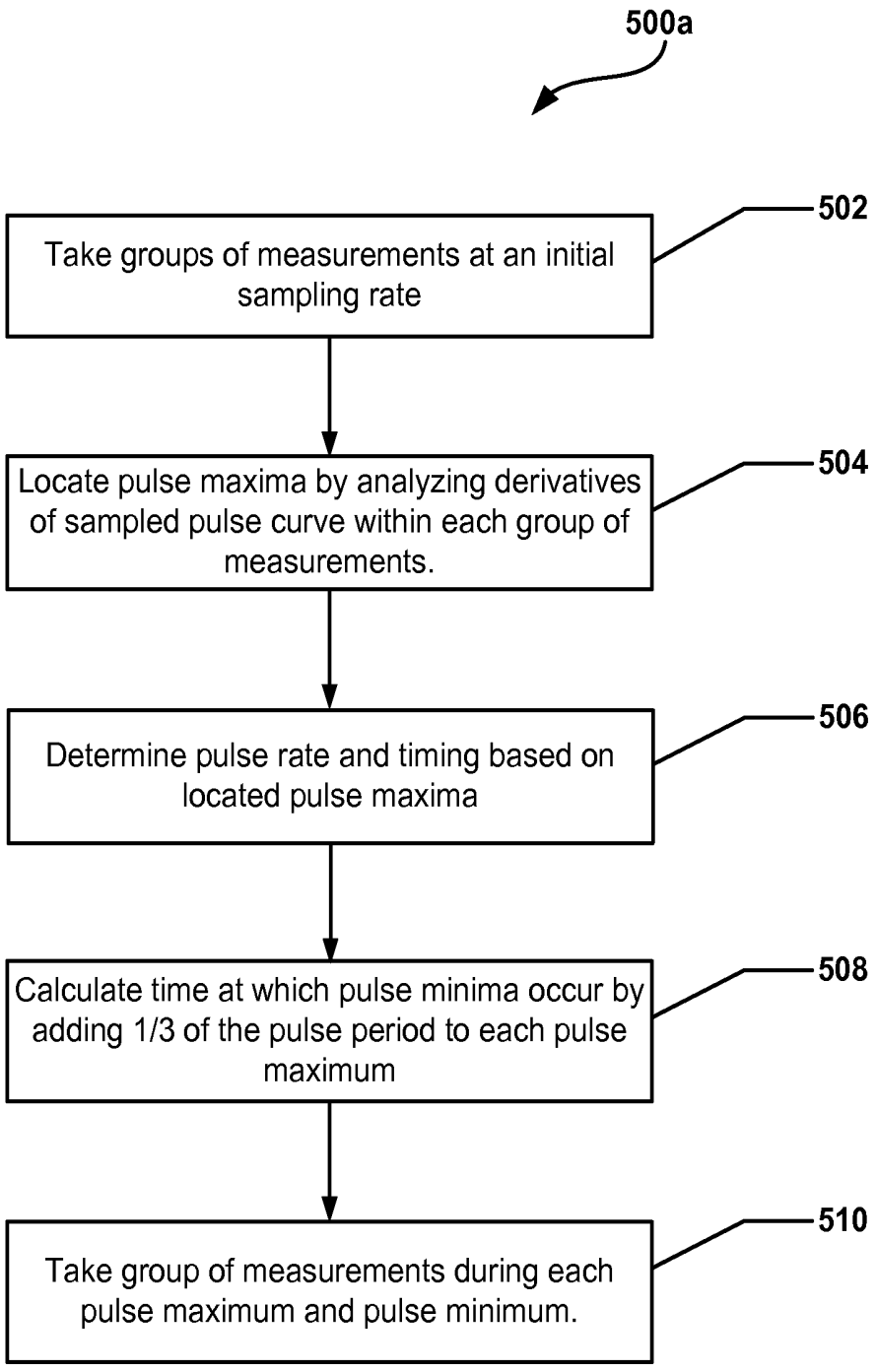

500a
Take groups of measurements at an initial sampling rate
502
Locate pulse maxima by analyzing derivatives of sampled pulse curve within each group of measurements.
504
Determine pulse rate and timing based on located pulse maxima
506
Calculate time at which pulse minima occur by adding 1/3 of the pulse period to each pulse maximum
508
Take group of measurements during each pulse maximum and pulse minimum.
510

FIG. 5A

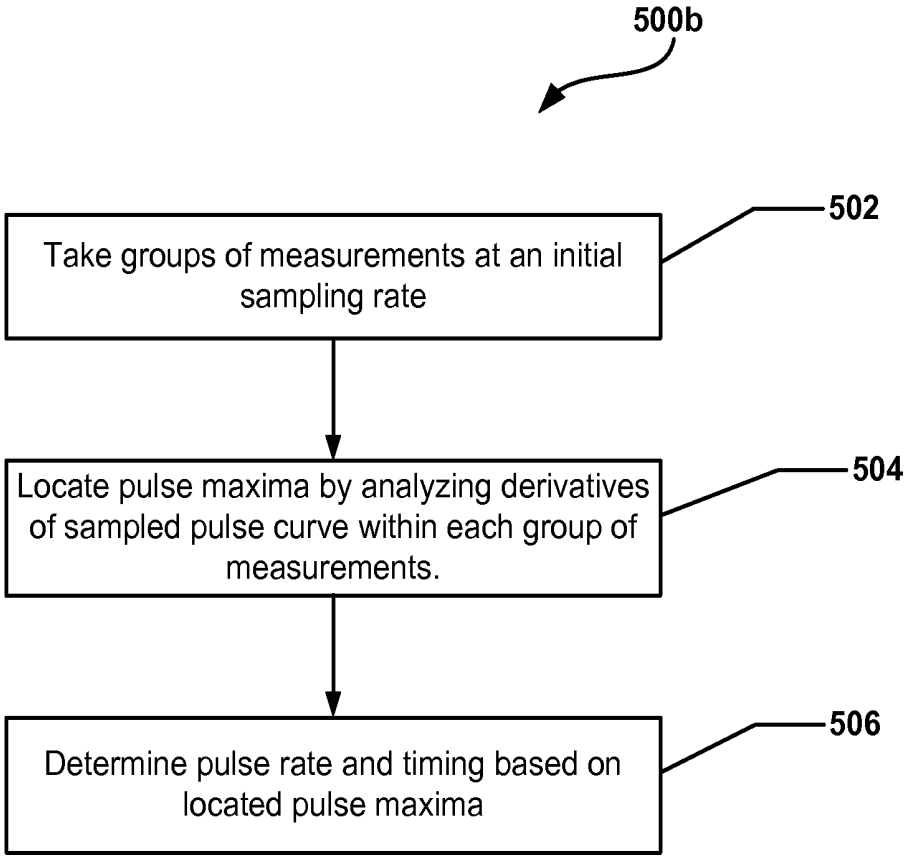

500b
Take groups of measurements at an initial sampling rate
502
Locate pulse maxima by analyzing derivatives of sampled pulse curve within each group of measurements.
504
Determine pulse rate and timing based on located pulse maxima
506

FIG. 5B

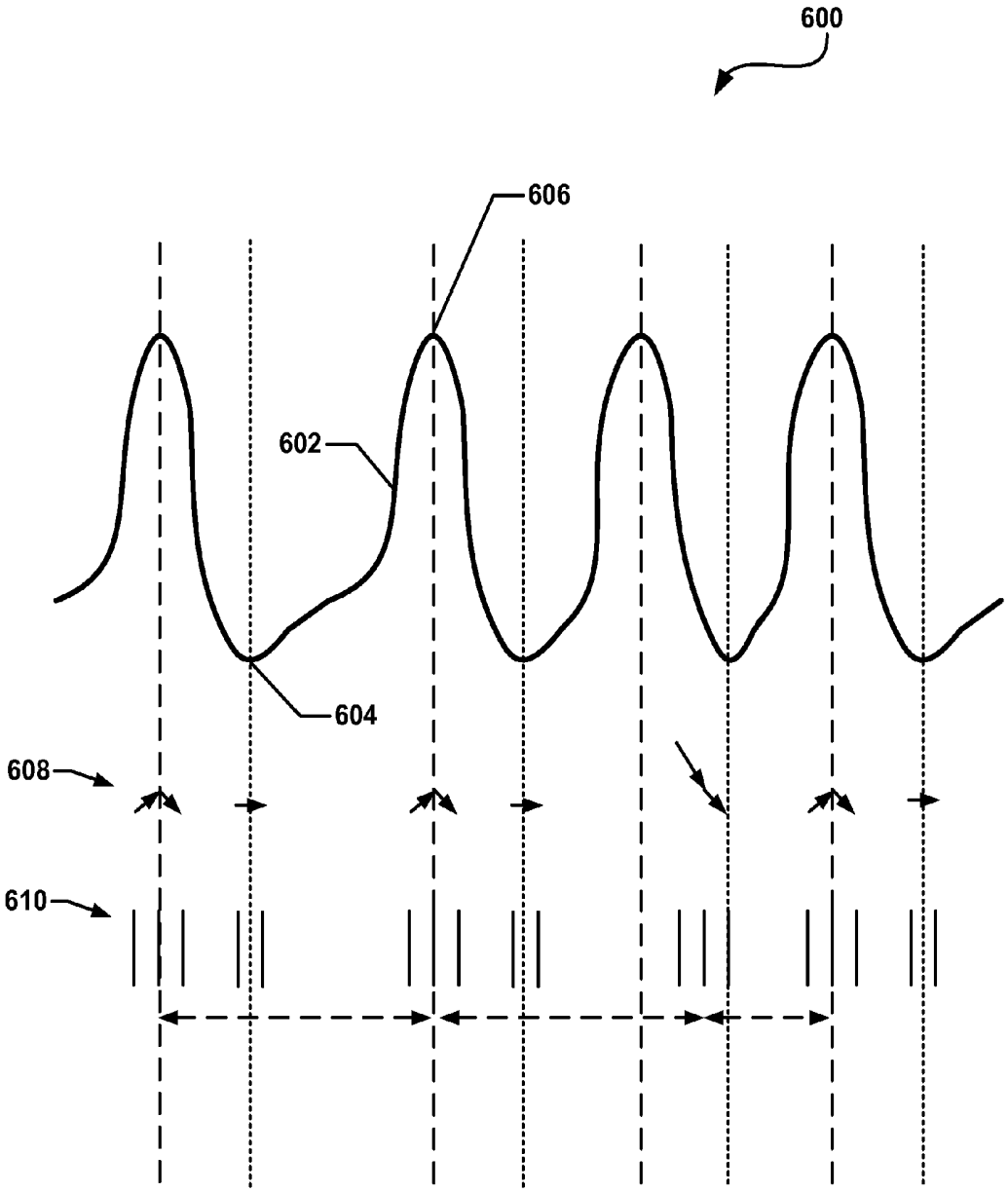


FIG. 6

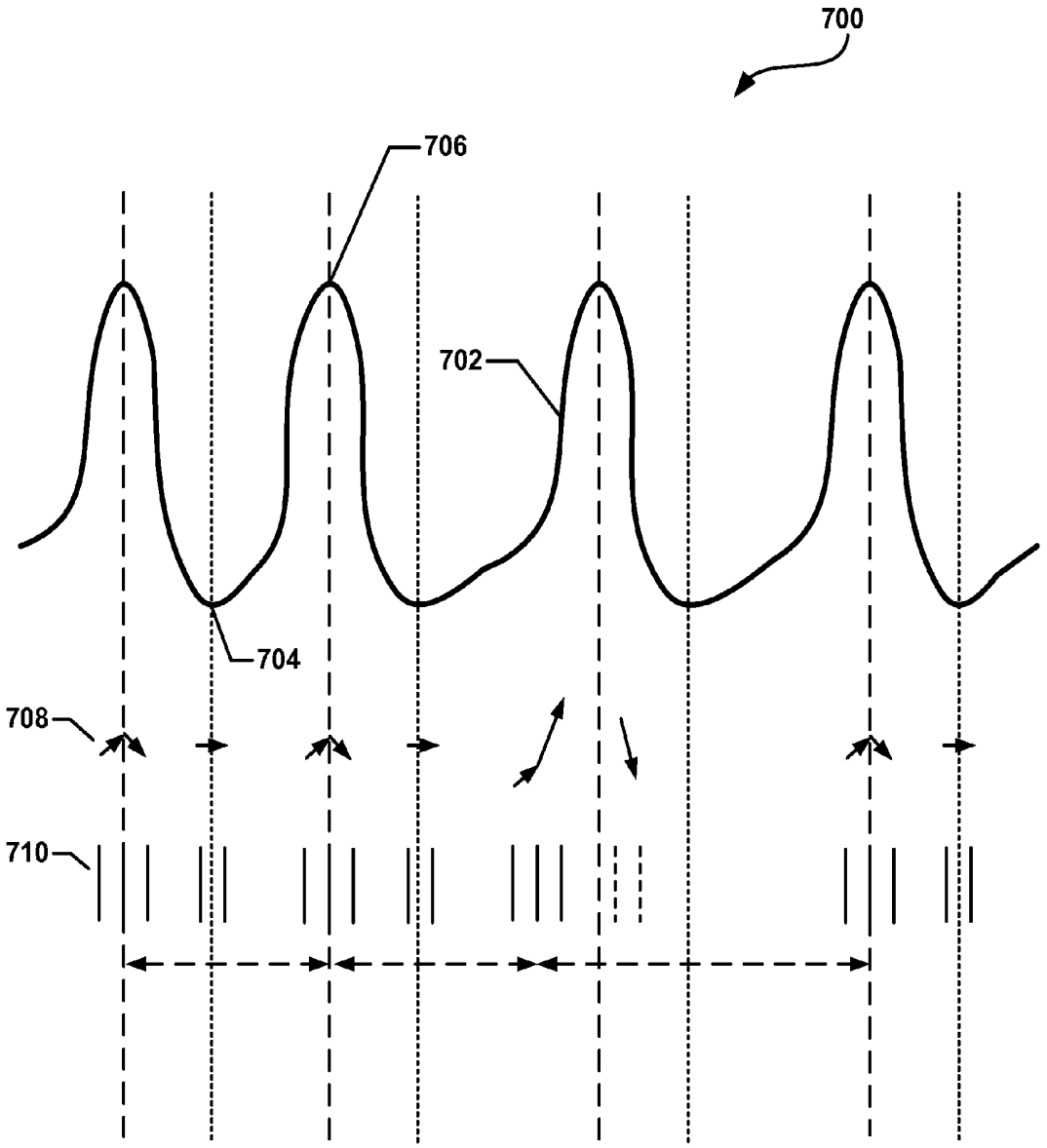


FIG. 7

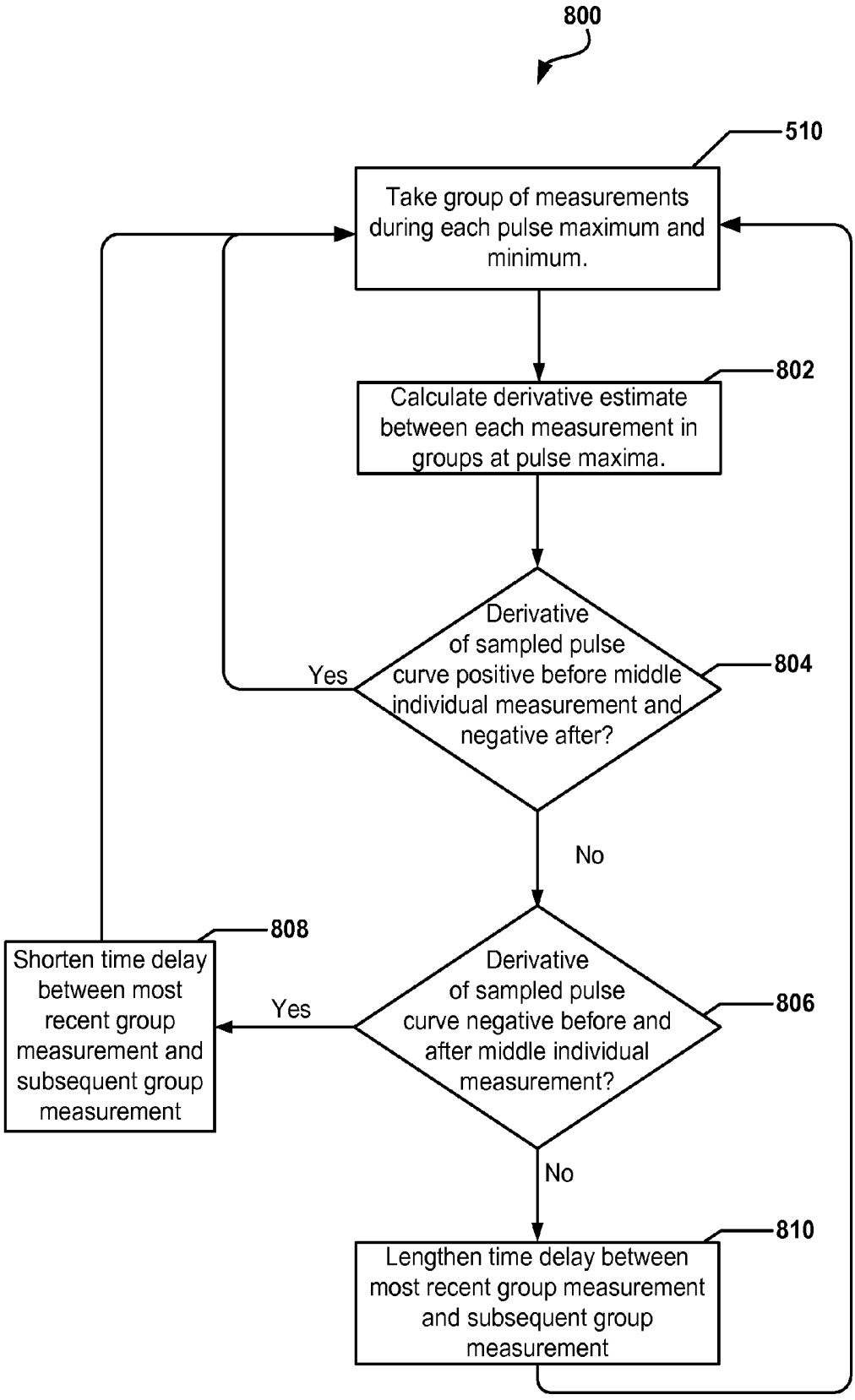

800
510
Take group of measurements during each pulse maximum and minimum.
802
Calculate derivative estimate between each measurement in groups at pulse maxima.
804
Derivative of sampled pulse curve positive before middle individual measurement and negative after?
Yes
No
806
Derivative of sampled pulse curve negative before and after middle individual measurement?
Yes
808
Shorten time delay between most recent group measurement and subsequent group measurement
No
810
Lengthen time delay between most recent group measurement and subsequent group measurement

FIG. 8

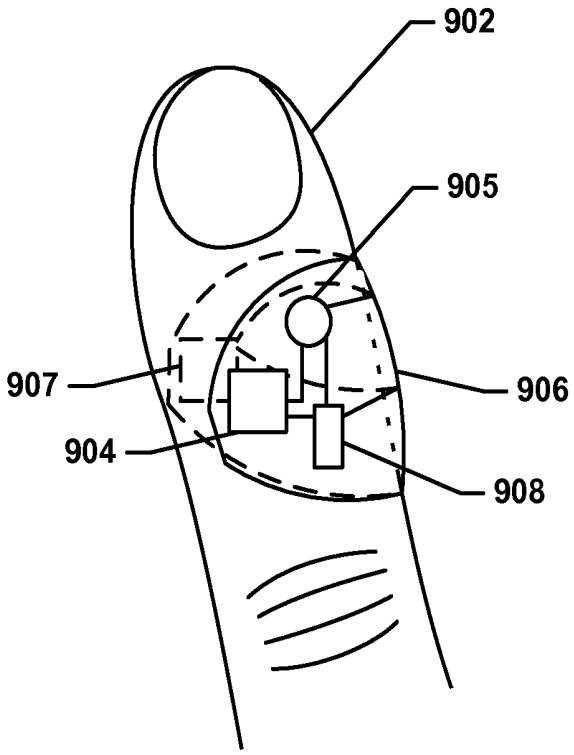


FIG. 9

CIRCUITRY TO ALLOW LOW CURRENT OPERATION OF A DEVICE CAPABLE OF DETERMINING A BLOOD PROPERTY

BACKGROUND

[0001] Continuous monitoring of vital signs with the ability to remotely monitor patient status is a growing field and the ability to incorporate multiple measurement capabilities into a single small unobtrusive patch that can be worn by a patient (i.e., a body worn patch) for multiple days at a time is a desirable feature. One such measurement is blood oxygen concentration, often carried out by a pulse oximeter. However, current pulse oximeter designs are not conducive to being powered by an ultra-low power source, such as a small coin cell battery, and thus not suited for incorporation into a body worn patch.

SUMMARY

[0002] The systems, methods, and devices of the various aspects provide a device capable of determining a blood property based at least in part on the measurement of the amount of light received by the receiver circuit, such as taking blood oxygen and/or pulse readings, while being powered by a power source with a limited current capacity. The various aspects may enable a device, such as a pulse oximeter or heart monitor, to be incorporated into a small unobtrusive body patch, while enabling the device to be powered by a current source equivalent to that of a small coin cell battery or printed cell battery. In an example device, a small coin cell battery or printed cell battery may be used to charge a capacitor. When the capacitor reaches a predefined voltage, the battery/charging circuit may be disconnected from the capacitor, and electricity may be allowed to flow from the capacitor to a light-emitting diode (LED). Because the LED no longer needs to be driven by a constant current, this technique may eliminate the need for a constant current and/or high power source in the device. In some example systems, methods, and devices the device may be a heart rate monitor capable of taking heart rate measurements while being powered by a power source with a limited current capacity. In some example systems, methods, and devices the device may be a pulse oximeter monitor capable of taking blood oxygen measurements while being powered by a power source with a limited current capacity.

[0003] In an example device, a photodetector may be closely synchronized with the discharge of the capacitor through the LED. An output of a photodetector may be connected to an integrating capacitor. Just before the charging capacitor is connected to the LED to cause the LED to switch on, the integrating capacitor may be discharged. When the LED is switched on, a portion of the photons emitted by the LED may be detected by the photodetector, which may convert these detected photons to a current that is integrated (i.e., stored) by the integrating capacitor. As the LED is switched off, a microprocessor of the device may measure the voltage stored in the integrating capacitor to determine the output of the photodetector, which may be converted to an LED signal amplitude or used to calculate blood oxygen concentration. Minimizing the time between discharging the integrating capacitor and turning on the LED and also the time between turning off the LED and taking a voltage reading of the integrating capacitor may minimize the amount of ambient light detected by the circuit and improve overall performance of the circuit.

[0004] In an aspect, current demand may be further limited by timing when measurements are taken to coincide with desired points in a patient's pulse cycle in order to minimize the amount of time that the circuit is energized to take samples. To synchronize with the pulse cycle, multiple preliminary samples may be taken with the LED over a short amount of time, such as one second. These samples may be frequent enough to span a complete pulse cycle regardless of the patient's current heart rate. In another aspect, the samples may be taken such that a full set of readings is not taken over one pulse cycle. Taking samples over less than the complete pulse cycle may increase the time required to obtain an initial reading, while reducing the current draw on a coin cell battery or printed cell battery. Using measurements from the preliminary sample, the microprocessor of the device may calculate the patient's heart rate and timing by observing changes in measurement values. The processor may use the calculated values to anticipate subsequent pulse maxima and minima and activate the circuitry to take readings at those points in the pulse cycle or waveform. A minimal number of readings may then be taken on each subsequent pulse cycle or waveform. For example, readings may be limited such that just enough readings are taken to ensure that readings remain synchronized to the maxima and minima portions of the pulse waveform. If the patient's pulse rate changes, the microprocessor may adjust the predicting timing of pulse maxima and minima to follow. If necessary, the processor may resynchronize with the heart rate by taking a full second's worth of samples and use those samples to recalculate the timing of pulse maxima and minima.

BRIEF DESCRIPTION OF THE DRAWINGS

[0005] The accompanying drawings, which are incorporated herein and constitute part of this specification, illustrate exemplary embodiments of the teachings of the disclosure, and together with the general description given above and the detailed description given below, serve to explain the features of the disclosure.

[0006] FIG. **1** is a circuit diagram illustrating first embodiment circuit for device, such as a pulse oximeter or heart rate monitor, configured to minimize current draw.

[0007] FIG. **2** is a circuit diagram illustrating a second embodiment circuit for device, such as a pulse oximeter or heart rate monitor, configured to minimize current draw.

[0008] FIG. **3** is a circuit diagram illustrating a third embodiment circuit for device, such as a pulse oximeter or heart rate monitor, configured to minimize current draw.

[0009] FIG. **4** is a sample heart rate graph illustrating a lock-in procedure and subsequent pulse measurements.

[0010] FIG. **5**A is a process flow diagram illustrating an embodiment method for executing a lock-in procedure.

[0011] FIG. **5**B is a process flow diagram illustrating an embodiment method for determining a heart rate based on an amount of light received by a heart rate monitor.

[0012] FIG. **6** is a sample heart rate graph illustrating a sample rate adjustment according to an embodiment.

[0013] FIG. **7** is sample heart rate graph illustrating another sample rate adjustment according to an embodiment.

[0014] FIG. **8** is a process flow diagram illustrating an embodiment sample rate adjustment procedure.

[0015] FIG. **9** is a diagram illustrating an embodiment electronic patch including a pulse oximeter or heart rate monitor placed on a patient.

DETAILED DESCRIPTION

[0016] The various embodiments will be described in detail with reference to the accompanying drawings. Wherever possible, the same reference numbers will be used throughout the drawings to refer to the same or like parts. References made to particular examples and implementations are for illustrative purposes, and are not intended to limit the scope of the invention or the claims.

[0017] The word "exemplary" is used herein to mean "serving as an example, instance, or illustration." Any implementation described herein as "exemplary" is not necessarily to be construed as preferred or advantageous over other implementations.

[0018] Pulse oximeters monitor oxygen levels in the blood stream. Pulse oximeters typically operate by shining light of two different wavelengths through a body part and measuring the relative differences in the amplitude of the original light and the received light at the two different wavelengths. For example, one wavelength may be red and the other infrared. Blood with lower levels of oxygen may tend to absorb less infrared light and more red light. Alternatively, blood with higher levels of oxygen may tend to absorb more infrared light and less red light. Thus, a properly calibrated pulse oximeter may determine oxygen levels by emitting light of red and infrared wavelengths and measuring the relative amounts of red and infrared light after the light has passed through a body part, such as a fingertip or earlobe.

[0019] Pulse oximeters require a power source to provide current to the sources of light (e.g., light-emitting diodes or LEDs). One solution is to continuously provide power to LEDs such that they are always on and the pulse oximeter constantly collects data. One example design is a pulse oximeter that uses a high precision current sink to control LEDs that are driven with a voltage-controlled source. These current pulse oximeter designs generally consume a considerable amount of boost power. However, lower power sources that may not be capable of providing continuous power sufficient to power the LEDs of a pulse oximeter may be cheaper and more efficient than high power sources, and may therefore be preferable for use in pulse oximeters. Moreover, continuously providing power to LEDs may not be well suited for incorporation into a body worn patch because high current consumption requires larger batteries that are not compatible with the patch form factor. For instance, typical LED drive current levels are approximately 10 mA, whereas typical coin cell batteries are limited to a maximum current draw of approximately 6 mA.

[0020] The various embodiments include a device, which may be a pulse oximeter or heart rate monitor, capable of operating based upon low voltage and/or current power sources, such as coin cell batteries or printed cell batteries. Coin cell batteries or printed cell batteries may be low current power sources that cannot supply high continuous current. For example in comparison to Lithium ion batteries that may supply 0.5 current continuous (i.e., 0.5 times the batteries rated capacity, such that a 70 mA battery may supply 35 mA for two hours), coin cells may only supply relatively small currents for a short duration (typically around 6 mA for a few seconds). The systems, methods, and devices of the various embodiments provide a heart rate monitor capable of taking heart rate measurements while being powered by a power source with a limited current capacity, such as coin cell batteries or printed cell batteries.

[0021] The systems, methods, and devices of the various embodiments include device, such as a pulse oximeter capable of taking blood oxygen readings or a heart rate monitory capable of monitoring heart beats, with the measurements being taken while drawing limited current. The various embodiments may enable devices (e.g., pulse oximeters) to be incorporated into small unobtrusive body patches, while enabling the devices to operate within the voltage and current constraints equivalent to that of a small coin cell battery or printed cell battery. In an embodiment pulse oximeter, a small coin cell battery or printed cell battery may charge a capacitor (sometimes referred to herein as the "charging capacitor"). When the charging capacitor reaches a predefined voltage it may be disconnected from the battery/charging circuitry (e.g., via a switch), and connected (e.g., via a switch) to the LED so that the stored charge may flow from the capacitor through an LED causing it to illuminate briefly. The charging capacitor may be disconnected from the battery/charging circuitry before being connected to the LED. To measure the oxygen concentration, light transmitted through the patient's tissues may be measured by using a photodetector to convert photons into current. In an embodiment, the output of the photodetector may be accumulated or integrated over the duration of the LED illumination using a second capacitor (sometimes referred to herein as the "integrating capacitor"). Thus, the illuminating LED is activated periodically using power stored in the charging capacitor and measurements are taken simultaneously using a photodetector coupled to an integrating capacitor. Because the LED no longer needs to be driven by a constant current, this technique may eliminate the need for a constant current and/or high power source in the pulse oximeter. Also, the periodic operation reduces the amount of power drawn from the battery, extending the operating life of the circuit when powered by a battery. Additionally, drawing a lower current over longer time increases the power efficiency of many batteries, further helping to make a coin cell battery or printed cell battery a viable power source for the pulse oximeter.

[0022] In an embodiment pulse oximeter, measurements of light by the photodetector may also be closely synchronized with the flash of the LED, and thus with the connection of the charging capacitor to the LED. For example, the photodetector may be connected to the integrating capacitor to begin the integration of its output signal just before the LED fires. The photodetector may then disconnect from the integrating capacitor to cease integration just after the LED turns off. A microprocessor of the pulse oximeter may control the actuation of switches that connect the charging capacitor to the LED and connect the integrating capacitor to the photodetector. The microprocessor may measure the output of the photodetector by measuring the voltage of the integrating capacitor. In an embodiment, the voltage of the integrating capacitor may be converted to LED signal amplitude. Limiting the time in which the photodetector measures an input may minimize ambient light detection, resulting in more accurate measurements.

[0023] In an embodiment, the current drawn by the pulse oximeter may be further limited by minimizing the measurements that are taken. This may be achieved by synchronizing measurements to the patient's pulse cycle (also referred to as the pulse waveform), and only taking measurements at particular points of interest, such as at the point of maximum blood flow ("pulse maxima") and at the point of minimum blood flow ("pulse minima"). To achieve such synchroniza-

tion the processor of the pulse oximeter may perform a synchronization routine in which multiple preliminary samples are taken over a short period of time, such as one second. The short period of time, such as one second, may be a length of time selected to increase the likelihood that at least one full pulse cycle will occur while the multiple preliminary samples are being taken. The samples may be taken frequently enough to provide adequate resolution of the pulse cycles regardless of the patient's heart rate. The microprocessor of the pulse oximeter may use the measurements gathered in the preliminary samples to calculate the heart rate and detect the timing of the pulse maxima. Using this information the processor may anticipate when subsequent maxima and minima will occur and schedule measurements accordingly. A minimal number of readings may then be used for each subsequent pulse(s), such as readings taken just at the pulse maxima and pulse minima. Readings may be limited so that just enough readings are taken to ensure that the processor can adjust the timing of readings so they remain synchronized to the pulse maxima and minima. If synchronization is lost, the microprocessor may resynchronize with the heart rate, such as by taking a full second's worth of samples and recalculate the anticipated maxima and minima.

[0024] In an embodiment, synchronization may be performed without taking a full set of readings over one pulse cycle. The microprocessor of the pulse oximeter may initially subsample the waveform and adjust the timing until it has locked onto the pulse waveform. In comparison to taking a full set of readings over one pulse cycle, this type of synchronization may take longer to obtain an initial reading. However, synchronization without taking a full set of readings over one pulse cycle may provide the advantage of drawing less peak power from the low current power source, such as a coin cell battery or printed cell battery. In an embodiment, a few readings, such as two or more readings, may be taken close together to enable the slope of the waveform to be observed and heart rate to be estimated. The timing of measurements may then be adjusted to lock onto the maxima and minima of the pulse or heartbeat cycles/waveforms.

[0025] Low voltage power sources alone may not be capable of continuously providing sufficient current to standard light sources, such as LEDs. The various embodiments address this characteristic of low voltage power sources with a pulse oximeter in which the light source(s) is powered by a capacitor that is charged by the power source. The capacitor may be coupled to the light source to emit light (and the pulse oximeter may gather data) intermittently. By avoiding a constant drain on the low voltage power source, the embodiment pulse oximeters may operate solely based upon a low voltage power source, such as a coin cell battery or printed cell battery.

[0026] FIG. **1** is a circuit diagram illustrating an embodiment circuit **100** for a device (e.g., a pulse oximeter or heart rate monitor) configured to minimize current draw of the circuit **100**. In an embodiment, the circuit **100** may be integrated into an electronic patch worn by a patient. A low voltage source **102**, such as a coin cell battery or printed cell battery, may be connected to a charging capacitor **106***a* by a voltage control element **104***a*. The voltage control element **104***a* may control when the low voltage source **102** charges the charging capacitor **106***a*. Persons skilled in the art will appreciate that the voltage control element **104***a* may be any type of controllable component capable of alternately electrically isolating the charging capacitor **106***a* from the low voltage source **102** and electrically connecting the charging capacitor **106***a* to the low voltage source **102**. For instance, the voltage control element **104***a* may be a switch, a voltage regulator, a field effect transistor (FET), a switch mode power supply (SMPS), etc. Preferably, the voltage control element **104***a* may be capable of electrically isolating the charging capacitor **106***a* such that when the LED **110** is turned on no further charge leaks onto the charging capacitor **106***a* from the low voltage source **102**.

[0027] The charging capacitor **106***a* may also be connected to a LED **110** by a voltage control element **104***b*. The voltage control element **104***b* may be any type of controllable component capable of alternately electrically isolating the charging capacitor **106***a* from the LED **110** and electrically connecting the charging capacitor **106***a* to the LED **110**, such as a transistor, field effect transistor (FET), switch, etc.

[0028] In an embodiment, the low voltage source **102** may supply a constant voltage. For a sufficiently constant voltage supply, there may be no need for a voltage regulator on the capacitor. However, the voltage supplied by some voltage sources, such as batteries, may diminish over time. To compensate for a changing voltage output by the low voltage source **102**, it may be desirable to measure the voltage on the charging capacitor **106***a* or utilize a regulator (e.g., a low dropout regulator or a boost regulator) to charge the capacitor to a constant voltage independent of the changing voltage output of the voltage source **102**. The voltage control element **104***a* may be controlled via a microprocessor to vary the amount of charge on the charging capacitor **106***a*. The general-purpose input/output **108***a* (GPIO) may mediate communication between a microprocessor and the voltage control element **104***a*. For example, the inputs on the GPIO **108***a* may control the voltage control element **104***a* to open to isolate the charging capacitor **106***a* from the low voltage source **102** and to close to provide charge from the low voltage source **102** to the charging capacitor **106***a*.

[0029] A low voltage source **102** in direct and constant connection with an LED may not by itself supply the voltage required to power the LED. Therefore, rather than maintaining a constant connection between the low voltage source **102** and the LED **110**, the voltage control element **104***a* may remain closed until the low voltage source **102** has charged the charging capacitor **106***a* to a predefined amount of voltage. When the charging capacitor **106***a* has been charged to the predefined amount, the voltage control element **104***a* may open while voltage control element **104***b* closes which may electrically isolate the low voltage source **102** from the charging capacitor **106***a* while electrically connecting the charging capacitor **106***a* to the LED **110**. The isolation of the low voltage source **102** from the charging capacitor **106***a* may ensure there is no additional load on the low voltage power source **102** when the measurement circuit **107** is measuring light, thereby removing a source of noise. The voltage control element **104***b* may be controlled via a microprocessor to synchronize the opening of the voltage control element **104***a* with the closing of voltage control element **104***b*, and vice versa. The GPIO **108***b* may mediate communication between the microprocessor and the voltage control element **104***b*. Further, although the voltage control element **104***b* is located before the LED **110**, it may alternatively be located after the LED **110**.

[0030] A resistor may be connected in series with the LED **110** to control the current through the LED **110**. Sufficient

charge may thus flow from the charging capacitor **106***a* to the LED **110** to turn the LED on for a short time (i.e., cause the LED to emit light **112**).

[0031] When the stored charge passes through the LED **110**, the LED emits light **112**. In an embodiment, the voltage control element **104***b* may be controlled by the microprocessor to provide charge from the charging capacitor **106***a* to the LED **110** for a period of time to cause the LED **110** to emit light **112** for a controlled duration of time, and after the period of time the voltage control element **104***b* may be controlled by the microprocessor to isolate the LED **110** from the charging capacitor **106***a*, thereby causing the LED **110** to cease emitting light. In this manner, light bursts may be generated from the LED **110** and the current draw of the circuit **100** may be minimized by only turning the LED **110** on for the period of time required to complete one measurement.

[0032] The light **112** emitted by the LED **110** propagates through a body part, such as an earlobe or a fingertip, and is measured by a receiver circuit **107** that includes a photodetector **114**, such as a phototransistor or light sensor, that is coupled to an integrating capacitor **106***b*, and an analog-to-digital (A/D) converter **116**. The photodetector **114** may be powered by a power supply **108***c*, such as the low power source **102**, a regulated power supply, GPIO, or any other type power supply. The photodetector **114** converts the light **112** into a current and the integrating capacitor **106***b* stores this energy in the form of an electric field characterized by the voltage across the capacitor. The processor may measure the energy stored in the integrating capacitor **106***b* by connecting it to an analog to digital (A/D) converter **116** that converts the charge in the capacitor to a digital signal. The processor may use this digital signal to determine the amount of light that passed through the patient's tissues, and from that information, calculate a heart rate and/or blood oxygen reading. The processor may analyze the digital signal independently or in conjunction with other data points. Thus, the digital output of the A/D converter **116** may be the output of the receiver circuit **107** that may be analyzed by the processor as measurements of blood properties, such as measurements of the heart rate and/or blood oxygen level.

[0033] The processor, such as using the A/D converter **116**, may be configured to discharge the integrating capacitor **106***b* just before a measurement is made in order to reduce a source of error in the measurements. This discharge of the integrating capacitor **106***b* may be synchronized with charging of the charging capacitor **106***a* and output of the light pulse of the LED **110** to improve the accuracy of measurements while reducing power requirements of the circuit **100**.

[0034] FIG. **2** is a circuit diagram illustrating a second embodiment circuit **200** for a device (e.g., pulse oximeter or heart rate monitor) configured to minimize current draw. In an embodiment, the circuit **200** may be integrated into an electronic patch worn by a patient. A low voltage source **202** powers the charging capacitor **206***a* when the switch **204***a* is closed. The switch may be located anywhere on the loop containing the low voltage source **202** and switch **204***a*, provided it can electrically separate the low voltage source **202** and switch **204***a*. The microprocessor **218** may control when the switch **204***a* opens or closes. For example, the microprocessor **218** may close switch **204***a* to allow charging capacitor **206***a* to collect charge. The charge on the charging capacitor **206***a* may correspond via a known relationship to the voltage across the charging capacitor **206***a*. The voltage across the charging capacitor **206***a* may be monitored by the voltmeter **220**. The voltmeter **220** may report the measured voltage to microprocessor **218**.

[0035] When the voltage across charging capacitor **206***a* reaches a predetermined threshold, the microprocessor **218** may open switch **204***a* at an appropriate time and close switches **204***b*, **204***c* to allow charge to flow from charging capacitor **206***a* to red LED **210***a* and infrared LED **210***b*. The opening of switch **204***a* may disconnect the low charging capacitor **206***a* from the low voltage power source **202** to isolate the low voltage power source **202** from the charging capacitor **206***a*. In this manner, opening switch **204***a* may ensure there is no additional load on the low voltage power source **202** when a measurement of light is taking place, thereby removing a source of noise in the measurements. The switches **204***b* and **204***c* may be closed consecutively to measure different wavelength absorption rates in quick succession. Switches **204***b*, **204***c* may remain open while the capacitor is charging to prevent unnecessary drain on the low voltage source **202**. Resistors **222***a*, **222***b* may be connected in series with a red LED **210***a* and an infrared LED **210***b* to control the current passing through each LED **210***a*, **210***b*. The resistors **222***a*, **222***b* may have the same or different resistances than each other. The resistors **222***a*, **222***b* may provide greater control on the allocation of current from the charging capacitor **206***a*, thus helping to eliminate the need for higher-current power supplies. In an embodiment, the switches **204***b*, **204***c* may be closed by the microprocessor **218** to provide charge from the charging capacitor **206***a* to the red LED **210***a* and infrared LED **210***b* for a period of time to cause the LEDs **210***a* and **210***b* to emit red light **212***a* and infrared light **212***b*, respectively. After the period of time, the switches **204***b*, **204***c* may be opened by the microprocessor **218** to isolate the LEDs **210***a* and **210***b* from the charging capacitor **206***a* to stop providing charge from the charging capacitor **206***a* to the LEDs **210***a* and **210***b* and stop the LEDs **210***a* and **210***b* from emitting red light **212***a* and infrared light **212***b*, respectively. In this manner, light bursts may be generated from the red LED **210***a* and the infrared LED **210***b*, and the current draw of the circuit **200** may be minimized by only turning the red LED **210***a* and infrared LED **210***b* on for the period of time. Additionally, only one LED **210***a* or **210***b* may be turned on at a time by closing either one of switch **204***b* or **204***c*, respectively, at a time. The charging capacitor **206***a* may need to be recharged to a known voltage before another LED **210***a* or **210***b* may be turned on.

[0036] When sufficient current passes through the red LED **210***a* and the infrared LED **210***b*, they emit red light **212***a* and infrared light **212***b*, respectively. The light **212***a*, **212***b* propagates through a body part **244**, such as a fingertip or earlobe. The amount of light absorbed by the body part **244** may be a function of the amount of oxygen in the blood and the amount of blood in the body part **244** at the time of sampling. Specifically, a body part **244** with a relatively large amount of oxygen may tend to absorb more infrared light **212***b* and less red light **212***a*. A body part **244** with a relatively small amount of oxygen may tend to absorb less infrared light **212***b* and more red light **212***a*. After passing through the body part **244**, the red light **212***a* and infrared light **212***b* may be absorbed by a photodetector **214**, such as a phototransistor or a light sensor, of a receiver circuit **207** comprised of the photodetector **214**, a switch **204***d*, a integrating capacitor **206***b*, and an A/D converter **216**. Analysis of the absolute amplitude of the detected light signal as well as the relative amplitudes of the

detected red light **212***a* and detected infrared light **212***b* may reveal various properties of the blood (i.e., blood properties), such as the pulse profile (e.g., heart rate) and the amount of oxygen in the blood.

[0037] The photodetector **214** may be powered by voltage source **224***a*. Microprocessor **218** may control switch **204***d*. When the switch **204***d* is open, current may not flow from the photodetector **214** and data may not be collected. When the switch **204***d* is closed, the photodetector **214** may transfer a charge onto the integrating capacitor **206***b*. The microprocessor may synchronize the opening and closing of switch **204***d* with switches **204***a*, **204***b*, **204***c* such that switch **204***d* is only closed when the photodetector **214** intercepts the light **212***a*, **212***b*. Power demand may be further reduced by leaving the switch **204***d* open when the photodetector is not receiving useful data. When the switch **204***d* is closed, current may flow from the photodetector **214** to the integrating capacitor **206***b* and be stored in the integrating capacitor **206***b* at the input to the A/D converter **216**. The A/D converter **216** may measure the voltage at the integrating capacitor **206***b* and transfer the data to the microprocessor **218**.

[0038] In an embodiment, the on periods of the red LED **210***a* and infrared LED **210***b* may be synchronized with the opening and closing of switch **204***d* by microprocessor **218**. The microprocessor **218** may close the switch **204***d* to allow the photodetector **214** to start integrating its received signal just before the red LED **210***a* and infrared LED **210***b* are turned on by discharging the integrating capacitor **206***b*, and may control the A/D converter **216** to take a voltage measurement as soon as the red LED **210***a* and infrared LED **210***b* are off.

[0039] In an embodiment, the photodetector **214** may be a single device and may include two separate detectors tuned separately for each wavelength of light in use. In another embodiment, the photodetector **214** may be a single device with a broadband response that covers both red and IR portions of the spectrum. The digital output of the A/D converter **216** may be the output of the receiver circuit **207** that may be analyzed by the microprocessor **218** as measurements of the blood oxygen level.

[0040] FIG. **3** is a circuit diagram **300** illustrating a third embodiment circuit **300** for a device (e.g., pulse oximeter or heart rate monitor) configured to minimize current draw. In an embodiment, the circuit **300** may be integrated into an electronic patch worn by a patient. Switch **304***a* may control when current flows to LED **310***a* that emits red light **312***a*, and switch **304***b* may control when current flows to LED **310***b* that emits infrared light **312***b*. To minimize current draw, instead of remaining closed, the switches **304***a*, **304***b* may open and close at strategic times. Switches **304***a*, **304***b* may be controlled by the same or different microprocessors. Although LEDs **310***a*, **310***b* are connected in parallel in circuit diagram **300**, in general they may also be powered by the same or different voltage sources. In an embodiment, the switches **304***a*, **304***b* may be closed by the microprocessor to provide charge to the LEDs **310***a*, **310***b* for a period of time to cause the LEDs **310***a*, **310***b* to emit light **312***a* and **312***b*, respectively. After the period of time, the switches **304***a*, and **304***b* may be opened by the microprocessor to isolate the LEDs **310***a*, **310***b* to stop providing charge to the LEDs **310***a*, **310***b* and stop the LEDs **310***a*, **310***b* from emitting light, respectively. In this manner, light bursts may be generated from the LEDs **310***a*, **310***b* and the current draw of the circuit **300** may be minimized by only turning the LEDs **310***a*, **310***b* on for the period of time.

[0041] Resistor **322***a* may control the amount of current that flows to LED **310***a*. Resistor **322***a* may thus control the amplitude of red light **312***a* emitted from LED **310***a*. Resistor **322***b* may control the amount of current that flows to LED **310***b*. Resistor **322***b* may thus control the amplitude of infrared light **312***b* emitted from LED **310***b*. The resistors **322***a*, **322***b* may have the same or different resistances, and may have fixed or variable resistance. Additionally, although LEDs **310***a*, **310***b* emit red and infrared light **310***a*, **310***b*, respectively, in general circuit diagram **300** may include LEDs that emit light in any portion of the electromagnetic spectrum.

[0042] Circuit **300** may include a receiver circuit **307** that includes a phototransistor **314** and a integrating capacitor **306**. The phototransistor **314** may detect red light **312***a* and infrared light **312***b* and convert the red light **312***a* and infrared light **312***b* to electrical energy. The electrical energy generated by the phototransistor **314** may be stored in an integrating capacitor **306**. A resulting charge may collect on integrating capacitor **306**, creating a voltage over the integrating capacitor **306**. The analog voltage signal may be measured, converted to a digital signal, and analyzed. Persons skilled in the art will appreciate that the phototransistor **314** may be substituted for any device capable of converting photons to a current. Further, to minimize current draw, rather than remaining on continuously, the phototransistor **314** may only turn on when the LEDs **310***a*, **310***b* emit light **312***a*, **312***b*.

[0043] While the circuits **200** and **300** illustrated in FIGS. **2** and **3**, respectively, each include two LEDs **210***a*, **210***b* and **310***a*, **310***b*, respectively, in embodiments in which the circuits **200** and **300** are used only to measure heart rate information (i.e., operated as a heart rate monitor), only one of the two LEDs may be needed. The second LED may be removed from the circuit, or may merely remain off, when heart rate information is the only blood property to be measured.

[0044] FIG. **4** is a sample heart rate graph **400** illustrating an embodiment lock-in procedure and subsequent pulse measurements. Waveform **402** has a pulse period of P such that each pulse maximum **406** occurs once every P units of time. As is typical, the pulse minima **404** occur p=P/3 units of time after the pulse maxima **406**.

[0045] At various times, such as when it begins monitoring oxygen levels, the pulse oximeter may need to lock on to waveform **402**. As used herein, to be locked on to waveform **402** means to be able to predict the curve of a subsequent portion of the waveform **402** to within some error. Rather than continuously sampling waveform **402**, the pulse oximeter may instead sample the waveform **402** periodically to minimize current draw. The ticks **410** represent when the pulse oximeter samples data (ex., when charging integrating capacitor **206***b* (FIG. **2**) discharges, causing LEDs **210***a*, **210***b* (FIG. **2**) to emit light **212***a*, **212***b* (FIG. **2**)) before it is locked on to waveform **402**. Sampling occurs only during an individual tick **410**. Persons skilled in the art will appreciate that although ticks **410** occur in groups of three in FIG. **4**, the ticks may also sample in groups of any number, such as two. The number of ticks **410** in a group may also vary, such as alternating between two and three ticks per group.

[0046] A point on the waveform **402** may be measured and analyzed at each tick **410**. In an embodiment, the slope **408** between the ticks **410** in each group may be calculated. The

pulse maxima **406** and pulse minima **404** are located where the slope is zero on the waveform **402**. Thus, as more data is collected and analyzed, the pulse maxima **406** and pulse minima **404** become more predictable. As various points on the waveform are sampled, the time between the samples (frequency) and the offset of the samples may be varied until the pulse oximeter has locked onto the pulse maxima **406** and pulse minima **404**. Both the slope **408** of the waveform **402** and the difference between the minimum and maximum readings may be used to locate the pulse maxima **406** and pulse minima **404**. Any algorithm may be used to locate the pulse maxima **406** and pulse minima **404**, such as the MM algorithm. That the pulse minima **404** usually occur one-third of a period after the pulse maxima **406** may also be used in locating the maxima **406** and minima **404**.

[0047] One potential issue when locking on to waveform **402** may be the possibility of locking onto a false waveform that is actually a fraction of the period of the true waveform. For example, assume the period of a waveform is 120 beats/minute. If the sampling begins at 50 samples per minute, the sampling rate will increase as it searches for the waveform period. However, the samples may lock on to a "false" period of 60 beats/minute, thereby only collecting data for alternating pulse extremes. To avoid this potential issue, the sampling may begin at a high rate, such as 180 samples per minute, and decrease as it locks on to the true period of the waveform, such as period P of waveform **402**.

[0048] After the pulse oximeter has locked onto the pulse maxima **406** and pulse minima **404**, the frequency of the samples may decrease even further, as illustrated by ticks **414**. Data may continue to be sampled and analyzed to ensure the pulse oximeter remains locked on, for example by measuring the slopes **412** of the waveform **402** between the samples. For example, for groups of three or more, the slope may be analyzed to ensure that the zero of the slope falls within the group of samples. For groups of two, the slope may be analyzed to ensure that it is close to zero. As shown in FIG. **4**, a group of three samples may encompass pulse maxima **406** and a group of two samples may encompass pulse minima **404**. However, groups consisting of any number of samples may be used. For example, groups of two may encompass the pulse maxima **406** and groups of three may encompass pulse minima **404**, or the number of samples in groups may vary, such as between two, three, four, etc. By limiting the number and frequency of samples, current consumption may be minimized. To further minimize current draw, samples may not be taken for every maxima and minima. For example, if the pulse oximeter is not monitoring an irregular heartbeat, the pulse oximeter may only sample one out of every three or five (or other fraction) periods.

[0049] FIG. **5**A is a process flow diagram illustrating an embodiment method **500***a* to lock on to the waveform. In an embodiment, the operations of the method **500***a* may be performed by a processor of a device (e.g., pulse oximeter), such as the microprocessor **218** described above. In block **502** the processor of the pulse oximeter may control the pulse oximeter circuitry, such as circuit elements **104***a*, **104***b*, **116** (FIG. **1**), **204***a*, **204***b*, **204***c*, **204***d*, **216** (FIG. **2**), **304***a*, **304***b* (FIG. **3**) described above, to take groups of measurements at an initial sampling rate. This initial sampling rate may be relatively high, such as 180 samples per minute or that for a 90 Hz pulse rate. In an embodiment, the sampling rate may be selected such that a full set of readings is not taken over one pulse cycle, thereby drawing less power from a coin cell battery or printed cell battery compared to taking a full set of readings over one pulse cycle. In block **504**, the processor of the pulse oximeter may locate pulse maxima by analyzing the derivatives of the sampled pulse curve within each group of measurements. In block **506** the processor of the pulse oximeter may determine the pulse rate (e.g., heart rate) and timing based on the located pulse maxima. In block **508** the processor of the pulse oximeter may calculate the time at which pulse minima occur by adding one-third of the pulse period to each pulse maximum. In block **510** the pulse oximeter processor may control the pulse oximeter circuitry, such as circuit elements **104***a*, **104***b*, **116** (FIG. **1**), **204***a*, **204***b*, **204***c*, **204***d*, **216** (FIG. **2**), **304***a*, **304***b* (FIG. **3**) described above, to take a group of measurements during each pulse maximum and pulse minimum. The frequency of these groups of measurements may be less frequent than the initial sampling rate to avoid excessive current draw.

[0050] FIG. **5**B is a process flow diagram illustrating an embodiment method **500**B to determine a heart rate based on the amount of light received by a heart rate monitor. In an embodiment, the operations of the method **500***b* may be performed by a processor of a device (e.g., heart rate monitor or a pulse oximeter operating in a heart rate monitor mode), such as the microprocessor **218** described above. In block **502**, the processor of the heart rate monitor may control the heart rate monitor circuitry, such as circuit elements **104***a*, **104***b*, **116** (FIG. **1**), **204***a*, **204***b*, **204***c*, **204***d*, **216** (FIG. **2**), **304***a*, **304***b* (FIG. **3**) described above, to take groups of measurements at an initial sampling rate. This initial sampling rate may be relatively high, such as 180 samples per minute for a 90 Hz pulse rate. In an embodiment, the sampling rate may be selected such that a full set of readings is not taken over one pulse cycle, thereby drawing less power from a coin cell battery or printed cell battery compared to taking a full set of readings over one pulse cycle. In an embodiment, because only the heart rate may be of interest to a heart rate monitor, or a pulse oximeter operating in a heart rate monitor mode, only one LED of the heart rate monitor circuitry may be turned on to take the groups of measurements. In block **504**, the processor of the heart rate monitor may locate pulse maxima by analyzing the derivatives of the sampled pulse curve within each group of measurements. In block **506** the processor of the heart rate monitor may determine the pulse rate (e.g., heart rate) and timing based on the located pulse maxima.

[0051] FIG. **6** is a sample heart rate graph **600** illustrating a sample rate adjustment according to an embodiment. Four periods of waveform **602** are shown. After the two leftmost periods, the frequency of pulse maxima **606** and pulse minima **604** increases, corresponding to an increasing heart rate. In this graph **600**, the pulse oximeter may already be locked on to the waveform **602** and may be taking periodic samples, the timing of which is illustrated by ticks **610**. Because the pulse oximeter may already be locked on, a group of samples encompasses the pulse maxima **606** in the two leftmost periods and the pulse minima **604** in the two leftmost periods. To ensure that the pulse oximeter remains locked on to the waveform **602**, the slopes **608** of the waveform **602** between the samples are analyzed.

[0052] Notwithstanding the increase in heart rate after the two leftmost periods, the pulse oximeter may sample when the subsequent pulse maximum is predicted to occur based upon its previous measurements. After analyzing the data and noting that the slope **608** is negative, the sampling may return

to a pre-lock on mode, and perform operations as described above with reference to FIG. **4**. This may include a change in group sample size, a change in sample frequency, a change in group sample frequency, and changes in any other suitable factors regarding sampling.

[0053] FIG. **6** illustrates three samples contained within the group that does not encompass a pulse maximum **606**, although the group could generally include any number of samples. The horizontal dashed arrows below the ticks **610** illustrate that the group sample frequency may change when the slope is measured to be negative after the pulse oximeter is already locked on. FIG. **6** shows group frequency increase; however, group frequency may alternatively decrease after detecting a change in heart rate.

[0054] FIG. **6** illustrates the pulse oximeter quickly locking back on to the waveform **602** after just one group measurement. In general, it may take more than one group measurement to lock back on to a heart rate after it has increased. Many group measurements may be required, similar to the samples illustrated by ticks **410** in FIG. **4**. Using sporadic sampling rather than continuous sampling to lock back on to the waveform **602** decreases power consumption, thereby enabling use of a low voltage battery or the equivalent.

[0055] FIG. **7** is sample heart rate graph **700** illustrating another sample rate adjustment according to an embodiment. In this graph **700**, the frequency of pulse maxima **706** and pulse minima **704** decreases, corresponding to an decreasing heart rate. In this graph **700**, as in graph **600** illustrated in FIG. **6**, the pulse oximeter may already be locked on to the waveform **702** and may be taking periodic samples, the timing of which is illustrated by ticks **710**. Because it is already locked on, a group of samples encompasses the pulse maxima **706** in the two leftmost periods and the pulse minima **704** in the two leftmost periods. To ensure that the pulse oximeter remains locked on to the waveform **702**, the slopes **708** of the waveform **702** between the samples are analyzed.

[0056] Notwithstanding the decrease in heart rate after the two leftmost periods, the pulse oximeter may sample when the subsequent pulse maximum is predicted to occur based upon its previous measurements. After analyzing the data and noting that the slope **708** is positive, the sampling may return to pre-lock on mode, as described above with reference to FIG. **4**. This may include a change in group sample size, a change in sample frequency, a change in group sample frequency, and changes in any other suitable factors regarding sampling.

[0057] FIG. **7** illustrates three samples contained within the group that does not contain a pulse maximum **706**, although the group could generally include any number of samples. The pulse oximeter may or may not sample for the pulse minimum **704** after measuring a positive slope where the pulse maximum **706** is predicted to be. This is illustrated by the two dashed vertical ticks **710**. The subsequent group measurements, including a subsequent sample for the pulse minimum **706**, may be any number of measurements, regardless of previous group measurements. For example, the subsequent sample for a pulse minimum **706** could be three or more measurements. The horizontal dashed arrows below the ticks **710** illustrate that the group sample frequency may change when the slope is measured to be positive after the pulse oximeter is already locked on. FIG. **7** shows group frequency decrease; however, group frequency may alternatively increase after detecting a change in heart rate.

[0058] FIG. **7** illustrates the pulse oximeter quickly locking back on to the waveform **702** after just one group measurement. In general, it may take more than one group measurement to lock back on to a heart rate after it has increased. Many group measurements may be required, similar to the samples illustrated by ticks **410** in FIG. **4**. Using sporadic sampling rather than continuous sampling to lock back on to the waveform **702** decreases power consumption, thereby enabling use of a low voltage battery or the equivalent.

[0059] FIG. **8** is a process flow diagram illustrating an embodiment method **800** for sample timing adjustment. In an embodiment, the operations of method **800** may be performed by a processor of a device (e.g., a pulse oximeter), such as microprocessor **218** described above. The operations of method **800** may be performed in conjunction with the operations of method **500** described above, for example when the processor of the pulse oximeter locks on to the pulse maxima and minima but the heart rate changes and the processor of the pulse oximeter has to re-locate the pulse maxima and minima. As described above, in block **510** the pulse oximeter processor may control the pulse oximeter circuitry, such as circuit elements **104***a*, **104***b*, **116** (FIG. **1**), **204***a*, **204***b*, **204***c*, **204***d*, **216** (FIG. **2**), **304***a*, **304***b* (FIG. **3**) described above, to take a group of measurements during each pulse maximum and pulse minimum. In block **802** the processor of the pulse oximeter may calculate the derivative estimate between each measurement in the groups at the pulse maxima. In block **804** the processor may determine whether the derivative of the sampled pulse curve is positive before the middle individual measurement and negative after. In response to determining the sampled pulse curve is positive before the middle individual measurements and negative after (i.e., determination block **804**="Yes"), then no adjustment may be necessary and in block **510** the processor may continue to take subsequent groups of measurements during each pulse maximum and minimum.

[0060] In response to determining that the derivative of the sampled pulse curve is not positive before the middle individual measurement and negative after (i.e., determination block **804**="No"), in determination block **806** the processor of the pulse oximeter may analyze whether the derivative of the sampled pulse curve is negative both before and after the middle individual measurement **806**. In response to determining the derivative of the sampled pulse curve is negative both before and after the middle individual measurement (i.e., determination block **806**="Yes"), in block **808** the processor of the pulse oximeter may shorten the time delay between the most recent group measurement and the subsequent group measurement. In block **510** the pulse oximeter may again take groups of measurements during each pulse maximum and minimum.

[0061] In response to determining that the derivative of the sampled pulse curve is positive both before and after the middle individual measurement (i.e., determination block **806**="No"), in block **810** the processor of the pulse oximeter may lengthen the time delay between the most recent group measurement and subsequent group measurement. In block **510** the pulse oximeter may again take groups of measurements during each pulse maximum and minimum.

[0062] FIG. **9** illustrates an embodiment electronic patch **906** including a pulse oximeter or heart rate monitor placed on a patient **902**, such as on a skin surface of a finger of a patient **902**. In various embodiments, an electronic patch **906** may be flexible and resilient so that placement and removal of the

electronic patch **906** from the patient **902** does not damage the electronic patch **906**. The electronic patch **902** may include a pulse oximeter or heart rate monitor circuit comprised of a transmitting circuit **904** comprised of at least one LED, a capacitor, and a low voltage power source, such as a coin cell battery or printed cell battery, a receiver circuit **907** configured to measure light emitted by the at least one LED, and a processor **908** connected to the transmitting circuit **904** and receiver circuit **907**. As specific examples, the pulse oximeter or heart rate monitor circuit may be the circuit **100**, **200**, or **300** described above. An adhesive layer may affix the electronic patch **906** to the patient **902**.

[0063] Further, those of skill in the art will appreciate that the foregoing method descriptions and the process flow diagrams are provided merely as illustrative examples and are not intended to require or imply that the steps of the various embodiments must be performed in the order presented. As will be appreciated by one of skill in the art the order of steps in the foregoing embodiments may be performed in any order. Words such as "thereafter," "then," "next," etc. are not intended to limit the order of the steps; these words are simply used to guide the reader through the description of the methods. Further, any reference to claim elements in the singular, for example, using the articles "a," "an" or "the" is not to be construed as limiting the element to the singular.

[0064] The various illustrative logical blocks, modules, circuits, and algorithm steps described in connection with the embodiments disclosed herein may be implemented as electronic hardware, computer software, or combinations of both. To clearly illustrate this interchangeability of hardware and software, various illustrative components, blocks, modules, circuits, and steps have been described above generally in terms of their functionality. Whether such functionality is implemented as hardware or software depends upon the particular application and design constraints imposed on the overall system. Skilled artisans may implement the described functionality in varying ways for each particular application, but such implementation decisions should not be interpreted as causing a departure from the scope embodiments.

[0065] The hardware used to implement the various illustrative logics, logical blocks, modules, and circuits described in connection with the embodiments disclosed herein may be implemented or performed with a general purpose processor, a digital signal processor (DSP), an application specific integrated circuit (ASIC), a field programmable gate array (FPGA) or other programmable logic device, discrete gate or transistor logic, discrete hardware components, or any combination thereof designed to perform the functions described herein. A general-purpose processor may be a microprocessor, but, in the alternative, the processor may be any conventional processor, controller, microcontroller, or state machine A processor may also be implemented as a combination of computing devices, e.g., a combination of a DSP and a microprocessor, a plurality of microprocessors, one or more microprocessors in conjunction with a DSP core, or any other such configuration. Alternatively, some steps or methods may be performed by circuitry that is specific to a given function.

[0066] The functions in the various embodiments may be implemented in hardware, software, firmware, or any combination thereof. If implemented in software, the functions may be stored as one or more processor executable instructions or code on a non-transitory computer readable medium or non-transitory processor readable medium. The steps of a method or algorithm disclosed herein may be embodied in a processor-executable software module that may reside on a non-transitory computer-readable or processor-readable storage medium. Non-transitory computer-readable or processor-readable storage media may be any storage media that may be accessed by a computer or a processor. By way of example but not limitation, such non-transitory computer-readable or processor-readable media may include RAM, ROM, EEPROM, FLASH memory, CD-ROM or other optical disk storage, magnetic disk storage or other magnetic storage devices, or any other medium that may be used to store desired program code in the form of instructions or data structures and that may be accessed by a computer. Disk and disc, as used herein, includes compact disc (CD), laser disc, optical disc, digital versatile disc (DVD), floppy disk, and blu-ray disc where disks usually reproduce data magnetically, while discs reproduce data optically with lasers. Combinations of the above are also included within the scope of non-transitory computer-readable and processor-readable media. Additionally, the operations of a method or algorithm may reside as one or any combination or set of codes and/or instructions on a non-transitory processor-readable medium and/or computer-readable medium, which may be incorporated into a computer program product.

[0067] The preceding description of the disclosed embodiments is provided to enable any person skilled in the art to make or use the present invention. Various modifications to these embodiments will be readily apparent to those skilled in the art, and the generic principles defined herein may be applied to other embodiments without departing from the spirit or scope of the invention. Thus, the present invention is not intended to be limited to the embodiments shown herein but is to be accorded the widest scope consistent with the following claims and the principles and novel features disclosed herein.

What is claimed is:

1. A device, comprising:

a capacitor configured to be charged by a low voltage power source;

at least one light-emitting diode (LED) connected to the capacitor by a switch;

a receiver circuit configured to measure light emitted by the at least one LED after the light passes through tissue of a patient; and

a processor connected to the switch and receiver circuit, wherein the processor is configured with processor executable instructions to perform operations comprising:

controlling the switch to provide charge from the capacitor to the at least one LED to cause the at least one LED to emit light;

controlling the switch to isolate the capacitor from the at least one LED to cause the at least one LED to stop emitting light after a period of time;

measuring an amount of light received by the receiver circuit after the period of time; and

determining a blood property based at least in part on a measurement of the amount of light received by the receiver circuit.

2. The device of claim **1**, wherein the processor is configured with processor-executable instructions to perform operations such that determining a blood property based at least in part on the measurement of the amount of light received by the receiver circuit comprises determining a heart

rate based at least in part on the measurement of the amount of light received by the receiver circuit.

3. The device of claim **1**, wherein the processor is configured with processor-executable instructions to perform operations such that determining a blood property based at least in part on the measurement of the amount of light received by the receiver circuit comprises determining a blood oxygen level based at least in part on the measurement of the amount of light received by the receiver circuit.

4. The device of claim **3**, wherein the processor is configured with processor-executable instructions to perform operations further comprising:

determining when the capacitor is charged by the low voltage power source to a predetermined voltage; and

controlling the switch to provide charge from the capacitor to the at least one LED to cause the at least one LED to emit light in response to determining the capacitor is charged by the low voltage power source to a predetermined voltage.

5. The device of claim **3**, wherein the processor is configured with processor-executable instructions to perform operations further comprising:

determining when it is time to perform a measurement; and

controlling the switch to provide charge from the capacitor to the at least one LED to cause the at least one LED to emit light in response to determining that it is time to perform a measurement.

6. The device of claim **5**, wherein the processor is configured with processor executable instructions to perform operations such that:

determining a blood oxygen level based at least in part on the measured amount of light received by the receiver circuit comprises determining a blood oxygen level and pulse waveform measurement based at least in part on the measured amount of light received by the receiver circuit; and

determining when it is time to perform a measurement comprises anticipating at least one of a pulse maxima and a pulse minima of the patient.

7. The device of claim **6**, wherein the processor is configured with processor executable instructions to perform operations such that anticipating at least one of a pulse maxima and a pulse minima of the patient comprises:

repeatedly controlling the switch to provide charge from the capacitor to the at least one LED to cause the at least one LED to emit light, controlling the switch to isolate the capacitor from the at least one LED to cause the at least one LED to stop emitting light after the period of time, and measuring the amount of light received by the receiver circuit after the period of time to take a group of pulse measurements at an initial sampling rate;

determining a local maxima of a sampled pulse curve of the group of pulse measurements based upon a derivative estimate of the sampled pulse curve;

determining a pulse rate and timing based on the determined local maxima of the sampled pulse curve of the group of pulse measurements; and

determining a time of a pulse maxima and a time of a pulse minima based on the determined pulse rate and timing and the determined local maxima.

8. The device of claim **7**, wherein the processor is configured with processor executable instructions to perform operations such that determining when it is time to perform a measurement comprises anticipating at least one of a pulse maxima and a pulse minima of the patient further comprises:

determining a derivative estimate of a sampled pulse curve of a group of pulse measurements taken at the determined time of the pulse maxima; and

adjusting a time delay between the determined time of the pulse maxima and the determined time of the pulse minima based on the determined derivative estimate of the sampled pulse curve of the group of pulse measurements taken at the determined time of the pulse maxima.

9. The device of claim **3**, wherein the at least one LED is two different LEDs, and

wherein the two different LEDs each emit light of different wavelengths.

10. The device of claim **9**, wherein the two LEDs comprise one red LED and one infrared LED.

11. The device of claim **1**, wherein the low voltage source is a coin cell battery or a printed cell battery.

12. A method of measuring a blood property of a patient, comprising:

charging a capacitor with a low voltage power source;

connecting the capacitor to a light-emitting diode (LED) positioned to transmit light into tissue of the patient;

measuring an amount of light passing through the tissue of the patient; and

determining a blood property based at least in part on a measurement of the amount of light.

13. The method of claim **12**, wherein determining a blood property based at least in part on the measurement of the amount of light comprises determining a heart rate based at least in part on the measurement of the amount of light.

14. The method of claim **12**, wherein determining a blood property based at least in part on the measurement of the amount of light comprises determining a blood oxygen level based at least in part on the measurement of the amount of light.

15. The method of claim **14**, further comprising:

determining when the capacitor is charged by the low voltage power source to a predetermined voltage;

disconnecting the capacitor from the low voltage power source in response to determining that the capacitor is charged by the low voltage power source to a predetermined voltage; and

connecting the capacitor to a light-emitting diode (LED) positioned to transmit light into tissue of the patient in response to determining the capacitor is charged by the low voltage power source to a predetermined voltage.

16. The method of claim **14**, further comprising:

determining when it is time to perform a measurement; and

connecting the capacitor to a light-emitting diode (LED) positioned to transmit light into tissue of the patient in response to determining that it is time to perform a measurement.

17. The method of claim **16**, wherein:

determining a blood oxygen level based at least in part on the measurement of the amount of light comprises determining a blood oxygen level and pulse waveform measurement based at least in part on the measurement of the amount of light; and

determining when it is time to perform a measurement comprises anticipating at least one of a pulse maxima and a pulse minima of the patient.

18. The method of claim **17**, wherein anticipating at least one of a pulse maxima and a pulse minima of the patient comprises:

repeatedly providing charge from the capacitor to the LED to cause the LED to emit light, isolating the capacitor from the LED to cause the LED to stop emitting light after a period of time, and measuring the amount of light received after the period of time to take a group of pulse measurements at an initial sampling rate;

determining a local maxima of a sampled pulse curve of the group of pulse measurements based upon a derivative estimate of the sampled pulse curve;

determining a pulse rate and timing based on the determined local maxima of the sampled pulse curve of the group of pulse measurements; and

determining a time of a pulse maxima and a time of a pulse minima based on the determined pulse rate and timing and the determined local maxima.

19. The method of claim **18**, wherein anticipating at least one of a pulse maxima and a pulse minima of the patient further comprises:

determining a derivative estimate of a sampled pulse curve of a group of pulse measurements taken at the determined time of the pulse maxima; and

adjusting a time delay between the determined time of the pulse maxima and the determined time of the pulse minima based on the determined derivative estimate of the sampled pulse curve of the group of pulse measurements taken at the determined time of the pulse maxima.

20. The method of claim **12**, wherein the low voltage source is a coin cell battery or a printed cell battery.

21. A device, comprising:

means for charging a capacitor with a low voltage power source;

means for connecting the capacitor to a light-emitting diode (LED) positioned to transmit light into tissue of a patient;

means for measuring an amount of light passing through the tissue of the patient; and

means for determining a blood property based at least in part on a measurement of the amount of light.

22. The device of claim **21**, wherein means for determining a blood property based at least in part on the measurement of the amount of light comprises means for determining a heart rate based at least in part on the measurement of the amount of light.

23. The device of claim **21**, wherein means for determining a blood property based at least in part on the measurement of the amount of light comprises means for determining a blood oxygen level based at least in part on the measurement of the amount of light.

24. The device of claim **23**, further comprising:

means for determining when the capacitor is charged by the low voltage power source to a predetermined voltage; and

means for connecting the capacitor to a light-emitting diode (LED) positioned to transmit light into tissue of the patient in response to determining the capacitor is charged by the low voltage power source to a predetermined voltage.

25. The device of claim **23**, further comprising:

means for determining when it is time to perform a measurement; and

means for connecting the capacitor to a light-emitting diode (LED) positioned to transmit light into tissue of the patient in response to determining that it is time to perform a measurement.

26. The device of claim **25**, wherein:

means for determining a blood oxygen level based at least in part on the measurement of the amount of light comprises means for determining a blood oxygen level and pulse waveform measurement based at least in part on the measurement of the amount of light; and

means for determining when it is time to perform a measurement comprises means for anticipating at least one of a pulse maxima and a pulse minima of the patient.

27. The device of claim **26**, wherein means for anticipating at least one of a pulse maxima and a pulse minima of the patient comprises:

means for repeatedly providing charge from the capacitor to the LED to cause the LED to emit light, isolating the capacitor from the LED to cause the LED to stop emitting light after a period of time, and measuring the amount of light received after the period of time to take a group of pulse measurements at an initial sampling rate;

means for determining a local maxima of a sampled pulse curve of the group of pulse measurements based upon a derivative estimate of the sampled pulse curve;

means for determining a pulse rate and timing based on the determined local maxima of the sampled pulse curve of the group of pulse measurements; and

means for determining a time of a pulse maxima and a time of a pulse minima based on the determined pulse rate and timing and the determined local maxima.

28. The device of claim **27**, wherein means for anticipating at least one of a pulse maxima and a pulse minima of the patient further comprises:

means for determining a derivative estimate of a sampled pulse curve of a group of pulse measurements taken at the determined time of the pulse maxima; and

means for adjusting a time delay between the determined time of the pulse maxima and the determined time of the pulse minima based on the determined derivative estimate of the sampled pulse curve of the group of pulse measurements taken at the determined time of the pulse maxima.

29. The device of claim **21**, wherein the low voltage source is a coin cell battery or a printed cell battery.

30. A non-transitory processor readable medium having stored thereon processor executable instructions configured to cause a processor to perform operations, comprising:

charging a capacitor with a low voltage power source;

connecting the capacitor to a light-emitting diode (LED) positioned to transmit light into tissue of a patient;

measuring an amount of light passing through the tissue of the patient; and

determining a blood property based at least in part on a measurement of the amount of light.

* * * * *

专利名称(译)	允许能够确定血液特性的装置的低电流操作的电路		
公开(公告)号	US20160143566A1	公开(公告)日	2016-05-26
申请号	US14/549167	申请日	2014-11-20
[标]申请(专利权)人(译)	高通股份有限公司		
申请(专利权)人(译)	高通公司		
当前申请(专利权)人(译)	高通公司		
[标]发明人	BALLAM ROBERT SCOTT GANTON ROBERT BRUCE		
发明人	BALLAM, ROBERT SCOTT GANTON, ROBERT BRUCE		
IPC分类号	A61B5/1455 A61B5/00		
CPC分类号	A61B5/14552 A61B5/7278 A61B2562/164 A61B2562/0238 A61B2560/0412 A61B2560/0214 A61B5/0205 A61B5/02427 A61B5/02438 A61B5/0261 A61B5/6816 A61B5/6826 A61B5/7239 A61B5/7292 A61B2560/0204		
其他公开文献	US9743868		
外部链接	Espacenet USPTO		

摘要(译)

各种实施例的系统，方法和设备提供了一种能够通过对具有低电压的电容器充电来至少部分地基于具有有限电流容量的接收器电路所接收的光量的测量来确定血液特性的设备。电源通过发光二极管间歇地对电容器放电。在一些实施例中，该装置可以是能够获取血氧读数的脉搏血氧计。在一些实施例中，该装置可以是心率监测器，以基于穿过组织的光量来确定心率。各种实施例可以使脉搏血氧计和/或心率监测器能够结合到小的不显眼的身体贴片中，同时使脉搏血氧计能够从等效于小型纽扣电池或印刷电池的功率输出操作。