US 20200000349A1

(19) United States
(12) Patent Application Publication
LIN et al.
(10) Pub. No.: US 2020/0000349 A1
(43) Pub. Date: Jan. 2, 2020

(54) **PULSE DETECTION MODULE AND USE-AS-YOU-NEED BLOOD PRESSURE MEASUREMENT DEVICE COMPRISING THE SAME**

(71) Applicants: **Shiming LIN**, Taipei (TW); **BIV MEDICAL, LTD.**, Caotun Township, Nantou County (TW)

(72) Inventors: **Shiming LIN**, Taipei (TW); **Shih-Wei CHIANG**, Taipei (TW); **Cheng-Yan GUO**, Taipei (TW); **Tai-Cun LIN**, Taipei (TW); **Wei-Chih HUANG**, Taipei (TW); **Chun-Nan CHEN**, Taipei (TW); **Ya-Ting CHANG**, Taipei (TW)

(21) Appl. No.: **16/465,446**

(22) PCT Filed: **Nov. 30, 2017**

(86) PCT No.: **PCT/CN2017/113920**

§ 371 (c)(1),
(2) Date: **May 30, 2019**

Related U.S. Application Data

(60) Provisional application No. 62/497,740, filed on Dec. 1, 2016, provisional application No. 62/497,741, filed on Dec. 1, 2016, provisional application No. 62/498,991, filed on Jan. 13, 2017, provisional application No. 62/604,137, filed on Jun. 26, 2017.

Publication Classification

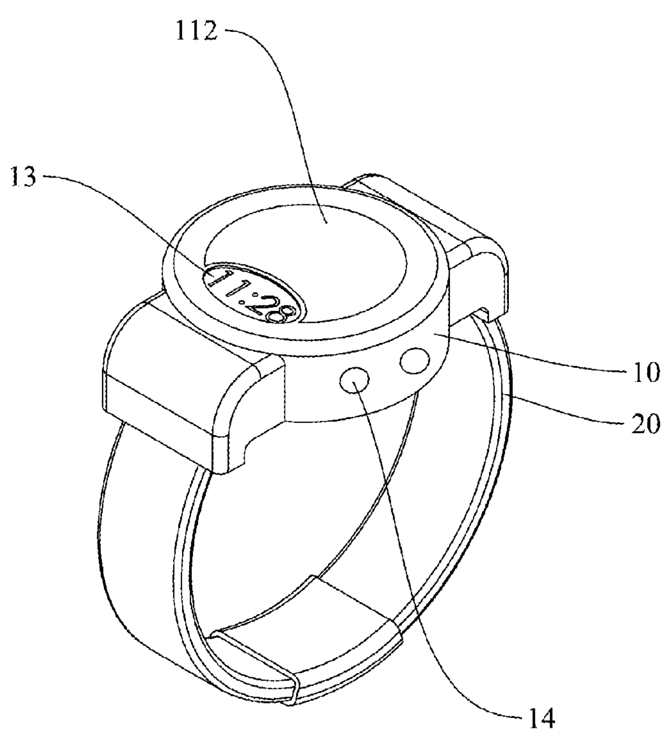
(51) **Int. Cl.**
A61B 5/021 (2006.01)
A61B 5/00 (2006.01)

(52) **U.S. Cl.**
CPC ***A61B 5/02108*** (2013.01); *A61B 5/02225* (2013.01); ***A61B 5/681*** (2013.01)

(57) **ABSTRACT**

The present invention provides a pulse detection module and a use-as-you-need blood pressure measurement device comprising the pulse detection module. The pulse detection module is characterized by comprising a plurality of sensors and a controller linked to the sensors, wherein the sensors are arranged horizontally on the wrist watch in a direction parallel to a user's limb on which the wrist watch is worn, and the controller obtains the user's pulse signals through the sensors.

100



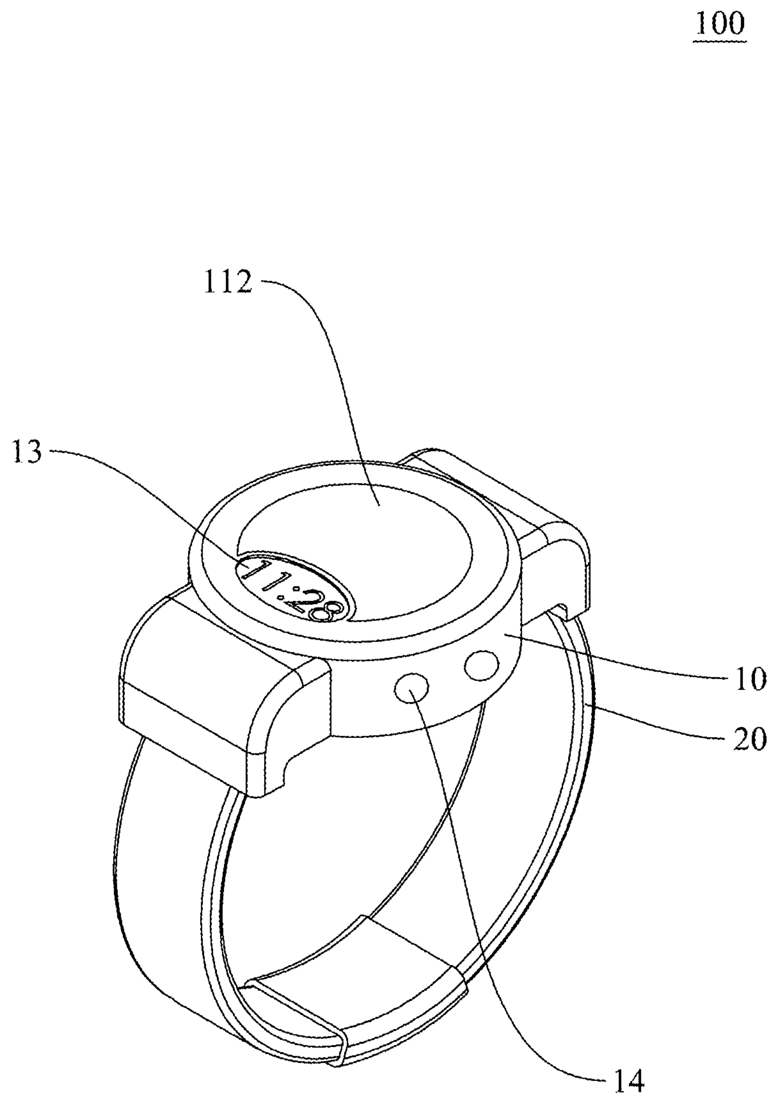


Fig.1

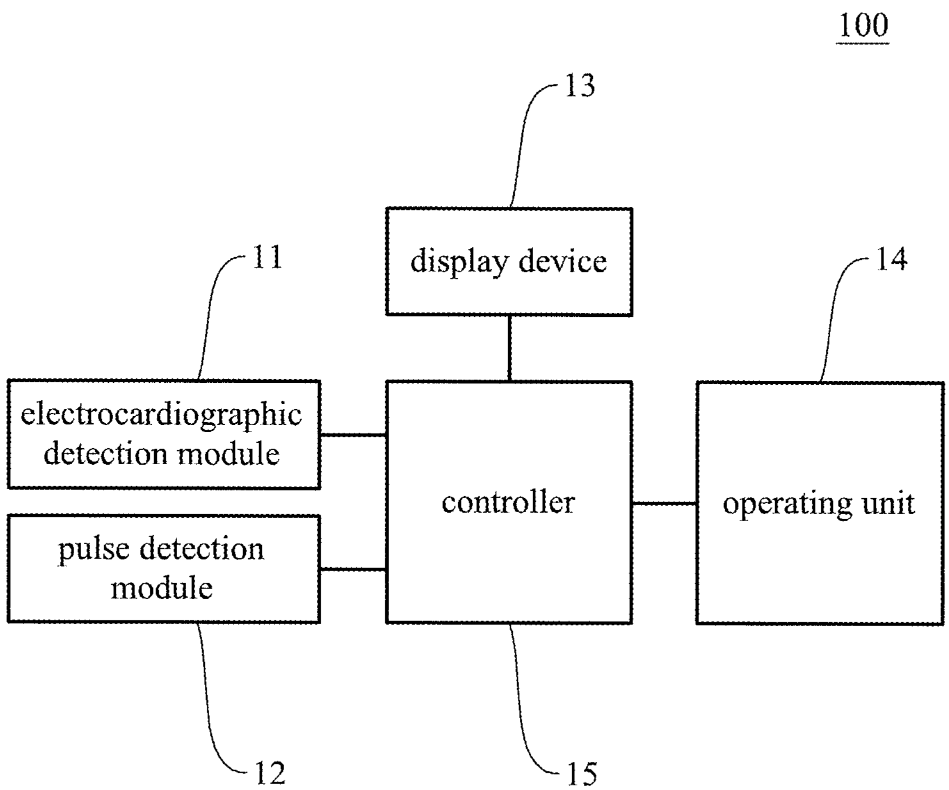

100
13
display device
11
14
electrocardiographic detection module
controller
operating unit
pulse detection module
12
15

Fig.2

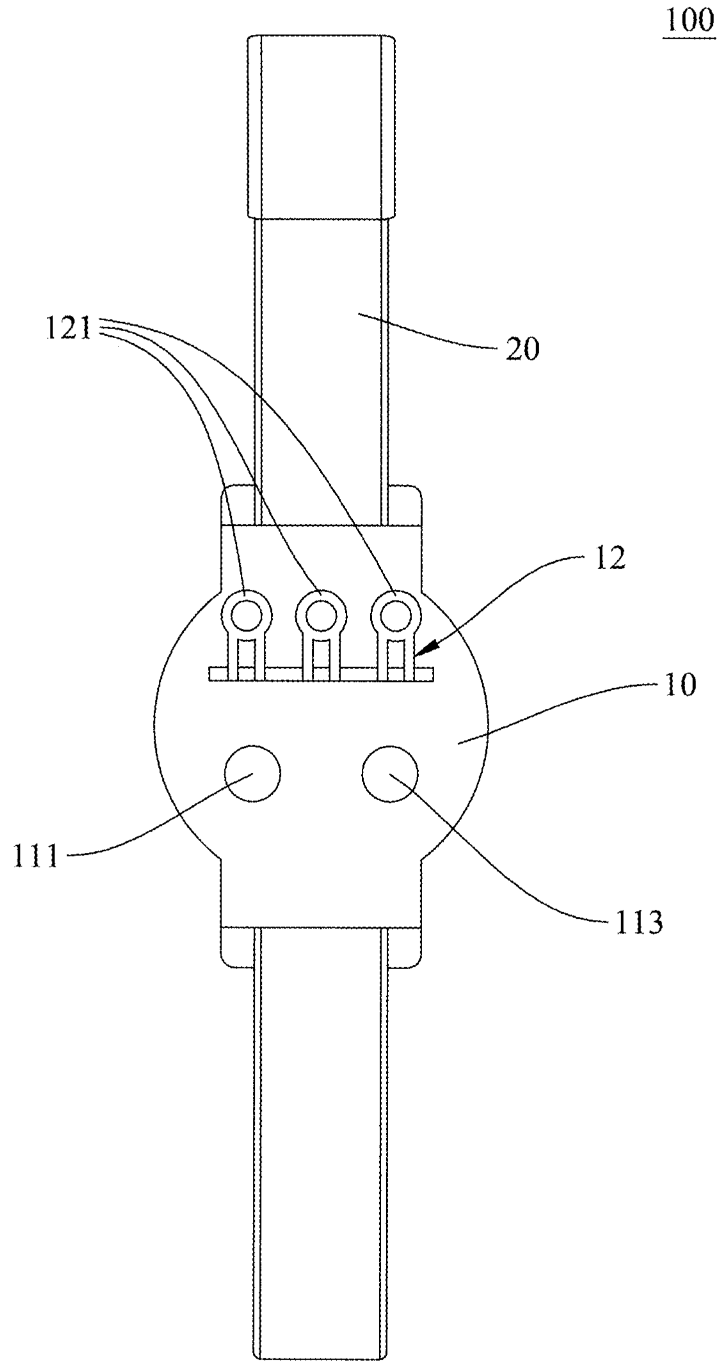


Fig.3

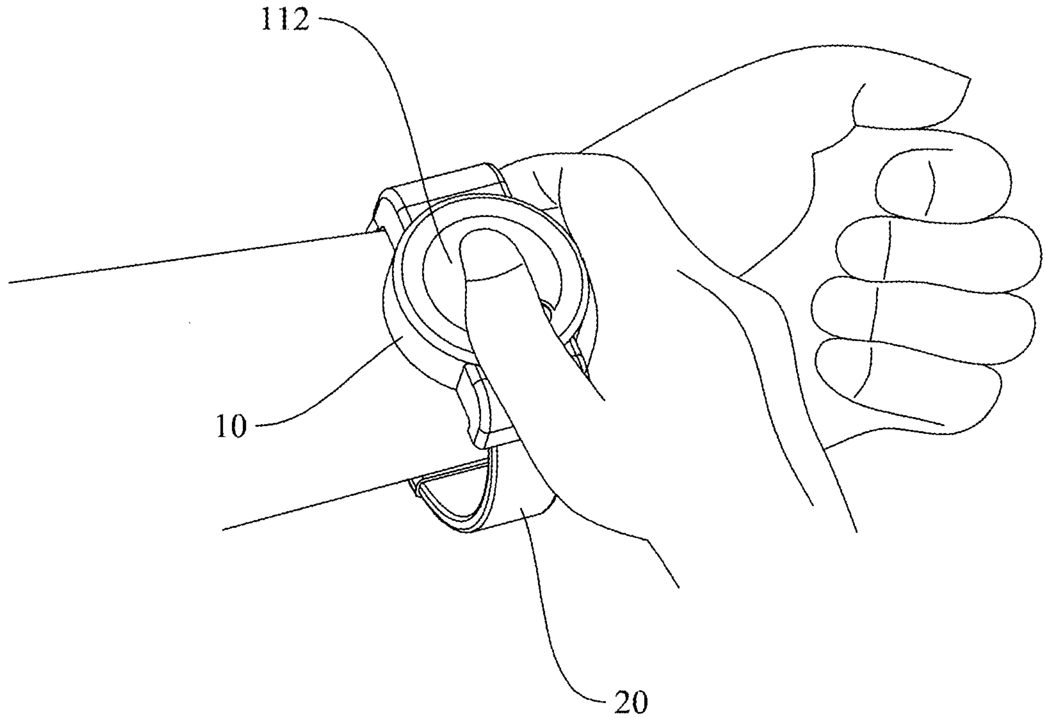


Fig.4

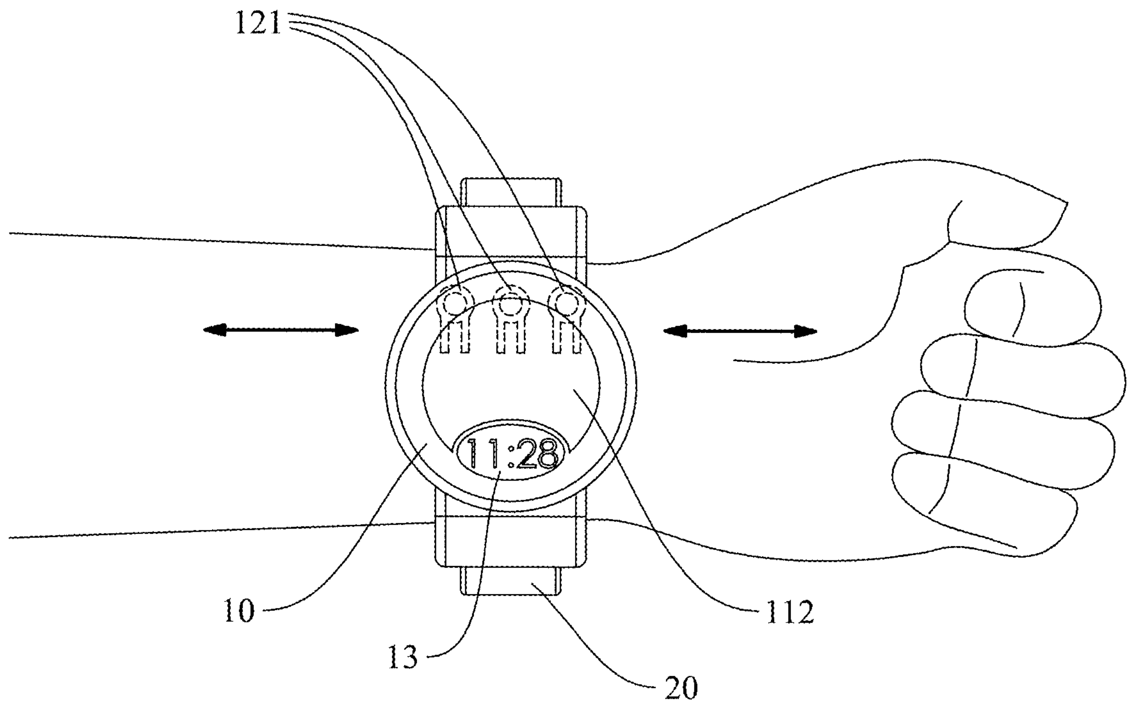


Fig.5

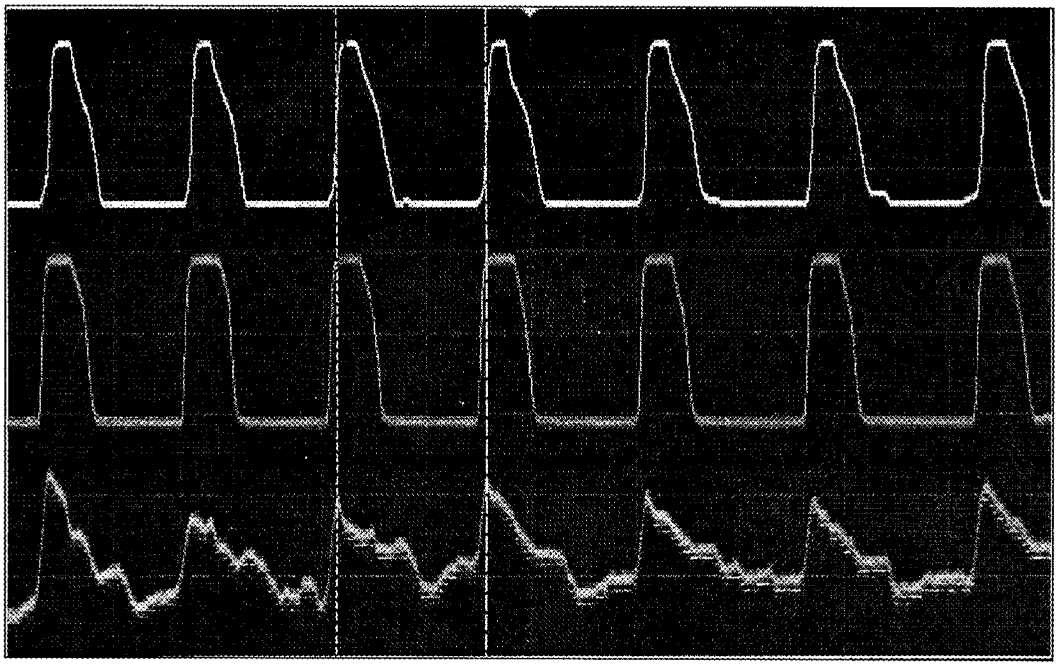


Fig.6

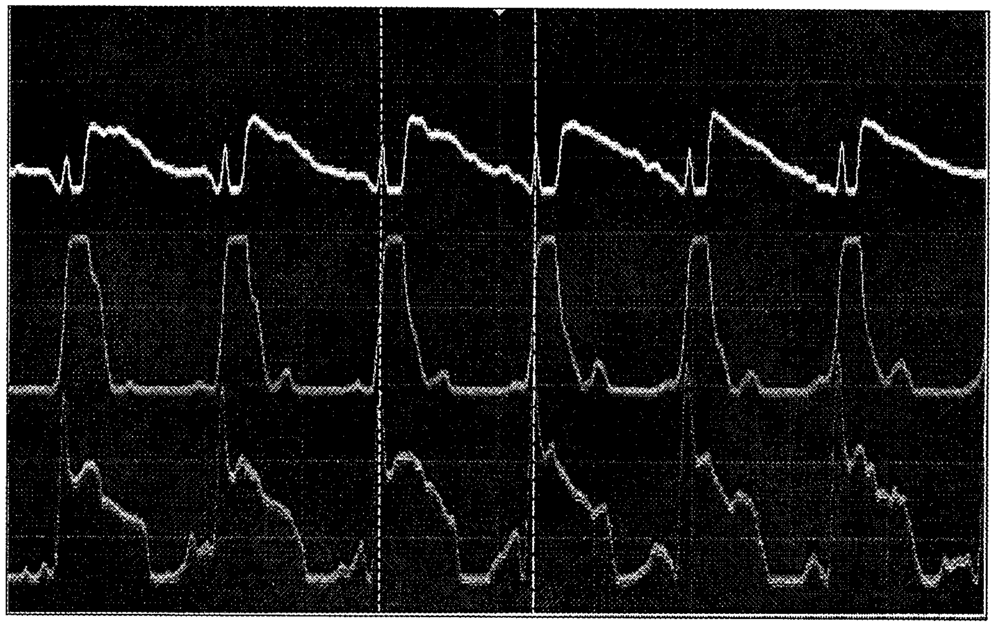


Fig.7

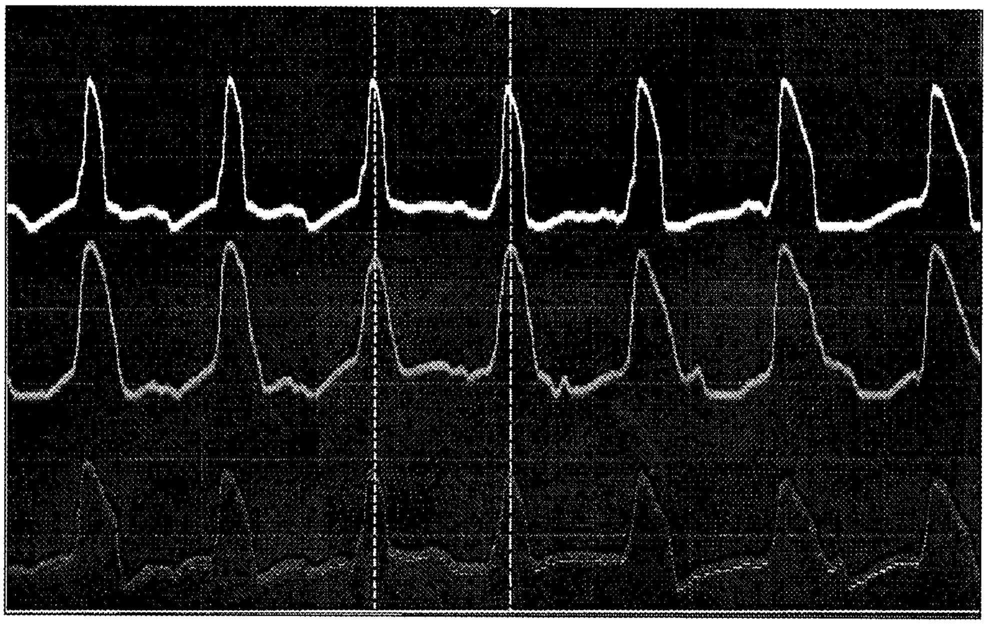


Fig.8

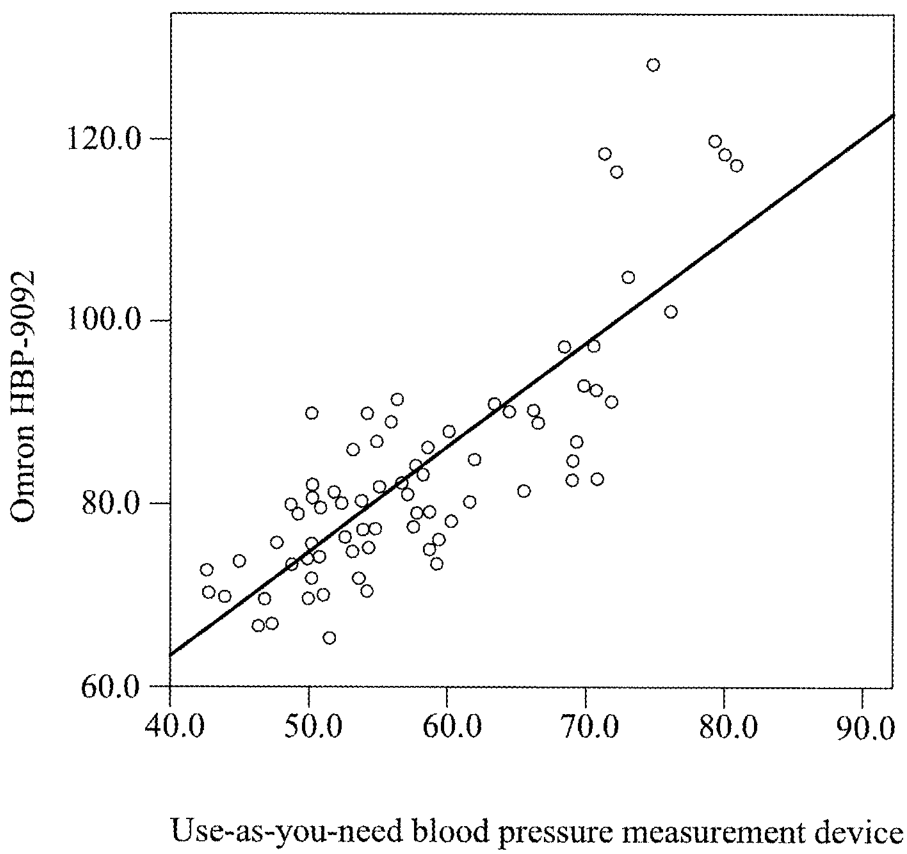

Omron HBP-9092
120.0
100.0
80.0
60.0
40.0
50.0
60.0
70.0
80.0
90.0
Use-as-you-need blood pressure measurement device

Fig.9

PULSE DETECTION MODULE AND USE-AS-YOU-NEED BLOOD PRESSURE MEASUREMENT DEVICE COMPRISING THE SAME

BACKGROUND OF THE INVENTION

1. Technical Field

[0001] The present invention relates to a pulse detection module and a use-as-you-need blood pressure measurement device comprising the pulse detection module. More particularly, the invention relates to a pulse detection module that can detect a user's pulse when located at any of a plurality of positions and a use-as-you-need blood pressure measurement device comprising the pulse detection module.

2. Description of Related Art

[0002] There are two major blood pressure measurement methods in the prior art: (A) the oscillometric method, which uses an oscilloscope to display pulse amplitudes; and (B) the Riva-Rocci/Korotkov method, which uses a mercury sphygmomanometer for sound analysis. Both methods require the brachial artery in the arm (or the radial artery in the wrist) to be compressed until complete occlusion occurs (i.e., when blood flow in the artery is stopped). This occlusion technique, however, not only tends to cause discomfort to the upper (or lower) limb being measured, but also is unsuitable for those with irregular heart beat and seniors (aged 50 to 80) who have mobility difficulties. It is therefore imperative to improve the conventional technique and supply the global medical product market with blood measuring products that are suitable for the aforementioned users.

BRIEF SUMMARY OF THE INVENTION

[0003] In view of the above, the inventor of the present invention developed a blood pressure monitoring technique and an innovative wearable medical sensing device that are both non-invasive and non-occlusive. A product embodying the invention can effectively detect a user's pulse signals and electrocardiographic signals and calculate the user's mean arterial pressure, systolic pressure, and diastolic pressure in real time according to the pulse signals and electrocardiographic signals detected.

[0004] In addition to the aforesaid features, a pulse detection module according to the present invention can effectively avoid loss of pulse data and inaccurate calculation that may otherwise result from the sensors being shifted away from the user's radial artery during real-time measurement.

[0005] In order to achieve the above objective, the present invention provides a pulse detection module, provided on a wrist watch. The pulse detection module is characterized by comprising a plurality of sensors and a controller linked to the sensors, wherein the sensors are arranged horizontally on the wrist watch in a direction parallel to a user's limb on which the wrist watch is worn, and the controller obtains the user's pulse signals through the sensors.

[0006] Furthermore, the sensors are piezoelectric sensors, Doppler radars, impedance pressure sensors, capacitance pressure sensors, acoustic wave sensors, ultrasonic sensors, or photoplethysmographic (PPG) devices.

[0007] Furthermore, the controller is connected to each of the sensors in order to obtain the pulse signals received by each sensor, and chooses the suitable wave peaks or valleys from the pulse signals as the correct pulse signals.

[0008] Another objective of the present invention is to provide a use-as-you-need blood pressure measurement device, comprising a watch case assembly and a watch band attached to the watch case assembly, wherein the watch case assembly comprises an electrocardiographic detection module provided on the watch case assembly to obtain a user's electrocardiographic signals, a pulse detection module provided on the watch case assembly and comprising a plurality of sensors provided on a backside of the watch case assembly, wherein the sensors are arranged horizontally in a direction parallel to the user's limb on which the use-as-you-need blood pressure measurement device is worn, in order to obtain the user's pulse signals, and a controller for obtaining the user's electrocardiographic signals through the electrocardiographic detection module and calculating the user's mean arterial pressure according to the electrocardiographic signals and the pulse signals.

[0009] Furthermore, the sensors are piezoelectric sensors, Doppler radars, impedance pressure sensors, capacitance pressure sensors, acoustic wave sensors, ultrasonic sensors, or photoplethysmographic (PPG) devices.

[0010] Furthermore, the controller is connected to each of the sensors in order to obtain the pulse signals received by each sensor, and chooses the suitable wave peaks or valleys from the pulse signals as the correct pulse signals.

[0011] Furthermore, the electrocardiographic detection module includes a first electrode and a second electrode. The first electrode is provided on the side of the watch case assembly that is adjacent to a user's limb on which the use-as-you-need blood pressure measurement device is worn, the objective being for the first electrode to lie on the user's skin during use, and the second electrode is also provided on the watch case assembly in order to be touched by a limb of the user that is on the opposite side of the body. A user's electrocardiographic signals are derived from the variation of electric potential between the first electrode and the second electrode.

[0012] Furthermore, the electrocardiographic detection module comprises a grounding electrode provided on a side of the watch case assembly that is adjacent to the user's limb in order for the grounding electrode to lie on a surface of the user's limb, and the controller is connected to the grounding electrode and uses an electric potential of the grounding electrode as a reference electric potential.

[0013] Furthermore, mean arterial pressure can be obtained by the following equation (I):

$$\text{mean arterial pressure } (MAP) = a\left(\frac{l_p}{t_{pa}} \times c\right) + b, \qquad \text{equation (I)}$$

where l_p is the length of the path along which a pulse propagates in an artery; t_{pa} is the pulse arrival time; and a, b, and c are correction parameters.

[0014] Furthermore, mean arterial pressure is obtained by equation (II):

$$\text{mean arterial pressure } (MAP) = A\left(\frac{l_p}{t_{pa}} \times C\right)^2 + B, \qquad \text{equation (II)}$$

where l_p is the length of the path along which a pulse propagates in an artery; t_{pa} is the pulse arrival time; and A, B, and C are correction parameters.

[0015] Furthermore, the display device is provided on the watch face of the watch case assembly and is connected to the controller in order to display a user's physiological data.

[0016] Furthermore, the second electrode is provided on the watch face of the watch case assembly, so a user wearing the use-as-you-need blood pressure measurement device on one wrist can press at the second electrode with a finger of the opposite hand.

[0017] A pulse detection module according to the present invention includes a plurality of piezoelectric sensors that are arranged in a direction parallel to a user's limb. Therefore, even if a wearable device (e.g., a wrist watch) provided with the pulse detection module is shifted away from its most desirable position on the wrist, at least one of the sensors can still detect the user's pulse and pulse waves to ensure completeness and continuity of the detection data. Moreover, the present invention provides a use-as-you-need blood pressure measurement device whose non-invasive and non-occlusive medical sensing technique/algorithm makes it possible to measure a user's mean arterial pressure, systolic pressure, diastolic pressure, and pulse (all of which are helpful in diagnosing heart rhythm irregularities) in real time without affecting the user's daily life.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

[0018] FIG. **1** is a perspective view of a use-as-you-need blood pressure measurement device according to the present invention.

[0019] FIG. **2** is a block diagram of a use-as-you-need blood pressure measurement device according to the present invention.

[0020] FIG. **3** is a rear view of a use-as-you-need blood pressure measurement device according to the present invention.

[0021] FIG. **4** is a state (I) of use of a use-as-you-need blood pressure measurement device according to the present invention.

[0022] FIG. **5** is a state (II) of use of a use-as-you-need blood pressure measurement device according to the present invention.

[0023] FIG. **6** is a group (I) of waveforms generated by three piezoelectric sensors.

[0024] FIG. **7** is a group (II) of waveforms generated by three piezoelectric sensors.

[0025] FIG. **8** is a group (III) of waveforms generated by three piezoelectric sensors.

[0026] FIG. **9** is a plot showing the test result of correlation between the present invention and a commercially available product.

DETAILED DESCRIPTION OF THE INVENTION

[0027] The details and technical solution of the present invention are hereunder described with reference to accompanying drawings. For illustrative sake, the accompanying drawings are not drawn to scale. The accompanying drawings and the scale thereof are not restrictive of the present invention.

[0028] Throughout the whole document, the terms "comprises or includes" and/or "comprising or including" used in the document mean that one or more other components, steps, operations, and/or the existence or addition of elements are not excluded in addition to the described components, steps, operations and/or elements. The terms "about or close to" or "substantially" mean a value or range that is close to the allowable specified error to avoid any unreasonable use by third parties, illegal or unfair use, to understand the precise or absolute value disclosed herein. The terms "a" and "an" refer to one or to more than one (i.e., to at least one) of the grammatical object of the article.

[0029] Please refer to FIG. **1** for a perspective view of a use-as-you-need blood pressure measurement device according to the present invention.

[0030] The present invention provides a use-as-you-need blood pressure measurement device **100** as shown in FIG. **1**. The blood pressure measurement device **100** measures a user's mean arterial pressure by detecting the pulse wave velocity of the aorta from the left ventricle (via an electrocardiographic (ECG) sensor) and the pulse signals of the radial artery (via a plurality of piezoelectric sensors) and then calculates the user's systolic pressure and diastolic pressure according to the mean arterial pressure. After repeated validation of the foregoing technical concept, the applicant has successfully designed and manufactured a wearable blood pressure sensing device for use by seniors aged 50 to 85 as disclosed herein, and has performed a correlation analysis on the measurement results of the wearable blood pressure sensing device and of a commercially available product. Apart from calculating blood pressure, the use-as-you-need blood pressure measurement device **100** of the present invention can measure mean arterial pressure and heart rate by means of a non-invasive and non-occlusive medical sensing technique/algorithm, thereby facilitating the diagnosis of heart rhythm irregularities.

[0031] All the modules and electronic components in the present invention can be disposed on a circuit board in order to be electrically connected with, and transmit signals to and from, one another through the circuits on the circuit board. While such a circuit board is not shown in the accompanying drawings, a person of ordinary skill in the art who has read the present disclosure will know how to construct the use-as-you-need blood pressure measurement device **100** of the invention from an arbitrary number of circuit boards.

[0032] The structural details (and their functions) of the use-as-you-need blood pressure measurement device of the present invention will be described below with reference to FIG. **2**, FIG. **3**, FIG. **4**, and FIG. **5**, which show a block diagram, a rear view, and two states of use of the use-as-you-need blood pressure measurement device respectively.

[0033] As shown in the drawings, the use-as-you-need blood pressure measurement device **100** includes a watch case assembly **10** and a watch band **20** attached to the watch case assembly **10**. The watch band **20** is connected to the watch case assembly **10** in a detachable manner so as to be replaceable when needed.

[0034] The watch case assembly **10** includes an electrocardiographic detection module **11**, a pulse detection module **12**, a display device **13**, at least one operating unit **14**, and a controller **15**. The electrocardiographic detection module **11** is configured to obtain a user's electrocardiographic signals, and the pulse detection module **12** is configured to obtain the user's pulse signals. The electrocardiographic detection module **11** and the pulse detection module **12** may be controlled by the same controller **15** or be driven to execute their respective algorithms by different controllers respectively; the present invention has no limitation in this regard.

[0035] The electrocardiographic detection module **11** includes a first electrode **111**, a second electrode **112**, and a grounding electrode **113**. The controller **15** is directly connected or is coupled to the first electrode **111**, the second electrode **112**, and the grounding electrode **113** in order to derive a user's electrocardiographic signals from the variation of electric potential between the first electrode **111** and the second electrode **112** while using the electric potential of the grounding electrode **113** as the reference electric potential.

[0036] The first electrode **111** and the grounding electrode **113** are provided on the side of the watch case assembly **10** that is adjacent to a user's limb on which the use-as-you-need blood pressure measurement device **100** is worn, the objective being for the two electrodes to lie on the user's skin during use, and the second electrode **112** is also provided on the watch case assembly **10** in order to be touched by a limb of the user that is on the opposite side of the body. In one preferred embodiment as shown in FIG. **4**, the second electrode **112** is provided on the watch face of the watch case assembly **10**, so a user wearing the use-as-you-need blood pressure measurement device **100** on one wrist can press at the second electrode **112** with a finger of the opposite hand, thereby allowing the controller **15** to obtain the user's electrocardiographic signals.

[0037] The pulse detection module **12** includes a plurality of sensors **121**. The controller **15** is directly connected or is coupled to the sensors **121**. Preferably, the sensors **121** are piezoelectric sensors, Doppler radars, impedance pressure sensors, capacitance pressure sensors, acoustic wave sensors, ultrasonic sensors, or photoplethysmographic (PPG) devices. While there are three sensors **121** in the embodiment shown in FIG. **3**, the number of the sensors **121** may vary, depending on the volume of the watch case assembly **10**, the area of each sensor **121**, or the average circumference of a user's wrist. For example, 2, 3, 4, 5, 6, or more sensors **121** may be used to meet practical needs; the present invention has no limitation in this regard. The sensors **121** are arranged horizontally on the watch case assembly **10** (e.g., of a wrist watch embodying the use-as-you-need blood pressure measurement device **100**) in a direction parallel to a user's limb on which the wrist watch is worn. The phrase "arranged horizontally . . . in a direction parallel to a user's limb on which the wrist watch is worn" means that the sensors **121** are arranged along a straight line on the backside of the watch case assembly **10**, and that the direction in which the sensors **121** are arranged is parallel to the user's limb (e.g., forearm) on which the wrist watch is worn. In this embodiment, in which the use-as-you-need blood pressure measurement device **100** is in the form of a wrist watch, the sensors **121** are perpendicular to the watch band **20** of the wrist watch; therefore, even if the watch band **20** is shifted in position on the user's wrist, the controller **15** can still obtain the user's pulse signals through at least one of the sensors **121** that remains at the intended sensing position.

[0038] Please refer to FIG. **6**, FIG. **7**, and FIG. **8** for three groups of waveforms, wherein each group of waveforms are generated by three piezoelectric sensors respectively. In the preferred embodiment illustrated herein, the controller **15** is connected to each of the sensors **121** in order to obtain the pulse signals received by each sensor **121**. As there are three sensors **121** in this embodiment, the controller **15** will receive three pulse signals as those shown in each of FIG. **6**, FIG. **7**, and FIG. **8**. The controller **15** will choose the suitable wave peaks or valleys from the three pulse signals as the correct pulse signals and then either derive the heart rhythm from the pulse signals or calculate blood pressure parameters according to the pulse signals in conjunction with the electrocardiographic signals. The term "suitable wave peaks or valleys" refers to pulse signals whose wave peaks or valleys have significant peak/valley values that can be sampled within an extremely short period of time.

[0039] The following paragraphs describe tests in which three piezoelectric sensors are used as the sensors **121**. The three piezoelectric sensors obtain a user's pulse signals separately and generate the waveforms in FIG. **6**, FIG. **7**, and FIG. **8**. An algorithm suitable for use in the present invention is also described below with reference to the waveforms.

[0040] In FIG. **6**, both the first signal (at the top of the graph) and the second signal (in the middle of the graph) have delayed wave peak values, making it impossible to measure the time points at which the wave peaks occur respectively; that is to say, the first signal and the second signal cannot be used in blood pressure measurement. In contrast to the first and the second signals, the exact positions of the vertical projections of the wave peaks of the third signal (at the bottom of the graph) on the time axis can be clearly measured.

[0041] In FIG. **7**, the first signal (at the top of the graph), whose corresponding sensor **121** is out of position, fails to reach the threshold value and hence cannot be sampled by the controller **15**. The second signal (in the middle of the graph) is delayed, so the time points at which its wave peaks occur respectively cannot be measured. Both the first signal and the second signal, therefore, cannot be used in blood pressure measurement. In contrast to the first and the second signals, the exact positions of the vertical projections of the wave peaks of the third signal (at the bottom of the graph) on the time axis can be clearly measured.

[0042] In FIG. **8**, the exact positions of the vertical projections of the wave peaks of all the three signals at the top, in the middle, and at the bottom of the graph can be clearly measured.

[0043] It is worth mentioning that, although it is difficult to determine the trigger times of the first and the second signals in FIG. **6** and FIG. **7** according to the sampled values of those signals, one preferred embodiment includes taking the positions of the vertical projections of the trigger edges on the time axis as reference values for use in calculating the user's blood pressure.

[0044] In one preferred embodiment, the controller **15** is configured to sample all the pulse signals one after another and, upon determining that the wave peaks or valleys of a pulse signal cannot be sampled, goes on to sample the pulse signal of another sensor **121**. In another preferred embodiment, the controller **15** can sample multiple pulse signals by the time-division multiplexing method and find pulse signals with the highest signal integrity or reliability as the correct pulse signals. The present invention, however, has no limitation on the sampling method of the controller **15**.

[0045] The display device **13** is provided on the watch face of the watch case assembly **10** and is connected to the controller **15** in order to display a user's physiological data, such as a user's blood pressure data, heart rhythm data, or the like. In addition to displaying the aforesaid data, the display device **13** may provide a control interface or graphical user interface (GUI) whereby a user can operate or set the use-as-you-need blood pressure measurement device **100**; the present invention has no limitation in this regard. The display device **13** may be an organic light-emitting diode (OLED) display panel, an in-plane switching (IPS) liquid crystal display panel, a low-temperature poly-silicon (LTPS) display panel, an indium gallium zinc oxide (IGZO) display panel, a vertical alignment (VA) liquid crystal display panel, a quantum dot display panel, or electronic paper (epaper). In one preferred embodiment, the display device **13** is a touch panel. The present invention has no limitation on the type of the display device **13**.

[0046] The at least one operating unit **14**, which may be provided on one side or two sides of the watch case assembly **10**, is connected to the controller **15** and serves as a user input interface. For example, the at least one operating unit **14** may be at least one physical button, a touch panel, at least one knob, or other similar input units; the present invention has no limitation in this regard.

[0047] The controller **15** may be a central processing unit (CPU), a programmable general-purpose or special-purpose microprocessor, a digital signal processor (DSP), a programmable controller, an application-specific integrated circuit (ASIC), other similar devices, or a combination of the above. In one preferred embodiment, and by way of example only, the controller **15** and a storage unit form a co-constructed processor. The controller **15** is directly connected or is coupled to the electrocardiographic detection module **11** and the pulse detection module **12** in order to obtain a user's electrocardiographic signals and pulse signals and then calculate the user's mean arterial pressure (MAP) from the electrocardiographic signals and pulse signals, as detailed below.

[0048] The processor **15** in the present invention determines blood pressure values according to the relationship between pressure and pulse wave velocity (PWV). In each cardiac cycle, a pressure pulse is generated by contraction of the left ventricle and propagates through the arteries to the peripheral vascular system. The pulse wave velocity in an artery depends on the stiffness of the artery and can be expressed by equation (a):

$$PWV = \sqrt{\left(\frac{V}{\rho}\right)\left(\frac{dP}{dV}\right)}, \qquad \text{equation (a)}$$

where ρ is blood density. The stiffness of an artery is associated with the transmural pressure across the artery wall, and this pressure is a function of the geometry of the blood vessel and the viscoelasticity of the blood vessel wall. As the pressure acting on an artery wall from outside the artery is typically negligible, the transmural pressure across the artery wall is equal to the blood pressure in the artery. The stiffness and pulse wave velocity of an artery, therefore, are a function of the blood pressure in the artery. Correlation between the pulse wave velocity and blood pressure in an artery forms the basis of non-invasive blood pressure measurement. In particular, pulse wave velocity has the strongest correlation to diastolic pressure and mean arterial pressure, as can be expressed by equation (b):

$$\text{PWV}=fcn(\text{MAP}) \qquad \text{equation (b).}$$

[0049] The relationship between pulse wave velocity and mean arterial pressure can be accurately described by the following linear model equation (c):

$$\text{PWV}(t)=a\cdot\text{MAP}(t)+\text{pwv}_0 \qquad \text{equation (c),}$$

where the slope a and the constant pwv_0 are user-specific parameters. To trace a patient's pulse pressure and velocity, the present invention uses the electrocardiographic detection module **11** and the pulse detection module **12** to monitor a known parameter, i.e., the pulse arrival time (PAT). Each pulse arrival time measurement is in fact the sum of two different periods of time, namely the vascular transit time (VTT) and the pre-ejection period (PEP). The vascular transit time is the time for which a pressure pulse travels along an arterial path. The pre-ejection period is the time interval between two adjacent peaks of a composite wave, or the interval at which the aortic valve opens, and includes electromechanical delay and isovolumic contraction. The pulse arrival time can be expressed by equation (d):

$$PAT = VTT + PEP + \left(\frac{L_t}{PWV}\right) + PEP, \qquad \text{equation (d)}$$

where the parameter L is the length of the path along which a pressure pulse propagates in an artery.

[0050] Assuming the pre-ejection period is constant while monitoring takes place, a change in the pulse arrival time directly results in a change in the vascular transit time, and these two parameters are associated with variation of the mean arterial pressure. To establish the relationship between pulse arrival time and mean arterial pressure and the linear relationship between mean arterial pressure and pulse wave velocity, it behaves as if equation (b) must be abstracted and defined in measuring the pulse delay time at the individual measurement pulse arrival time, as expressed by equation (e):

$$PAT = \left(\frac{L_t}{PWV}\right) = \left(\frac{L_t}{aMAP + pwv_0}\right). \qquad \text{equation (e)}$$

[0051] While estimating the mean arterial pressure, any error in the pulse arrival time will render the unknown constant pwv_0 inaccurate, but this can be corrected by tracing the variation of pulse arrival time and of mean arterial pressure over time. And by doing so, the estimation error of mean arterial pressure, which is multiplied by the unknown slope a, will also be minimized. The present invention introduces correction parameters into the foregoing equations to produce an algorithm for calculating mean arterial pressure and reducing possible deviation.

[0052] In one preferred embodiment, mean arterial pressure can be obtained by the following equation (I):

$$\text{mean arterial pressure } (MAP) = a\left(\frac{l_p}{t_{pa}} \times c\right) + b, \quad \text{equation (I)}$$

where l_p is the length of the path along which a pulse propagates in an artery; t_{pa} is the pulse arrival time; and a, b, and c are correction parameters. The correction parameters are derived from a target subject database to provide necessary adjustment to the algorithm. In one preferred embodiment, the correction parameter a ranges from 0.01 to 0.15 and may be, but is not limited to, 0.01, 0.02, 0.03, 0.04, 0.05, 0.06, 0.07, 0.08, 0.09, 0.10, 0.11, 0.12, 0.13, 0.14, or 0.15; the correction parameter b ranges from 0.01 to 0.15 and may be, but is not limited to, 0.01, 0.03, 0.05, 0.07, 0.09, 0.11, 0.13, or 0.15; and the correction parameter c ranges from 1 to 1000 and may be, but is not limited to, 1, 10, 100, or 1000. In a more preferred embodiment, the correction parameter a ranges from 0.02 to 0.04, the correction parameter b ranges from 0.02 to 0.04, and the correction parameter c is 1.

[0053] The pulse arrival time in the equation is obtained as the time difference between an R-wave peak value of an electrocardiographic signal and the corresponding peak value of the corresponding pulse signal. In another preferred embodiment, the pulse arrival time is obtained by detecting the time difference between the corresponding valleys of an electrocardiographic signal and the corresponding pulse signal, wherein the valleys serve as the trigger conditions. The present invention has no limitation on the method by which to determine the pulse arrival time. In one preferred embodiment, the pulse detection module **12** is configured to detect the pulse of the radial artery at the wrist, and the length of the path along which such a pulse propagates in the arteries is the length of the arm.

[0054] In another preferred embodiment, mean arterial pressure is obtained by equation (II):

$$\text{mean arterial pressure } (MAP) = A\left(\frac{l_p}{t_{pa}} \times C\right)^2 + B, \quad \text{equation (II)}$$

where l_p is the length of the path along which a pulse propagates in an artery; t_{pa} is the pulse arrival time; and A, B, and C are correction parameters. The correction parameters are derived from a target subject database to provide necessary adjustment to the algorithm. In one preferred embodiment, the correction parameter A ranges from 0.01 to 0.15 and may be, but is not limited to, 0.01, 0.02, 0.03, 0.04, 0.05, 0.06, 0.07, 0.08, 0.09, 0.10, 0.11, 0.12, 0.13, 0.14, or 0.15; the correction parameter B ranges from 0.1 to 1.0 and may be, but is not limited to, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, or 1.0; and the correction parameter C ranges from 1 to 1000 and may be, but is not limited to, 1, 10, 100, or 1000. In a more preferred embodiment, the correction parameter A ranges from 0.02 to 0.10, the correction parameter B ranges from 0.1 to 1.0, and the correction parameter C is 100.

[0055] The pulse arrival time in the equation is obtained as the time difference between an R-wave peak value of an electrocardiographic signal and the corresponding peak value of the corresponding pulse signal. In another preferred embodiment, the pulse arrival time is obtained by detecting the time difference between the corresponding valleys of an electrocardiographic signal and the corresponding pulse signal, wherein the valleys serve as the trigger conditions. The present invention has no limitation on the method by which to determine the pulse arrival time. In one preferred embodiment, the sensors **121** are configured to detect the pulse of the radial artery at the wrist, and the length of the path along which such a pulse propagates in the arteries is the distance from the chest to the wrist.

[0056] FIG. **9** is a plot showing the test result of correlation between the present invention and a commercially available product.

[0057] To determine whether the arterial pulse wave velocity measured by the present invention differs from the measurement result of a commercially available brachial sphygmomanometer, the inventor conducted a brachial artery pressure (BAP) measurement study in which the mean arterial pressures of a group of subjects (including healthy people and those with heart rhythm irregularities) were recorded using a commercially available product (Omron HBP-9092®) as well as the use-as-you-need blood pressure measurement device **100** of the present invention, and in which a correlation analysis was performed on the measurement results of the two devices.

[0058] As shown in FIG. **9**, during the 30 seconds when brachial artery pressure (BAP) measurements were taken simultaneously with the use-as-you-need blood pressure measurement device **100** of the present invention and Omron HBP-9092®, there is a significant correlation, or a linear relationship, between the mean arterial pressures recorded by the use-as-you-need blood pressure measurement device **100** of the present invention and the BAP values recorded by Omron HBP-9092®, the correlation coefficient R being 0.85 ($p<0.001$).

[0059] According to the above, a pulse detection module according to the present invention includes a plurality of piezoelectric sensors that are arranged in a direction parallel to a user's limb. Therefore, even if a wearable device (e.g., a wrist watch) provided with the pulse detection module is shifted away from its most desirable position on the wrist, at least one of the sensors can still detect the user's pulse and pulse waves to ensure completeness and continuity of the detection data. Moreover, the present invention provides a use-as-you-need blood pressure measurement device whose non-invasive and non-occlusive medical sensing technique/algorithm makes it possible to measure a user's mean arterial pressure, systolic pressure, diastolic pressure, and pulse (all of which are helpful in diagnosing heart rhythm irregularities) in real time without affecting the user's daily life.

[0060] The above is the detailed description of the present invention. However, the above is merely the preferred embodiment of the present invention and cannot be the limitation to the implement scope of the present invention, which means the variation and modification according to the present invention may still fall into the scope of the invention.

What is claimed is:

1. A pulse detection module, provided on a wrist watch, the pulse detection module being characterized by comprising a plurality of sensors and a controller linked to the sensors, wherein the sensors are arranged horizontally on the wrist watch in a direction parallel to a user's limb on which the wrist watch is worn, and the controller obtains the user's pulse signals through the sensors.

2. The pulse detection module of claim **1**, wherein the sensors are piezoelectric sensors, Doppler radars, impedance pressure sensors, capacitance pressure sensors, acoustic wave sensors, ultrasonic sensors, or photoplethysmographic (PPG) devices.

3. The pulse detection module of claim **1**, wherein the controller is connected to each of the sensors in order to obtain the pulse signals received by each sensor, and chooses the suitable wave peaks or valleys from the pulse signals as the correct pulse signals.

4. A use-as-you-need blood pressure measurement device, comprising a watch case assembly and a watch band attached to the watch case assembly, wherein the watch case assembly comprises:

an electrocardiographic detection module provided on the watch case assembly to obtain a user's electrocardiographic signals;

a pulse detection module provided on the watch case assembly and comprising a plurality of sensors provided on a backside of the watch case assembly, wherein the sensors are arranged horizontally in a direction parallel to the user's limb on which the use-as-you-need blood pressure measurement device is worn, in order to obtain the user's pulse signals; and

a controller for obtaining the user's electrocardiographic signals through the electrocardiographic detection module and calculating the user's mean arterial pressure according to the electrocardiographic signals and the pulse signals.

5. The use-as-you-need blood pressure measurement device of claim **4**, wherein the sensors are piezoelectric sensors, Doppler radars, impedance pressure sensors, capacitance pressure sensors, acoustic wave sensors, ultrasonic sensors, or photoplethysmographic (PPG) devices.

6. The use-as-you-need blood pressure measurement device of claim **4**, wherein the controller is connected to each of the sensors in order to obtain the pulse signals received by each sensor, and chooses the suitable wave peaks or valleys from the pulse signals as the correct pulse signals.

7. The use-as-you-need blood pressure measurement device of claim **4**, wherein the electrocardiographic detection module includes a first electrode and a second electrode; the first electrode is provided on the side of the watch case assembly that is adjacent to a user's limb on which the use-as-you-need blood pressure measurement device is worn, the objective being for the first electrode to lie on the user's skin during use, and the second electrode is also provided on the watch case assembly in order to be touched by a limb of the user that is on the opposite side of the body; and, a user's electrocardiographic signals are derived from the variation of electric potential between the first electrode and the second electrode.

8. The use-as-you-need blood pressure measurement device of claim **7**, wherein the electrocardiographic detection module comprises a grounding electrode provided on a side of the watch case assembly that is adjacent to the user's limb in order for the grounding electrode to lie on a surface of the user's limb, and the controller is connected to the grounding electrode and uses an electric potential of the grounding electrode as a reference electric potential.

9. The use-as-you-need blood pressure measurement device of claim **4**, wherein mean arterial pressure is obtained by the following equation (I):

$$\text{mean arterial pressure } (MAP) = a\left(\frac{l_p}{t_{pa}} \times c\right) + b, \quad \text{equation (I)}$$

where l_p is the length of the path along which a pulse propagates in an artery; t_{pa} is the pulse arrival time; and a, b, and c are correction parameters.

10. The use-as-you-need blood pressure measurement device of claim **4**, wherein mean arterial pressure is obtained by equation (II):

$$\text{mean arterial pressure } (MAP) = A\left(\frac{l_p}{t_{pa}} \times C\right)^2 + B, \quad \text{equation (II)}$$

where l_p is the length of the path along which a pulse propagates in an artery; t_{pa} is the pulse arrival time; and A, B, and C are correction parameters.

11. The use-as-you-need blood pressure measurement device of claim **4**, wherein the display device is provided on the watch face of the watch case assembly and is connected to the controller in order to display a user's physiological data.

12. The use-as-you-need blood pressure measurement device of claim **7**, wherein the second electrode is provided on the watch face of the watch case assembly, so a user wearing the use-as-you-need blood pressure measurement device on one wrist can press at the second electrode with a finger of the opposite hand.

* * * * *