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(54) **PROXIMITY SENSOR IN PULSE OXIMETER**

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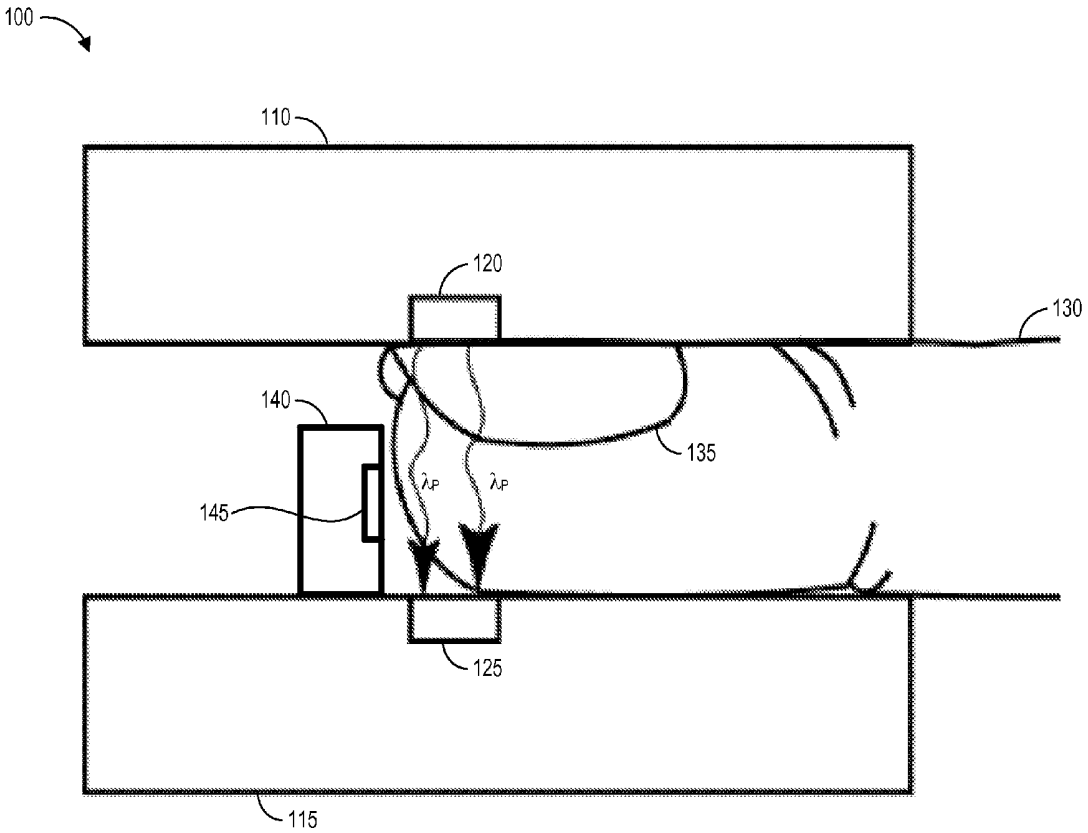
(57) **ABSTRACT**

Systems and methods are disclosed for proximity sensing in physiological sensors, and more specifically to using one or more proximity sensors located on or within a physiological sensor to determine the positioning of the physiological sensor on a patient measurement site. Accurate placement of a physiological sensor on the patient measurement site is a key factor in obtaining reliable measurement of physiological parameters of the patient. Proper alignment between a measurement site and a sensor optical assembly provides more accurate physiological measurement data. This alignment can be determined based on data from a proximity sensor or sensors placed on or within the physiological sensor.



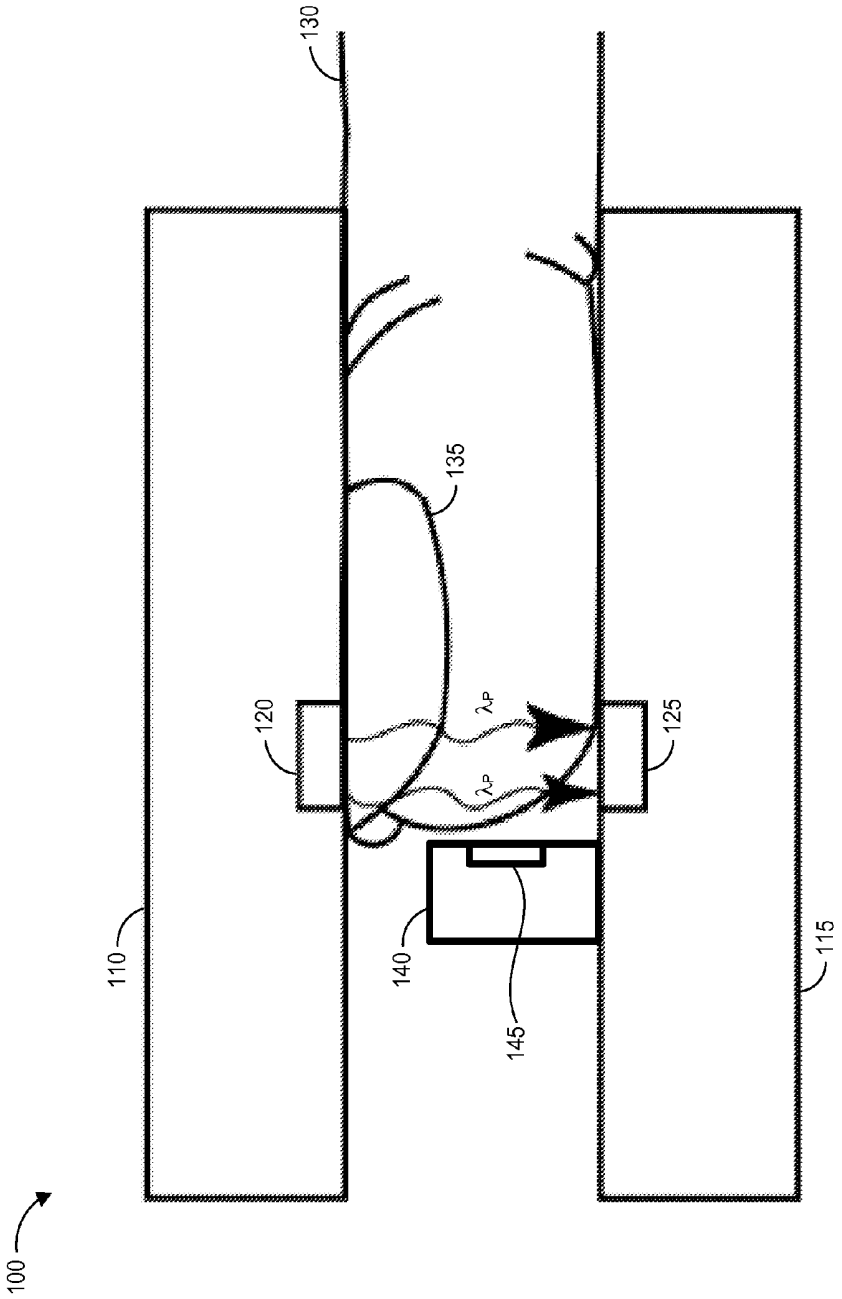


FIG. 1A

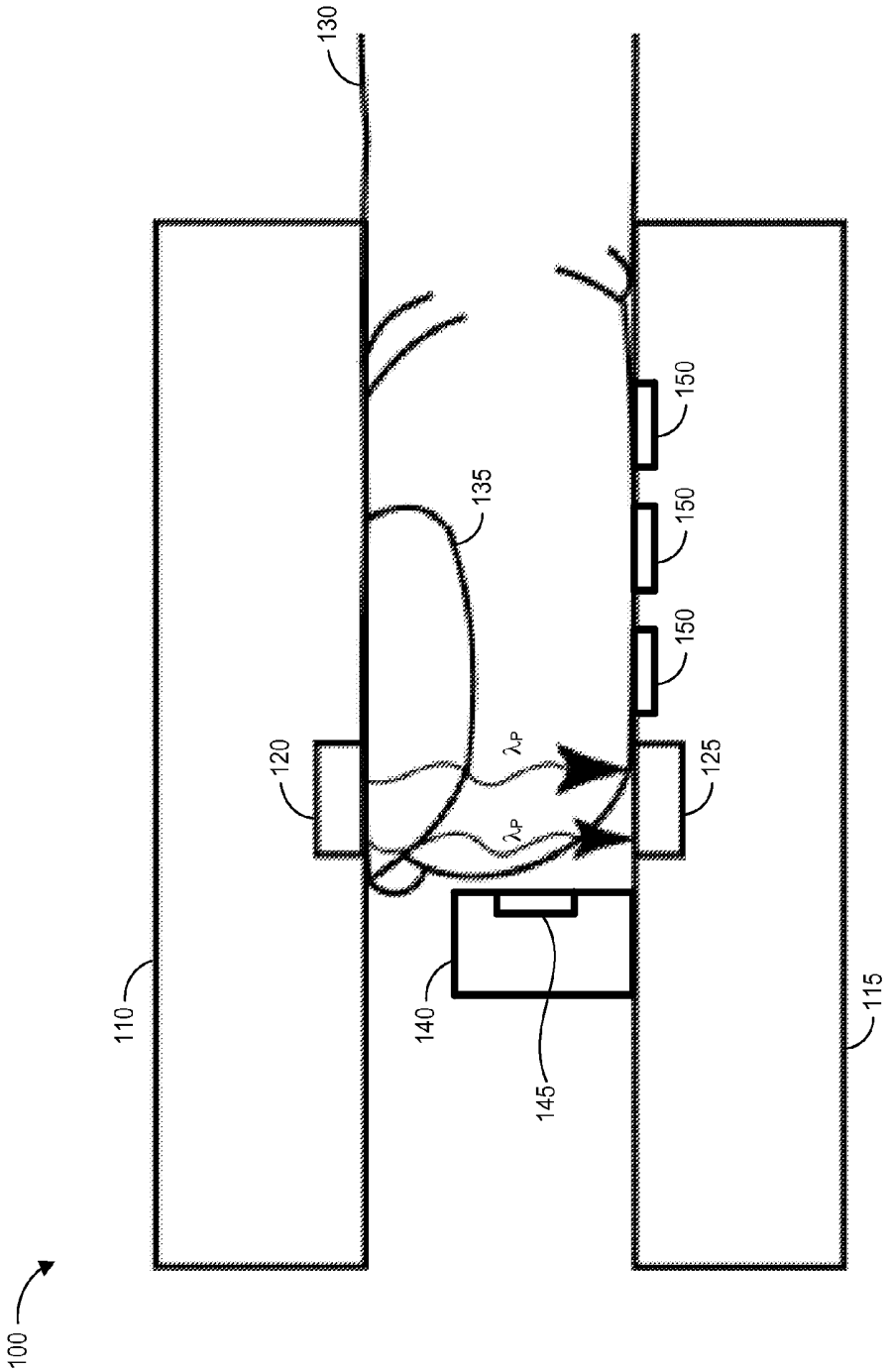

130
150
150
150
135
120
λ_P
λ_P
125
110
140
145
115
100

FIG. 1B

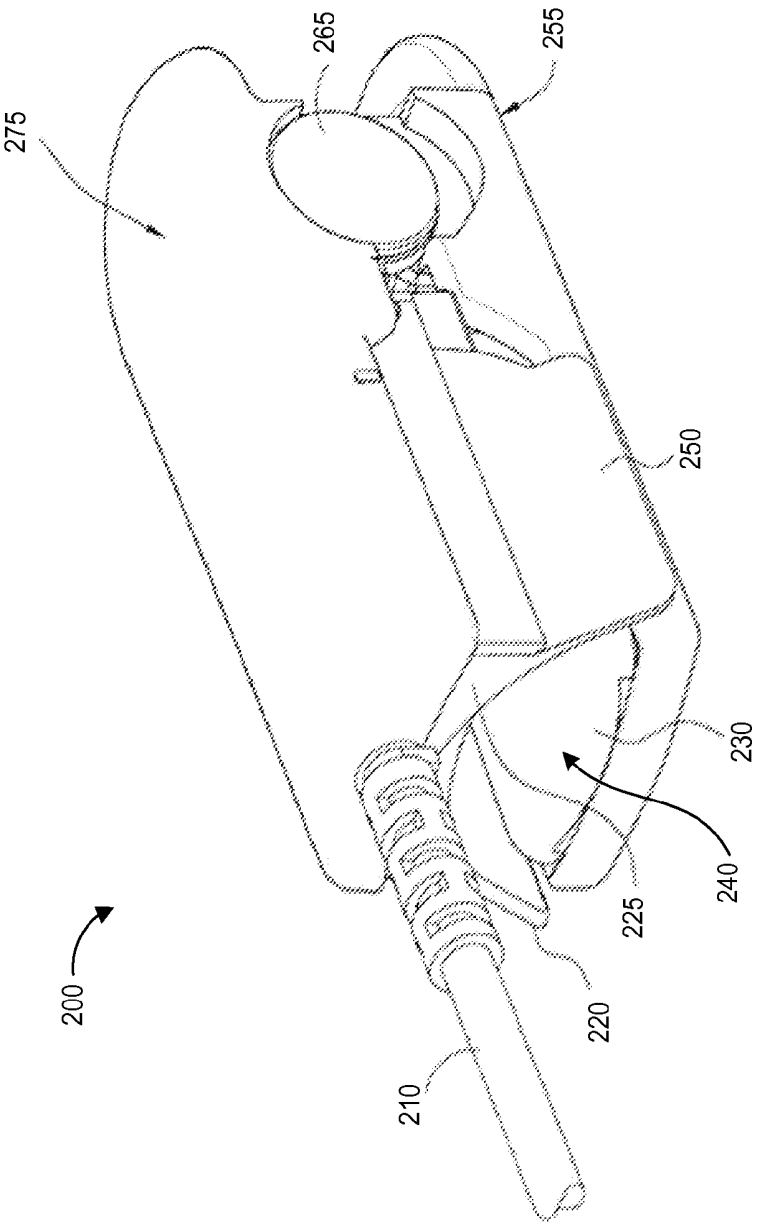


FIG. 2A

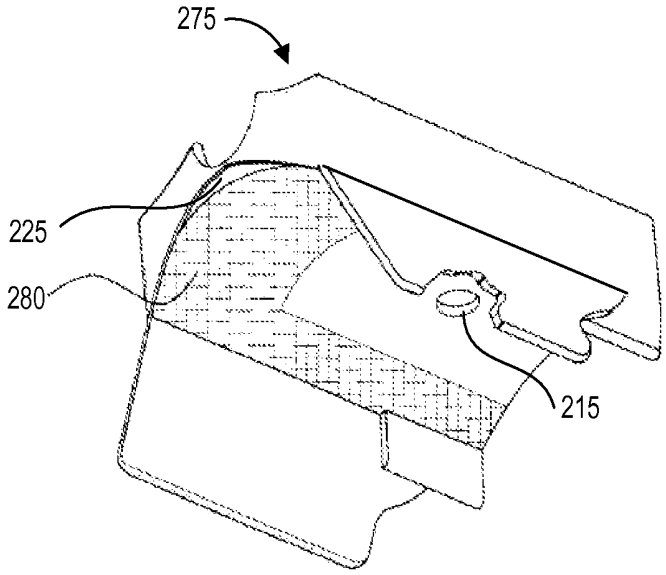


FIG. 2B

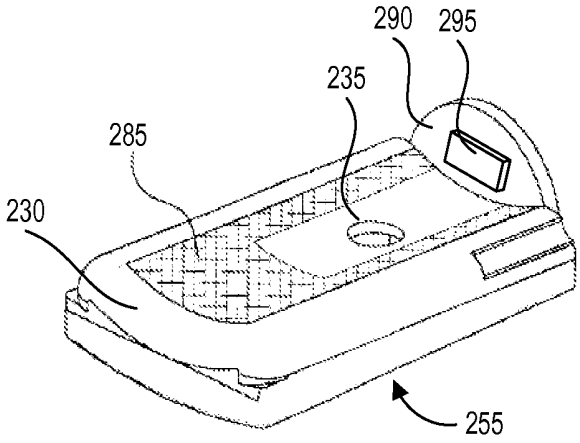


FIG. 2C

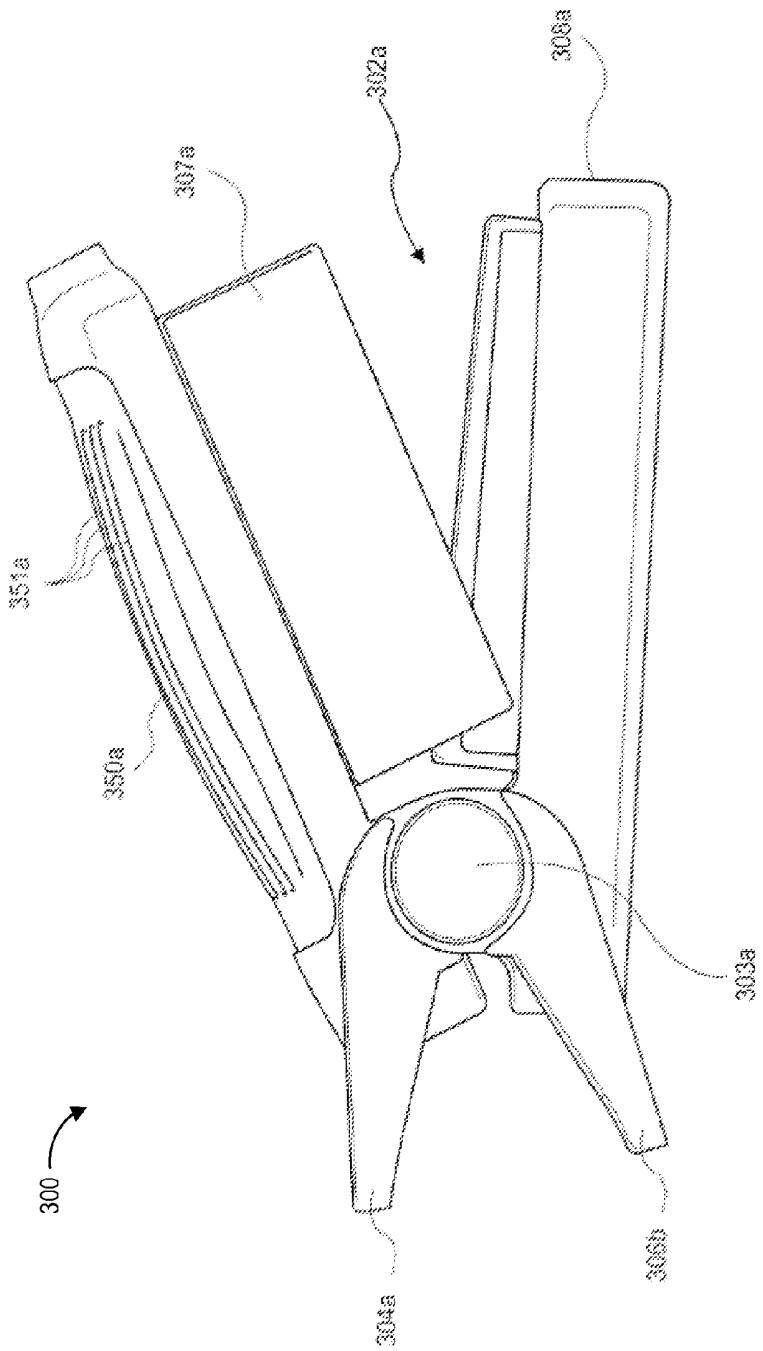


FIG. 3A

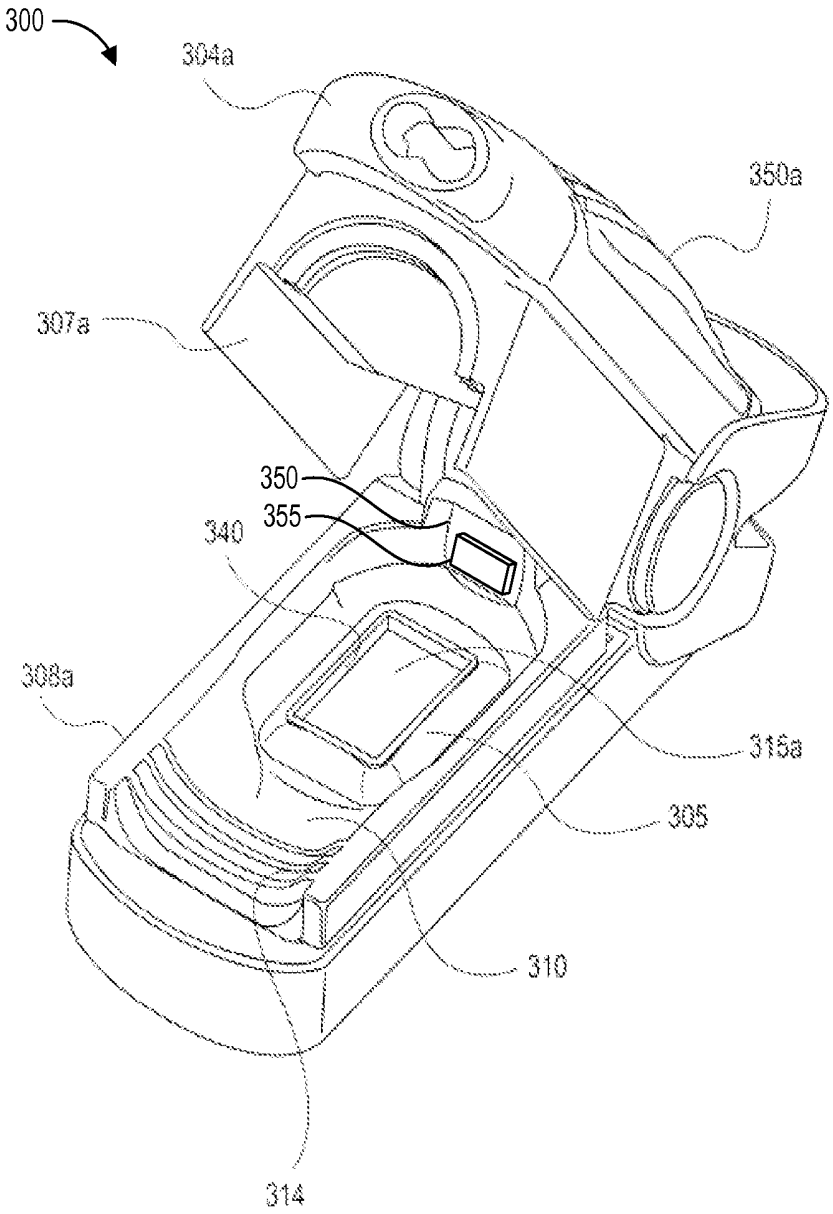


FIG. 3B

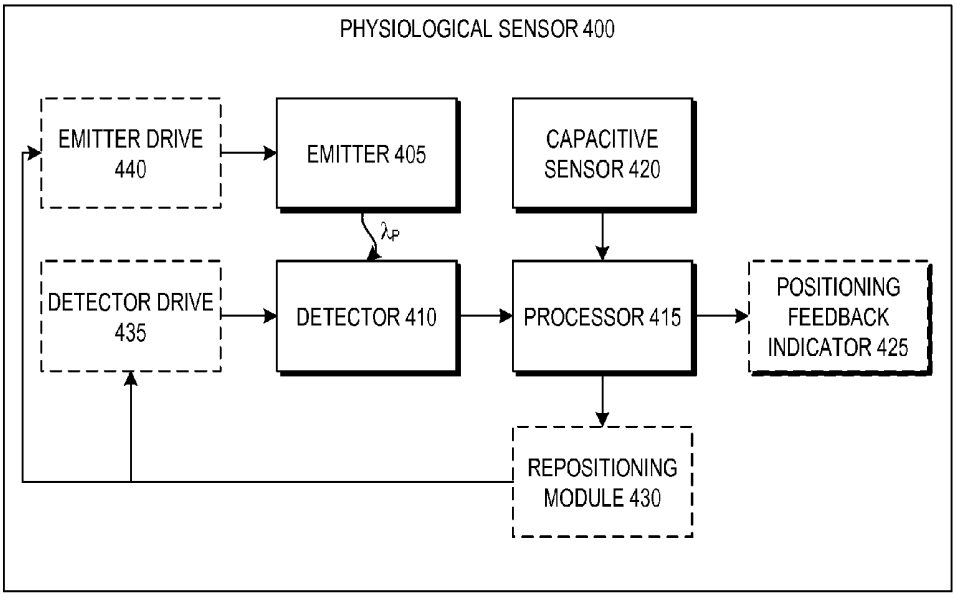

PHYSIOLOGICAL SENSOR 400
EMITTER DRIVE 440
EMITTER 405
CAPACITIVE SENSOR 420
λP
DETECTOR DRIVE 435
DETECTOR 410
PROCESSOR 415
POSITIONING FEEDBACK INDICATOR 425
REPOSITIONING MODULE 430

FIG. 4

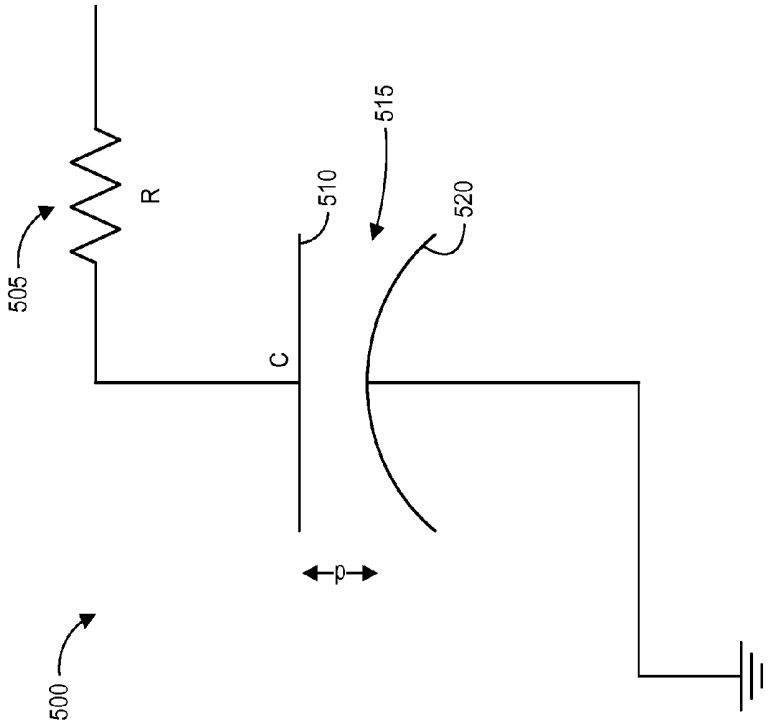


FIG. 5

SENSOR APPLICATION POSITIONING DETECTION

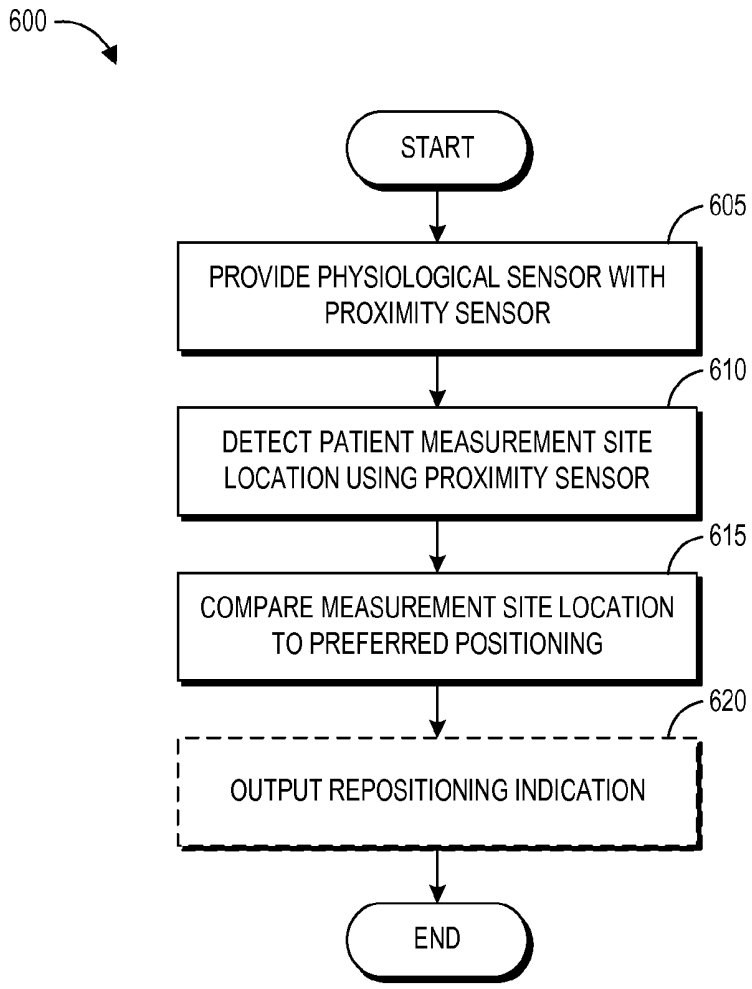


FIG. 6

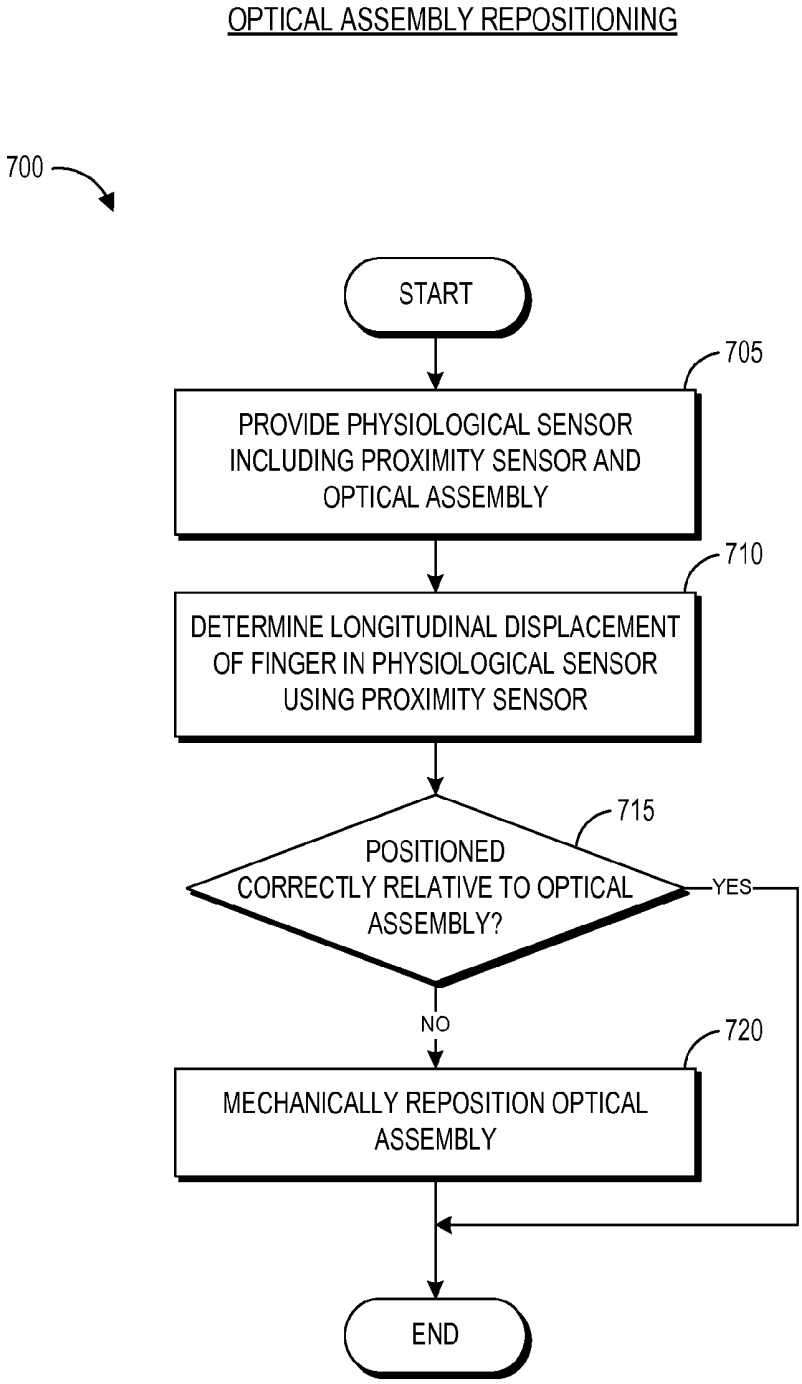

OPTICAL ASSEMBLY REPOSITIONING
700
START
705
PROVIDE PHYSIOLOGICAL SENSOR INCLUDING PROXIMITY SENSOR AND OPTICAL ASSEMBLY
710
DETERMINE LONGITUDINAL DISPLACEMENT OF FINGER IN PHYSIOLOGICAL SENSOR USING PROXIMITY SENSOR
715
POSITIONED CORRECTLY RELATIVE TO OPTICAL ASSEMBLY?
YES
NO
720
MECHANICALLY REPOSITION OPTICAL ASSEMBLY
END

FIG. 7

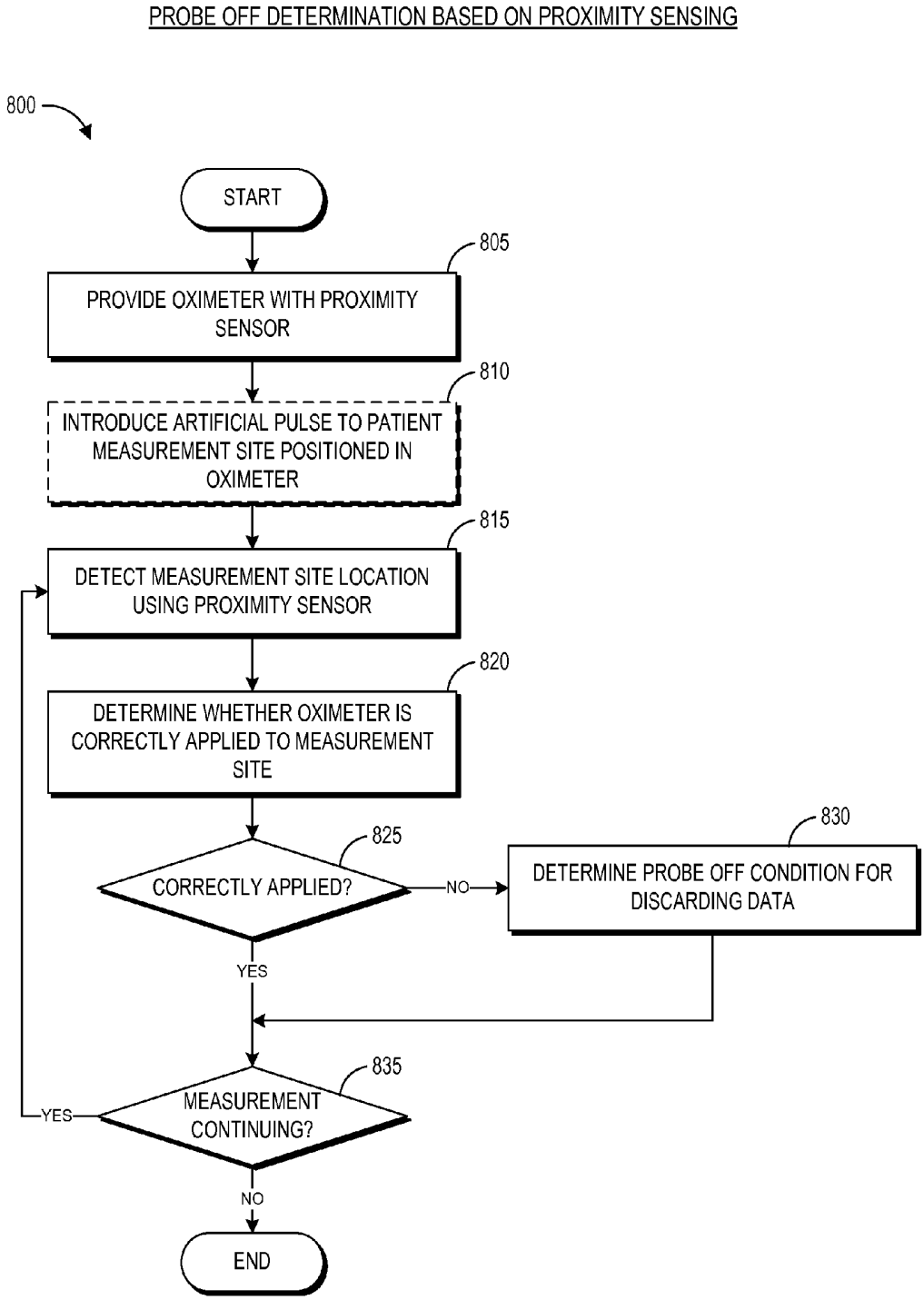

PROBE OFF DETERMINATION BASED ON PROXIMITY SENSING
800
START
805
PROVIDE OXIMETER WITH PROXIMITY SENSOR
810
INTRODUCE ARTIFICIAL PULSE TO PATIENT MEASUREMENT SITE POSITIONED IN OXIMETER
815
DETECT MEASUREMENT SITE LOCATION USING PROXIMITY SENSOR
820
DETERMINE WHETHER OXIMETER IS CORRECTLY APPLIED TO MEASUREMENT SITE
825
CORRECTLY APPLIED?
NO
830
DETERMINE PROBE OFF CONDITION FOR DISCARDING DATA
YES
835
MEASUREMENT CONTINUING?
YES
NO
END

FIG. 8

PROXIMITY SENSOR IN PULSE OXIMETER

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Application Ser. No. 62/014,611, filed Jun. 19, 2014, titled "PROXIMITY SENSOR IN PULSE OXIMETER," the entirety of which is hereby incorporated by reference.

TECHNICAL FIELD

[0002] The systems and methods disclosed herein are directed to patient monitoring, and, more particularly, to pulse oximeter patient monitors capable of capacitive proximity detection.

BACKGROUND

[0003] The standard of care in caregiver environments includes patient monitoring through spectroscopic analysis using, for example, a pulse oximeter. Devices capable of spectroscopic analysis generally include a light source(s) transmitting optical radiation into or reflecting off a measurement site, such as, body tissue carrying pulsing blood. After attenuation by tissue and fluids of the measurement site, a photodetection device(s) detects the attenuated light and outputs a detector signal(s) responsive to the detected attenuated light. A signal processing device(s) process the detector(s) signal(s) and outputs a measurement indicative of a blood constituent of interest, such as glucose, oxygen, methemoglobin, total hemoglobin, other physiological parameters, or other data or combinations of data useful in determining a state or trend of wellness of a patient.

[0004] In noninvasive devices and methods, a sensor is often adapted to position a finger proximate the light source and light detector. For example, noninvasive finger clip sensors often include a clothespin-shaped housing that includes a contoured bed conforming generally to the shape of a finger.

[0005] Accurate determination of physiological measurements is often dependent upon proper application of the optical sensor to the measurement site. Clip-type pulse oximeter sensors typically include a physical stop near the hinge of the housing to indicate desired placement of a user's finger or other measurement site within the sensor. However, the physical stop does not ensure that the patient's finger is positioned far enough into the sensor. In addition, even if a sensor is initially placed correctly, movement, either of the patient or of the sensor during artificial pulsing, can longitudinally displace the patient's finger within the sensor. This can result in the light source and detector of the oximeter being positioned around a portion of the finger that provides inaccurate physiological measurements.

SUMMARY

[0006] The foregoing and other problems are addressed, in some embodiments, by providing an oximeter with proximity sensing technology that can be used to determine whether the oximeter is correctly applied to a patient measurement site. For example, one or more capacitive sensor electrodes can provide an indication to a processor of the oximeter regarding whether the sensor is correctly positioned by sensing proximity to the skin of the measurement site. Capacitive sensor electrodes can provide data representing a distance or relative distance between the electrodes and skin of the measurement site. Due to the inverse relationship between capacitance and distance, the sensitivity to the distance between the measurement site and the capacitive sensor electrodes increases as the distance between the measurement site and the capacitive sensor electrodes decreases. Accordingly, in one embodiment, a plurality of capacitive sensor electrodes can be positioned at various locations within the oximeter housing to provide proximity accurate feedback when the measurement site is located at a number of different positions relative to the oximeter. Though discussed primarily herein in the context of capacitive sensor electrodes, proximity feedback in pulse oximeters can be provided in other examples by optical, mechanical, or electrical sensors interfacing with skin of a measurement site, or a combination of one or more of capacitive, optical, mechanical, and electrical sensors.

[0007] In some embodiments, capacitive sensor electrodes can be used to determine the longitudinal displacement of a patient's finger within a clip-type pulse oximeter sensor housing. Using the determined displacement, the oximeter can determine whether to provide an indication to the patient or physician to reposition the oximeter. The oximeter can additionally or alternatively use the determined displacement to determine whether to mechanically reposition the optical assembly of the oximeter relative to the patient's finger. In oximeters implementing artificial pulsing, the capacitive sensor electrodes can periodically or continuously monitor the longitudinal displacement of the patient's finger within the sensor housing to determine a probe off condition. These examples illustrate some of the many benefits of an oximeter sensor having proximity sensing technology for determining positioning of the sensor relative to a measurement site.

[0008] For purposes of summarizing the disclosure, certain aspects, advantages and novel features of the inventions have been described herein. It is to be understood that not necessarily all such advantages can be achieved in accordance with any particular embodiment of the inventions disclosed herein. Thus, the inventions disclosed herein can be embodied or carried out in a manner that achieves or optimizes one advantage or group of advantages as taught herein without necessarily achieving other advantages as can be taught or suggested herein.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] Throughout the drawings, reference numbers can be re-used to indicate correspondence between referenced elements. The drawings are provided to illustrate embodiments of the inventions described herein and not to limit the scope thereof.

[0010] FIG. **1**A illustrates a high-level diagram of an embodiment of a physiological sensor having proximity sensing capabilities positioned around a patient measurement site.

[0011] FIG. **1**B illustrates another embodiment of the physiological sensor of FIG. **1**A.

[0012] FIG. **2**A illustrates a perspective view of an embodiment of a physiological sensor having proximity sensing capabilities.

[0013] FIGS. **2**B and **2**C illustrate an exploded view of two components of the physiological sensor of FIG. **2**A when disassembled.

[0014] FIG. **3**A illustrates a perspective view of another embodiment of a physiological sensor having proximity sensing capabilities.

[0015] FIG. **3**B illustrates a perspective view of the physiological sensor of FIG. **3**A in an open position.

[0016] FIG. **4** illustrates a high-level schematic block diagram of an embodiment of a physiological sensor having proximity sensing capabilities.

[0017] FIG. **5** illustrates a schematic diagram of an embodiment of a circuit for measuring proximity of a measurement site to a sensor.

[0018] FIG. **6** illustrates an example process for determining positioning during sensor application.

[0019] FIG. **7** illustrates an example process for repositioning an applied sensor based on proximity sensing.

[0020] FIG. **8** illustrates an example process for determining a probe off condition based on proximity sensing.

DETAILED DESCRIPTION

I. Introduction

[0021] Implementations described herein relate generally to proximity sensing in physiological sensors, and more specifically to using one or more proximity sensors located on or within a physiological sensor to determine the positioning of the physiological sensor on a patient measurement site. Accurate placement of a physiological sensor on the patient measurement site is a key factor in obtaining reliable measurement of physiological parameters of the patient. For example, in clip-type pulse oximeter sensors, longitudinal positioning of the patient's finger within the sensor housing determines which portion of the patient's finger is aligned with an optical assembly used to generate physiological measurement data for determining one or more physiological parameters. Proper alignment with the optical assembly covers a detector of the optical assembly with the patient's fingertip and reduces introduction of ambient light to the detector, and accordingly provides more accurate physiological measurement data. This alignment can be determined based on data from a proximity sensor or sensors placed on or within the physiological sensor. Suitable proximity sensors include one or more capacitive sensors, optical scanning sensors, electrical sensors, or mechanical contact sensors.

[0022] The proximity data generated by the proximity sensors on or within a pulse oximeter can enable provision of more accurate physiological measurement data. For example, the proximity sensors described herein can be used to provide an indication to the oximeter to generate feedback for a patient or physician to reposition an improperly aligned oximeter sensor. In another example, the proximity sensors can be used to provide alignment information for mechanically repositioning the optical assembly with respect to the oximeter housing and patient finger. As a further example, the proximity sensors can be used to determine a probe off condition indicating that physiological measurement data obtained during persistence of the probe off condition should be discarded due to improper alignment. In additional examples, the proximity sensors can be used to associate distance data with measurement data output by the sensor, e.g. for assigning a confidence value to the measurement data.

II. Overview of Example Proximity Sensing Physiological Monitoring Systems

[0023] FIGS. **1**A and **1**B illustrate embodiments of a high-level diagram of an embodiment of a physiological sensor having proximity sensing capabilities positioned around a patient measurement site. The sensor **100** can include a first housing component **110** including an emitter **120** and a second housing component **115** including a detector **125**. The sensor **100** can also include a physical stop **140** to guide the positioning of a patient finger **130** or other measurement site within the sensor **100**. One or more proximity sensors **145** can be positioned on or within the sensor **100**.

[0024] The emitter **120** can be configured to emit light having multiple primary wavelengths λ_P into the tissue of the patient finger **130** or other measurement site. The emitter **120** can be comprised of one or more devices such as semiconductive light emitting diodes (LEDs), although it will be appreciated that other light generating devices may be used. The light emitter **120** may be chosen to emit light at a single known discrete wavelength, at multiple discrete wavelengths, or across a portion of the spectrum (such as that emitted by a "white light" LED), depending on the needs of the particular application. In one embodiment, the emitter **120** consists of two or more diodes emitting light energy in the infrared and red regions of the electromagnetic spectrum, and a parallel resistor (or resistors) used for security. The construction and operation of such light source drive circuitry is described in U.S. Pat. No. 5,758,644 incorporated herein by reference.

[0025] The detector **125** can be any suitable light energy detector responsive to light energy from the emitter, for example a semi-conductive photodetector. The emitter **120** and detector **125** can be aligned such that the detector **125** detects the emitted light after attenuation by the tissue of the patient finger **130**.

[0026] The physical stop **140** can provide tactile feedback to a clinician or patient positioning the finger **130** within the sensor in order to achieve proper positioning. Proper positioning of the patient finger **130** or other tissue site relative to the detector **125** enables accurate physiological measurements to be made. In particular, the emitter **120** is placed so as to illuminate a blood-perfused tissue site **135**, such as a nail bed, and the detector **125** is positioned so that only light transmitted by the emitter **120** and attenuated by pulsatile blood flowing within the tissue site **135** is received by the detector **125**.

[0027] Physical stop **140** can prevent the tissue site **135** from being positioned beyond the emitter **120** and detector **125**, that is, too far into the sensor **100**. However, the physical stop **140** does not ensure that the tissue site **135** will be placed far enough within the sensor **100** for adequate transmission of light from the emitter **120** through the tissue site **135** to the detector **125** to enable clinically accurate physiological measurements. Accordingly, the sensor **100** can be provided with one or more proximity sensors **145** positioned within the sensor housing. The proximity sensor(s) **145** can be used to determine whether the tissue site **135** is positioned properly relative to the emitter **120** and detector **125**.

[0028] Proximity sensor **145** can be a capacitive sensor, in some embodiments, that uses capacitance of the human body as an input to determine a distance between the patient's finger **130** and the proximity sensor **145**. In another embodiment, proximity sensor **145** can be an optical scanning sensor, for example a camera or a near-infrared proximity sensor that uses light to determine how close or far the patient's finger **130** is from the proximity sensor **145**. In still further embodiments, proximity sensor **145** can be a mechanical contact sensor that determines whether physical contact is made between the patient's finger **130** and the proximity sensor **145** mounted on the physical stop **140**. Other sensors suitable for determining contact or distance between patient finger **130** and sensor **145** can be used in other embodiments.

[0029] As illustrated by FIG. **1**A, the physical stop **140** can include a proximity sensor **145**. The proximity sensor **145** of FIG. **1**A can be used to determine the distance (or whether there is contact) between the location of the proximity sensor **145** on the physical stop **140** and the end of the patient's finger **130** nearest the stop **140**. The proximity sensor **145** can be positioned on the physical stop **140** so as to sense or contact a portion of the patient fingertip below the nail, in particular for embodiments in which a capacitive proximity sensor is implemented. As illustrated by FIG. **1**B, an additional array of proximity sensors **145** can be positioned longitudinally along the finger bed of the second housing component **115**. The array **150** of proximity sensors can provide additional feedback regarding the longitudinal positioning of the patient finger **130** within the sensor **100**.

[0030] As illustrated in FIGS. **2**A and **2**B, an embodiment of a sensor **200** can include a two-piece housing and an electrical supply and signal cable **210**. The housing consists of a first (upper) housing element **275** and a second (lower) housing element **255**, which can be rotatably attached to one another via a pivot element **265**. A light emitter can be disposed within the upper housing element **275**, while a detector can be disposed within the lower housing element **255**. The housing is adapted to receive the distal end of a finger as shown in the block diagrams of FIGS. **1**A and **1**B, with the "upper" housing element **275** engaging the upper surface of the finger, and the "lower" housing element engaging the lower surface of the finger. It will be recognized, however, that the sensor **200** may be used in any orientation, such as with the first housing element **275** being located below the second housing element **255**. Furthermore, the light emitter may alternatively be placed in the lower housing element **255**, and the detector in the upper housing element **275** if desired, subject to modification of other probe components as described further below. It is also noted that while the following discussion describes a series of exemplary embodiments based on measuring the optical characteristics of a finger, the sensor **200** may be adapted for use with any number of other body parts, such as earlobes or loose skin, with equal success. Additional details of an embodiment of the sensor are disclosed in U.S. Pat. No. 6,580,086 entitled "Shield Optical Probe and Method," filed on Oct. 19, 1999 and assigned to Masimo Corporation, the entirety of which is hereby incorporated by reference.

[0031] The first and second housing elements **275**, **255** can be generally rectangular in form with a pivot element **265** disposed near a common end of each of the elongate housing elements **275**, **255**. The two housing elements **275**, **255** can be biased around the rotational axis of the pivot element by a biasing element, for example a hinge spring. The upper housing element **275** can be accordingly biased against the lower housing element **255** for secure placement on a patient finger or other measurement site. The user can grasp the sensor **200** between his or her fingers and separate the probe housing elements **275**, **255** by applying force counter to the spring biasing force. In this fashion, the user simply grasps the sensor **200**, opens it by applying a light force with the grasping fingers, and inserts the distal end of the patient's finger into the end **240** of the sensor **200**. Once the finger is inserted into the sensor **200**, the disproportionate compression of the finger (due to interaction of the angled housing elements **275**, **255** and the substantially cylindrical finger) and the aforementioned bias spring separating force act to lower housing elements **275**, **255** substantially parallel to each other, allowing more of the surface area of the upper and lower support surface elements **225**, **230** to contact the finger, and for more even pressure distribution thereon. This assists with accurate positioning of the finger with respect to the emitter and detector for clinically accurate physiological measurement readings using the sensor **200**.

[0032] As shown in more detail in FIGS. **2**B and **2**C, the housing elements **275**, **255** can include first (upper) and second (lower) support surface elements **225**, **230**, respectively, which provide support and alignment for the tissue material, such as the finger, when the sensor **200** is clamped thereon. The upper support surface element **225** can be fashioned from a substantially pliable polymer such as silicone rubber, so as to permit some deformation of the element **225** when in contact with the fairly rigid upper portion **280** of the patient's finger. The upper support surface element **225** further includes an optical energy shield **250** which protrudes from the upper support surface element **225**. The shield **250** can be sized and shaped so as to conform substantially to the outer circumference of the patient's finger, providing at least a partial seal against ambient light incident on the probe exterior and otherwise exposed portions of the finger. In this fashion, patients having fingers of different circumferences can be accommodated with the same sensor **200** due to use of shield **250**. The lower surface element **230** can be fashioned from a substantially solid and rigid (i.e., higher durometer) polymer. This harder, solid polymer can be used for the lower surface element **230** since the lower portion of the finger is generally more fleshy and deformable, thereby allowing the skin and tissue material thereof to deform and contour to the shape of the inner region **285** of the lower surface element. The inner regions **280**, **285** can be contoured to assist in mitigating the effects of patient movement during operation of the sensor **200**. Accordingly, the construction of the sensor **200** provides some alignment between the patient finger and the sensor **200** for proper positioning relative to the emitter and detector.

[0033] The upper surface element **225** includes an aperture **215** for transmission of light therethrough after emission by the emitter in the upper housing element **275**. The lower surface element **230** includes an aperture **235** aligned with the detector for transmission of light therethrough after passing through the measurement site. The apertures **215**, **235** allow for light energy to be transmitted between the light emitter and tissue material of the measurement site, and similarly between the tissue material and detector. The first aperture **215** is also axially located with the second aperture **235** in the vertical dimension, such that when the probe **100** is in the closed configuration with the patient's finger disposed between the upper and lower surface support elements **225**, **230**, light emitted by the light source through the first aperture **215** is transmitted through the finger and the second aperture **235** and received by the detector. Hence, the light source, first aperture **215**, second aperture **235**, and detector are substantially axial in this configuration.

[0034] The lower support element **230** is further provided with a physical stop **290** disposed near the pivot element of the sensor **200**. The physical stop **290** is oriented vertically with respect to the lower support element **230** so as to stop the distal end of the patient's finger from being inserted into the probe past a certain point, thereby facilitating proper alignment of the finger within the sensor **200**, especially with respect to the source and detector apertures **215**, **235**. While the present embodiment uses a semi-circular tab as the physi-

cal stop **290**, it will be recognized that other configurations and locations of the physical stop **290** may be used. For example, the tab could be bifurcated with a portion being located on the upper support surface element **230**, and a portion on the lower support surface element **225**. Alternatively, the positioning element could be in the form of a tapered collar which receives, aligns, and restrains only the distal portion of the patient's finger. Many such alternative embodiments of the positioning element are possible, and considered to be within the scope of the present invention.

[0035] A proximity sensor **295** is positioned on the physical stop **290** that can be used to determine whether the patient finger or other measurement site is positioned properly within the sensor **200**. As discussed above, proximity sensor **295** can be a capacitive sensor, an optical scanning sensor, or a mechanical contact sensor, or a combination of two or more of these sensors in some embodiments. Proximity sensor **295** provides feedback regarding distance or contact between the patient finger and the proximity sensor **295** located on physical stop **290**, and accordingly can be used to determine whether the patient finger is aligned with the emitter and detector of the sensor **200**. This feedback can be used to provide a repositioning indication to the user of the sensor **200**, to mechanically reposition the optical components of the sensor **200**, or for data filtering, as described in more detail below. Accordingly, the feedback from the proximity sensor **295** can enable more accurate physiological measurements using the sensor **200**.

[0036] FIGS. **3**A and **3**B illustrate another embodiment of a sensor **300**. The sensor **300** shown can include all of the features of the sensors **100** and **200** described above.

[0037] Referring to FIG. **3**A, the sensor **300** in the depicted embodiment is a clothespin-shaped clip sensor that includes an enclosure **302***a* for receiving a patient's finger. The enclosure **302***a* is formed by an upper housing or emitter shell **304***a*, which is pivotably connected with a lower housing or detector shell **306***a*. The emitter shell **304***a* can be biased with the detector shell **306***a* to close together around a pivot point **303***a* and thereby sandwich finger tissue between the emitter and detector shells **304***a*, **306***a*.

[0038] In an embodiment, the pivot point **303***a* advantageously includes a pivot capable of adjusting the relationship between the emitter and detector housings **304***a*, **306***a* to effectively level the sections when applied to a tissue site. In another embodiment, the sensor **300** includes some or all features of the finger clip described in U.S. Pat. No. 8,437,825, entitled "Contoured Protrusion for Improving Spectroscopic Measurement of Blood Constituents," filed on Jul. 2, 2009 and assigned to Cercacor Laboratories, the entirety of which is hereby incorporated by reference. For example, the sensor **300** can include a spring that causes finger clip forces to be distributed along the finger.

[0039] The emitter housing **304***a* can position and house various emitter components of the sensor **301***a*. It can be constructed of reflective material (e.g., white silicone or plastic) and/or can be metallic or include metalicized plastic (e.g., including carbon and aluminum) to possibly serve as a heat sink including one or more fins **351***a*. The emitter housing **304***a* can also include absorbing opaque material, such as, for example, black or grey colored material, at various areas, such as on one or more flaps **307***a*, to reduce ambient light entering the sensor **301***a*. The emitter housing **304***a* can also include optical shield **307***a* to block ambient light from entering the sensor **300**.

[0040] The detector housing **306***a* can position and house one or more detector portions of the sensor **301***a*. The detector housing **306***a* can be constructed of reflective material, such as white silicone or plastic. As noted, such materials can increase the usable signal at a detector by forcing light back into the tissue and measurement site (see FIG. **1**). The detector housing **306***a* can also include absorbing opaque material at various areas, such as lower area **308***a*, to reduce ambient light entering the sensor **301***a*.

[0041] Referring to FIG. **3**B, an example of finger bed **310** is shown in the sensor **301***b*. The finger bed **310** includes a generally curved surface shaped generally to receive tissue, such as a human digit. The finger bed **310** includes one or more ridges or channels **314**. Each of the ridges **314** has a generally convex shape that can facilitate increasing traction or gripping of the patient's finger to the finger bed. Advantageously, the ridges **314** can improve the accuracy of spectroscopic analysis in certain embodiments by reducing noise that can result from a measurement site moving or shaking loose inside of the sensor **301***a*. The ridges **314** can be made from reflective or opaque materials in some embodiments to further increase signal to noise ration (SNR). In other implementations, other surface shapes can be used, such as, for example, generally flat, concave, or convex finger beds **310**.

[0042] Finger bed **310** can also include an embodiment of a tissue thickness adjuster or protrusion **305**. The protrusion **305** includes a measurement site contact area **370** that can contact body tissue of a measurement site. The protrusion **305** can be removed from or integrated with the finger bed **310**. Interchangeable, different shaped protrusions **305** can also be provided, which can correspond to different finger shapes, characteristics, opacity, sizes, or the like. In some embodiments, protrusion **305** can include one or more proximity sensors to determine positioning of a patient finger over the protrusion **305**.

[0043] The detector housing **306***a* can also include a physical stop **350** to prevent a patient's finger from being longitudinally placed too far into the sensor for proper alignment with the emitter and detector. Proper positioning of the patient finger or other tissue site relative to the detector enables accurate physiological measurements to be made. The physical stop **350** can include one or more proximity sensors **355** for determining distance or contact between the end of the patient's finger and the proximity sensor **355** to provide feedback regarding alignment of the patient's finger with the emitter and detector. As described above, the proximity sensor **355** can be a capacitive sensor, optical scanning sensor, or mechanical contact sensor. Data from proximity sensor **355** can be used to determine whether the patient finger is aligned with the emitter and detector of the sensor **300**. This feedback can be used to provide a repositioning indication to the user of the sensor **300**, to mechanically reposition the optical components of the sensor **200**, or for data filtering, as described in more detail below. Accordingly, the feedback from the proximity sensor **295** can enable more accurate physiological measurements using the sensor **200**.

[0044] In a vascular bed the arterial vasculature is coupled mechanically to the venous vasculature through the tissues. Although this coupling is small, the optical arterial pulse, e.g. photo-plethysmograph, has invariably a small venous component. This component is not fixed across subjects but its average is indirectly calibrated for in the saturation calibration curve. Its effect on the arterial pulse is proportional to the coupling size as well as the difference between the arterial

and venous saturations at the site. Its effects may be explained by the reduction in the optical effect of venous coupling as the delta saturation between the arterial and the venous is reduced due to the increase in availability of plasma oxygen. Under this condition, the venous blood will look, optically, a lot like the arterial blood. Hence, the size of the Red photo-plethysmograph signal will shrink with respect to the IR indicating a shrinking ΔSat, i.e. higher venous saturation. In 1995, Masimo Corporation (Masimo) introduced a new technique for calculation the venous oxygen saturation ($SpvO_2$) by introducing an artificial pulse into the digit (see, e.g., U.S. Pat. No. 5,638,816, incorporated herein by reference).

[0045] The sensor **300** depicted in FIGS. **3**A and **3**B can be capable of introducing an artificial pulse into the measurement site. The sensor **300** can induce an artificial pulse at a frequency distinguishable from the frequency of a human arterial pulse. As a result, information related to both the arterial pulse as well as the artificial pulse is recoverable from the body. The redundant nature of both pieces of information provide additional information useful in determining physiological parameters.

[0046] Introducing an artificial excitation can cause perturbations in the blood flow similar to the effects of a heart beat. These artificial excitations can be used as an alternative to the natural pulse rate or in addition to the natural pulse rate. Artificial excitations have the added benefit that the excitations introduced are introduced at known frequencies. Thus, it is not necessary to first determine the pulse rate of an individual.

[0047] However, the movement required to generate the artificial pulse can cause movement of the sensor relative to the patient, introducing the variable of distance into denoising equations for the resultant sensor data. For example, the artificial pulse can dislodge the sensor **300** from the patient measurement site or misalign the measurement site with the emitter and detector of the sensor **300**. Accordingly, sensor data from active pulse sensors typically is filtered to determine probe off and probe on conditions, where probe on conditions indicate reliable sensor data and probe off conditions include their ordinary broad meaning known to one of skill in the art, including designating improper application of an optical probe to a measurement site, for example due to movement of the sensor relative to the patient caused by artificial pulsing.

[0048] Data from the proximity sensor **355** within the sensor **300** can be used instead of or in addition to more complex data processing methods to determine a probe off condition due to improper alignment of the measurement site and the sensor. For example, if data from the proximity sensor **355** indicates that the measurement site is not properly aligned with the sensor **300**, then the sensor **300** can determine a probe off condition for the duration of such data from the proximity sensor **335**. Accordingly, data from proximity sensor **355** can provide a computationally simple and accurate means for determining the probe off condition.

[0049] In some embodiments, instead of or in addition to using proximity data to determine a probe off condition, data from the proximity sensor **355** can be used to generate a confidence value indicating potential accuracy of measurement data, e.g., plethysmographic data output by a pulse oximeter. For example, during operation a sensor can supply associated proximity data and plethysmographic data to a patient monitor without utilizing probe-off detection or probe repositioning. The patient monitor can then determine a confidence value for each portion of the plethysmographic data based on the associated proximity data, for example a measured distance between a fingertip and a capacitive proximity sensor measured at substantially the same time as when the plethysmographic data was captured. Using the confidence values for the plethysmographic data (e.g., to discard certain portions of the plethysmographic data or to assign different weights to different portions of the plethysmographic data), the patient monitor can estimate pulse rates, respiration rates, and the like for the patient.

[0050] FIG. **4** illustrates a high-level schematic block diagram of an embodiment of a physiological sensor **400** having proximity sensing capabilities. The physiological sensor **400** includes an emitter **405**, detector **410**, processor **415**, and capacitive sensor **420**. In other embodiments the capacitive sensor **420** can be replaced or supplemented by the other types of proximity sensors discussed herein. Various embodiments of the sensor **400** can also include one or more of a set of optional components such as positioning feedback indicator **425**, repositioning module **430**, emitter drive **440**, or detector drive **435**. Though not illustrated, the sensor **400** can also include memory, a display, connection ports, user interface elements, alarms, and other components.

[0051] The emitter **405** can be capable of emitting light at one or a plurality of wavelengths λ_P for noninvasive measurement of constituents of blood flowing within the tissue of a patient measurement site. The emitter **405** and detector **410** can be aligned so that some or all of the light λ_P is incident on detector **410** after passage through the measurement site and attenuation by the constituents of the blood.

[0052] Intensity signals representing the light λ_P incident on detector **410** can be sent to processor **415**. Processor **415** can analyze the intensity signals and determine one or more physiological parameter values. For example, processor **415** can calculate a ratio of detected red and infrared intensities, and an arterial oxygen saturation value is empirically determined based on that ratio. Processor **415** can also perform noise filtering on the raw intensity signal data, and can determine probe off and probe on conditions for purposes of excluding unreliable data from use in calculating physiological parameters. Data from the capacitive sensor **420** can provide feedback regarding the distance of a patient measurement from the capacitive sensor, which can be compared to a threshold to determine whether the sensor and finger are improperly aligned. The determination of improper alignment can be used by the processor **415** in one embodiment to determine a probe off condition.

[0053] In some embodiments, the processor **415** can generate a repositioning signal based at least partly on the determination of improper alignment from capacitive sensor data. This signal can be sent, in one embodiment, to positioning feedback indicator **425**. Positioning feedback indicator **425** can provide visual, audible, or tactile feedback to a user of sensor **400** to indicate whether the sensor should be repositioned. For example, sensor **400** may emit a beep or audible alarm when the sensor **400** is improperly positioned. Sensor **400** may also include one or more visual indications, for example LED lights, that can be used to provide positioning feedback to the user. For instance, a green light may be illuminated to indicate to the user that the sensor **400** is properly positioned. A red light may be illuminated to indicate to the user that sensor **400** is improperly positioned. As another example, sensor **400** may output text or voice commands indicating how far the user must adjust the sensor **400**

in order to achieve proper alignment based on the proximity sensor data. Positioning feedback indicator **425** can provide an initial positioning indication when the user first applies the sensor in one embodiment. In some embodiments, positioning feedback indicator **425** can periodically or continuously output positioning feedback to the user, for example for active pulse sensors introducing an artificial pulse during measurement.

[0054] The repositioning signal can be sent, in another embodiment, to repositioning module **430**. Repositioning module **430** can use the repositioning signal to generate instructions for mechanical repositioning of the emitter **405** and detector **410**, for example using emitter drive **440** and detector drive **435**. In some embodiments, emitter drive **440** and detector drive **435** could be implemented together as a single optical assembly drive. Emitter drive **440** and detector drive **435** can be used to reposition the emitter **405** and detector **410**, respectively, according to the data provided by the capacitive sensor **420** in order to align the emitter **405** and detector **410** with the measurement site.

[0055] As discussed above with respect to the sensors of FIGS. **1**A-3B, the capacitive sensor **420** can be placed within the body of the sensor **400** to gauge longitudinal displacement of a patient's finger relative to the sensor **400** and, more specifically, the optical assembly including the emitter **405** and detector **410**. In some embodiments, multiple capacitive sensors can be positioned along a longitudinal axis of the sensor **400** for additional data as the patient's finger moves within the sensor housing.

III. Overview of Example Capacitive Proximity Sensor

[0056] FIG. **5** illustrates a schematic diagram of an embodiment of a circuit **500** that can be used to determine proximity of a patient measurement site to a physiological sensor. The circuit includes a capacitor **515** and a resistor **505**. Here the capacitance, C, can be calculated according to Equation (1), below:

$$C \propto \frac{A}{d} \tag{1}$$

where the capacitance, C, is proportional to the area, A, of the capacitor divided by the distance, d, between the capacitor plates. The capacitor **515** has two plates **510**, **520**. The first capacitive plate **510** is integrated or connected to the physiological sensor, for example a physical stop near the hinge of the housing of clip-type pulse oximeter, or in an array along the longitudinal axis of the surface of a finger bed of clip-type pulse oximeter. The second capacitor plate **520** is the skin surface of the patient measurement site, with the assumption that the patient is a capacitor. A typical adult has a capacitance of about 120 pF, however capacitance of different people will vary. Accordingly, the distance, d, between the capacitor plates **510**, **520** represents the distance between the location of the capacitive sensor within the physiological sensor and the surface of the patient measurement site. In order to obtain the value of the distance, d, from Equation (1), the values of both the capacitance, C, and the area, A, must be known. The area can be predetermined based on the dimensions of the first capacitive plate **510**.

[0057] The capacitance can be determined from the value of the resistance, R, of the resistor **505** and the value of a time constant, τ, of the circuit **500**. The time constant of the circuit **500** can be calculated according to Equation (2), below:

$$\tau = RC \tag{2}$$

where the time constant, τ, is equal to the resistance, R, times the capacitance, C. Hence, the distance, d, between the capacitor plates **510**, **520** can be calculated through the combination of Equations (1) and (2) through the measurement of the circuit time constant. Accordingly, as a distance between a patient measurement site, such as a digit of a hand, and the capacitor plate **510** decreases, the time constant τ increases and the capacitance C increases.

[0058] In one embodiment, the time constant τ can be determined from the time required to trip a set voltage level, such as about 2.2 volts, given a power supply of known power, such as about 3.3 volts. Although not illustrated, a processor or microprocessor can be in communication with the circuit **500** to measure the time constant. The determined time constant τ can be used to calculate the capacitance, C, using Equation (2). The capacitance C can then used to calculate the distance or relative distance through Equation (1). Accordingly, as a distance between a patient measurement site, such as a digit of a hand, and the capacitor plate **510** decreases, the time constant τ increases and the capacitance C increases.

[0059] The value of the distance d can be used to provide a repositioning indication to the patient or physician, to mechanically reposition the optical assembly of an oximeter sensor, or to determine a probe off condition for removing potentially unreliable data from a physiological measurement data set. In some embodiments, a number of circuits **500** can be provided within an oximeter for precise determination of longitudinal displacement of a patient finger within the oximeter housing. Accordingly, at least one of the repositioning indication, optical assembly repositioning, or probe off can be based on a number of distance values corresponding to each of the circuits. Although an example capacitive circuit **500** is depicted, this is for purposes of illustration and in other embodiments other capacitive circuit arrangements can be used. For example, other suitable circuits can include amplifiers, additional resistors, and other elements, for instance to amply the signal to noise and to minimize changes to capacitance based on environmental changes.

IV. Overview of Example Proximity-Sensing Physiological Monitoring Processes

[0060] FIG. **6** illustrates an example process **600** for determining positioning during sensor application. The process **600** can be implemented on any physiological sensor including proximity sensing capabilities, for example the physiological sensors illustrated in FIGS. **1**A-FIG. **4**.

[0061] At block **605**, a physiological sensor is provided with at least one proximity sensor. For example, one proximity sensor or an array of proximity sensors can be provided including capacitive, optical, electrical, or mechanical proximity sensors, or a combination thereof. The proximity sensor can be configured to determine distance or contact between a measurement site and itself, and can be positioned within the sensor so as to provide feedback regarding alignment of the measurement site and optical components of the sensor.

[0062] At block **610**, the patient measurement site location is detected using the proximity sensor. For example, using a capacitive proximity sensor, a distance between a capacitive plate in the sensor and the capacitive skin of the patient can be determined. An optical scanning proximity sensor can also

determine a distance between the sensor and a patient measurement site. In another example, using a mechanical contact proximity sensor, it can be determined whether the patient measurement site has contacted the mechanical contact proximity sensor, such as by depressing a button.

[0063] At block **615**, the measurement site location can be compared to preferred positioning. The preferred positioning can include a range of placements relative to the optical components of the sensor that are likely to produce clinically accurate physiological measurements. To illustrate, if a capacitive proximity sensor is used on a physical stop in a pulse oximeter finger clip sensor such as is depicted in FIGS. **2**A, **2**B, **3**A, or **3**B, a distance of approximately 4 mm-10 mm between the capacitive proximity sensor and the patient fingertip can correspond to proper positioning of an adult finger with respect to an LED emitter and detector. In one embodiment, a distance of approximately 6 mm between the capacitive sensor and the fingertip can indicate preferred positioning of the finger within the sensor. Other ranges can be used to indicate preferred placement in other sensor configurations, for other finger sizes, or for other measurement sites.

[0064] At block **620**, the sensor can optionally cause the sensor to output a repositioning indication. For instance, in one embodiment of a pulse oximeter finger clip sensor such as is depicted in FIGS. **2**A, **2**B, **3**A, or **3**B having a capacitive sensor on a physical stop, if the capacitive proximity sensor data indicates that the patient fingertip is closer than approximately 4 mm to the capacitive sensor or farther than approximately 10 mm from the capacitive sensor, the sensor may output a repositioning indication. In some embodiments, the sensor may output a first positioning indication when the sensor is correctly positioned and may output a second positioning indication when the sensor is incorrectly positioned. The second positioning indication may be a visual, auditory, or tactile signal alerting the user that the sensor is incorrectly positioned, and in one example may include specific instructions regarding how to reposition the sensor for proper placement.

[0065] Process **600** can be implemented when a user first applies a sensor to a measurement site to indicate proper positioning. In some embodiments, blocks **610**-**620** may be repeated one or more times during measurement to gauge whether the sensor positioning continues to be proper or whether the sensor should be repositioned. Repetition of this measurement site location detection and comparison portion of process **600** can be beneficial, in one example, in active pulse oximeters that introduce an artificial pulse to a measurement site and therefore possibly introduce movement of the sensor relative to the measurement site. Repetition of blocks **610**-**620** can also be beneficial, in another example, in patient monitoring situations in which the patient can move during the time in which the sensor is worn and therefore may dislodge the sensor.

[0066] FIG. **7** illustrates an example process **700** for repositioning an applied sensor based on proximity sensing. The process **700** can be implemented by the components of any physiological sensor including proximity sensing capabilities, for example the physiological sensors illustrated in FIGS. **1**A-FIG. **4**.

[0067] At block **705**, a physiological sensor is provided with at least one proximity sensor. For example, one proximity sensor or an array of proximity sensors can be provided including capacitive, optical, electrical, or mechanical proximity sensors, or a combination thereof. The proximity sensor can be configured to determine distance or contact between a measurement site and itself, and can be positioned within the sensor so as to provide feedback regarding alignment of the measurement site and optical components of the sensor. The physiological sensor also includes an optical assembly, for instance an aligned emitter and detector as discussed above with respect to FIGS. **1**A-FIG. **4**, for generating intensity signals from which to determine physiological signals.

[0068] At block **710**, the sensor determines longitudinal displacement of a patient finger in the physiological sensor using the proximity sensor. Many pulse oximeters are contoured to naturally center a patient finger within the sensor, and therefore the proximity sensing discussed herein focuses primarily on determining longitudinal displacement. However, in other sensor embodiments displacement of the measurement site along a vertical or horizontal axis of the sensor may alternatively or additionally be determined. For example, using a capacitive proximity sensor, a distance between a capacitive plate in the sensor and the capacitive skin of the patient can be determined. An optical scanning proximity sensor can also determine a distance between the sensor and a patient measurement site. In another example, using a mechanical contact proximity sensor, it can be determined whether the patient measurement site has contacted the mechanical contact proximity sensor, such as by depressing a button.

[0069] At block **715**, the sensor determines whether it the patient measurement site is correctly positioned relative to the optical assembly based on the proximity sensor data. As discussed above, for capacitive proximity sensors the distance between the capacitive proximity sensor and the skin of the measurement site can be compared to a threshold or to a range of acceptable positions to determine whether the measurement site is correctly positioned. For a mechanical contact sensor producing a binary contact or no contact output, the correct positioning determination may be made based on the binary output.

[0070] If the measurement site is positioned correctly relative to the optical assembly, then the process **700** ends. If the measurement site is not positioned correctly relative to the optical assembly, then the process **700** transitions to block **720** in which the sensor mechanically repositions the optical assembly to achieve proper alignment with the measurement site. For example, capacitive sensing data can be used to determine a distance to mechanically move the optical assembly along the longitudinal axis of the sensor.

[0071] FIG. **8** illustrates an example process **800** for determining a probe off condition based on proximity sensing. The process **800** can be implemented by the components of any physiological sensor including proximity sensing capabilities, for example the physiological sensors illustrated in FIGS. **1**A-FIG. **4**. Some embodiments of process **800** can be implemented on an active pulse sensor capable of introducing an artificial pulse into a measurement site.

[0072] At block **805**, a physiological sensor is provided with at least one proximity sensor. For example, one proximity sensor or an array of proximity sensors can be provided including capacitive, optical, electrical, or mechanical proximity sensors, or a combination thereof. The proximity sensor can be configured to determine distance or contact between a measurement site and itself, and can be positioned within the sensor so as to provide feedback regarding alignment of the measurement site and optical components of the sensor.

[0073] At block **810**, the sensor optionally introduces an artificial pulse to the patient measurement site, such as a finger positioned within a pulse oximeter. As discussed above, the artificial pulse can assist in obtaining more reliable measurement data, however it can also cause movement of the sensor relative to the measurement site, thereby affecting proper positioning of the sensor on the measurement site.

[0074] At block **815**, the patient measurement site location is detected using the proximity sensor. As discussed above, in some embodiments of a finger clip pulse oximeter the sensor may be placed on a physical stop, and may be oriented to determine longitudinal displacement of the patient finger within the sensor relative to the optical assembly. In one example, using a capacitive proximity sensor, a distance between a capacitive plate in the sensor and the capacitive skin of the patient can be determined. An optical scanning proximity sensor can also determine a distance between the sensor and a patient measurement site. In another example, using a mechanical contact proximity sensor, it can be determined whether the patient measurement site has contacted the mechanical contact proximity sensor, such as by depressing a button.

[0075] At block **820**, the measurement site location can be compared to preferred positioning data to determine whether the oximeter is correctly applied to the measurement site. Preferred positioning data can be stored in memory of the oximeter, for example a read-only memory (ROM). The preferred positioning can include a range of placements relative to the optical components of the sensor that are likely to produce clinically accurate physiological measurements. In one embodiment, if a capacitive proximity sensor is used on a physical stop in a pulse oximeter finger clip sensor such as is depicted in FIGS. **2**A, **2**B, **3**A, or **3**B, a distance of approximately 4 mm-10 mm between the capacitive proximity sensor and the patient fingertip can correspond to proper positioning of an adult finger with respect to an LED emitter and detector. As an example, a distance of approximately 6 mm between the capacitive sensor and the fingertip can indicate preferred positioning of the finger within the sensor. As discussed above, other ranges can be used to indicate preferred placement in other sensor configurations, for other finger sizes, or for other measurement sites.

[0076] At block **825**, the sensor determines based on the comparison of block **810** whether the oximeter is correctly applied to the measurement site. If the sensor is not correctly applied, then the process **800** transitions to block **830** in which the sensor, for example a processor of the sensor or a processor of another device connected to and receiving data from the sensor, determines a probe off condition for discarding the data taken while the sensor was not correctly applied. In some embodiments, a default may be to determine a probe on condition for including data, and data may only be discarded when a probe off condition is determined for a time or range of times during which sensor data was gathered at improper positioning.

[0077] After determining the probe off condition at block **830**, or if the sensor is determined at block **825** to be correctly applied, the process **800** transitions to block **835** to determine whether measurement is continuing. If measurement continues, then the process **800** loops back to block **815** to determine the measurement site location and to repeat blocks **820** and **825**. Once measurement has concluded, for instance when the sensor is powered off or if the sensor detects that the patient measurement site is no longer at least partially within the sensor housing, then the process **800** ends.

V. Terminology

[0078] Although many of the examples discussed herein are in the context of pulse oximetry, this is for illustrative purposes only. The sensors, signal conditioning techniques, and proximity sensing applications discussed herein can be adapted for other physiological sensors monitoring other physiological parameters or multiple physiological parameters.

[0079] Many other variations than those described herein will be apparent from this disclosure. For example, depending on the embodiment, certain acts, events, or functions of any of the algorithms described herein can be performed in a different sequence, can be added, merged, or left out all together (e.g., not all described acts or events are necessary for the practice of the algorithms). Moreover, in certain embodiments, acts or events can be performed concurrently, e.g., through multi-threaded processing, interrupt processing, or multiple processors or processor cores or on other parallel architectures, rather than sequentially. In addition, different tasks or processes can be performed by different machines and/or computing systems that can function together.

[0080] The various illustrative logical blocks, modules, and algorithm steps described in connection with the embodiments disclosed herein can 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, 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. The described functionality can be implemented in varying ways for each particular application, but such implementation decisions should not be interpreted as causing a departure from the scope of the disclosure.

[0081] The various illustrative logical blocks and modules described in connection with the embodiments disclosed herein can be implemented or performed by a machine, such as 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 can be a microprocessor, but in the alternative, the processor can be a controller, microcontroller, or state machine, combinations of the same, or the like. A processor can 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. Although described herein primarily with respect to digital technology, a processor can also include primarily analog components. For example, any of the signal processing algorithms described herein can be implemented in analog circuitry. A computing environment can include any type of computer system, including, but not limited to, a computer system based on a microprocessor, a mainframe computer, a digital signal processor, a portable computing device, a personal organizer, a device controller, and a computational engine within an appliance, to name a few.

[0082] The steps of a method, process, or algorithm described in connection with the embodiments disclosed herein can be embodied directly in hardware, in a software module executed by a processor, or in a combination of the two. A software module can reside in RAM memory, flash memory, ROM memory, EPROM memory, EEPROM memory, registers, hard disk, a removable disk, a CD-ROM, or any other form of non-transitory computer-readable storage medium, media, or physical computer storage known in the art. An exemplary storage medium can be coupled to the processor such that the processor can read information from, and write information to, the storage medium. In the alternative, the storage medium can be integral to the processor. The processor and the storage medium can reside in an ASIC. The ASIC can reside in a user terminal. In the alternative, the processor and the storage medium can reside as discrete components in a user terminal.

[0083] Conditional language used herein, such as, among others, "can," "might," "may," "e.g.," and the like, unless specifically stated otherwise, or otherwise understood within the context as used, is generally intended to convey that certain embodiments include, while other embodiments do not include, certain features, elements and/or states. Thus, such conditional language is not generally intended to imply that features, elements and/or states are in any way required for one or more embodiments or that one or more embodiments necessarily include logic for deciding, with or without author input or prompting, whether these features, elements and/or states are included or are to be performed in any particular embodiment. The terms "comprising," "including," "having," and the like are synonymous and are used inclusively, in an open-ended fashion, and do not exclude additional elements, features, acts, operations, and so forth. Also, the term "or" is used in its inclusive sense (and not in its exclusive sense) so that when used, for example, to connect a list of elements, the term "or" means one, some, or all of the elements in the list.

[0084] Disjunctive language such as the phrase "at least one of X, Y, or Z," unless specifically stated otherwise, is otherwise understood with the context as used in general to present that an item, term, etc., may be either X, Y, or Z, or any combination thereof (e.g., X, Y, and/or Z). Thus, such disjunctive language is not generally intended to, and should not, imply that certain embodiments require at least one of X, at least one of Y, or at least one of Z to each be present.

[0085] Unless otherwise explicitly stated, articles such as "a" or "an" should generally be interpreted to include one or more described items. Accordingly, phrases such as "a device configured to" are intended to include one or more recited devices. Such one or more recited devices can also be collectively configured to carry out the stated recitations. For example, "a processor configured to carry out recitations A, B and C" can include a first processor configured to carry out recitation A working in conjunction with a second processor configured to carry out recitations B and C.

[0086] While the above detailed description has shown, described, and pointed out novel features as applied to various embodiments, it will be understood that various omissions, substitutions, and changes in the form and details of the devices or algorithms illustrated can be made without departing from the spirit of the disclosure. As will be recognized, certain embodiments of the inventions described herein can be embodied within a form that does not provide all of the features and benefits set forth herein, as some features can be used or practiced separately from others. It should be emphasized that many variations and modifications may be made to the above-described embodiments, the elements of which are to be understood as being among other acceptable examples. All such modifications and variations are intended to be included herein within the scope of this disclosure and protected by the following claims.

What is claimed is:

1. A physiological monitoring system comprising:

a sensor housing configured to at least accept a measurement site of a patient, the sensor housing comprising:

a first housing component including an emitter configured to at least emit light at one or more wavelengths when in use,

a second housing component including a detector aligned with the emitter to detect at least a portion of the light, the detector configured to at least generate intensity signals representing detected light when in use, and

a proximity sensor positioned on one or both of the first housing and the second housing; and

a processor configured to at least:

receive data from the proximity sensor representing positioning of the measurement site relative to the proximity sensor, and

based at least partly on the data from the proximity sensor, determine positioning of the measurement site relative to the emitter and the detector.

2. The system of claim **1**, wherein the proximity sensor comprises a capacitor.

3. The system of claim **1**, the second housing component comprising a physical stop positioned to contact the measurement site when inserted into the sensor housing and configured to assist in positioning the measurement site relative to the detector.

4. The system of claim **3**, wherein the proximity sensor is located along a surface of the physical stop.

5. The system of claim **1**, the second housing component comprising a finger bed including a generally curved surface shaped generally to receive the measurement site, the finger bed including an aperture over the detector.

6. The system of claim **5**, further comprising a plurality of proximity sensors positioned in an array along a longitudinal axis of the finger bed.

7. The system of claim **1**, wherein the proximity sensor comprises one or more of an optical, mechanical, or electrical sensor configured to interface with skin of a measurement site.

8. The system of claim **1**, further comprising a processor configured to:

determine improper alignment of the measurement site and detector based at least partly on the data from the proximity sensor; and

generate a repositioning signal indicating that the measurement site should be repositioned within the sensor housing.

9. The system of claim **8**, further comprising a positioning feedback indicator configured to receive the repositioning indication and output positioning feedback to a user of the system.

10. The system of claim **8**, further comprising a repositioning module configured to receive the repositioning signal and to reposition one or both of the emitter and detector based at least partly on the repositioning signal.

11. A physiological monitoring method comprising:

providing a physiological sensor housing configured to accept a measurement site of a patient, the sensor housing including an optical assembly and a proximity sensor;

detecting a location of the measurement site relative to the proximity sensor; and

based at least partly on the location of the measurement site, determining positioning of the measurement site relative to the optical assembly.

12. The method of claim **11**, further comprising generating capacitive sensor data representing a distance between the measurement site and the proximity sensor.

13. The method of claim **12**, wherein determining positioning of the measurement site relative to the optical assembly is based at least partly on the distance between the measurement site and the proximity sensor.

14. The method of claim **11**, further comprising generating a repositioning indication based at least partly on the positioning of the measurement site relative to the optical assembly.

15. The method of claim **14**, further comprising mechanically repositioning the optical assembly relative to the measurement site based at least partly on the repositioning feedback.

16. The method of claim **14**, further comprising generating repositioning feedback based at least partly on the positioning of the measurement site relative to the optical assembly and the repositioning indication.

17. The method of claim **16**, further comprising outputting the repositioning feedback to a user of the physiological sensor housing for assistance in manually repositioning of the measurement site within the physiological sensor.

18. The method of claim **16**, further comprising mechanically repositioning the optical assembly relative to the measurement site based at least partly on the repositioning feedback.

19. The method of claim **11**, further comprising comparing the positioning of the measurement site relative to the optical assembly to a preferred positioning.

20. The method of claim **19**, further comprising determining improper alignment based at least partly on comparing the positioning of the measurement site relative to the optical assembly to the preferred positioning.

21. The method of claim **20**, further comprising determining a probe off condition based on the improper alignment.

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专利名称(译)	脉搏血氧仪中的接近传感器		
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摘要(译)

公开了用于生理传感器中的接近感测的系统和方法，并且更具体地，公开了使用位于生理传感器上或内的一个或多个接近传感器来确定生理传感器在患者测量部位上的定位。在患者测量部位上准确放置生理传感器是获得患者生理参数的可靠测量的关键因素。测量位置和传感器光学组件之间的适当对准提供了更准确的生理测量数据。可以基于来自接近传感器或放置在生理传感器上或内部的传感器的数据来确定该对准。