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(54) A period and frequency measurement device

(57) Objective

To provide a cycle and frequency measurement device that can perform appropriate window determination by making the window follow the changes even when pulse rate or pitch changes greatly.

Means of solving the problem

In a device for measuring pulse rate, first, the upper margin of the window for the measurement result is set 20% larger than the previous measurement value and the lower margin is set 20% smaller than the previous measurement value. Subsequently, when body movements become larger, for the following 4 seconds, the upper margin is widened by 80% from the previous measurement value and the lower margin is narrowed by 10%. From then on, the upper margin is narrowed to +60%, +40%, and +20%. Note that if body movements become smaller, the upper margin is widened by 10% from the previous measurement value while the lower margin is set at -60% of the previous measurement value.

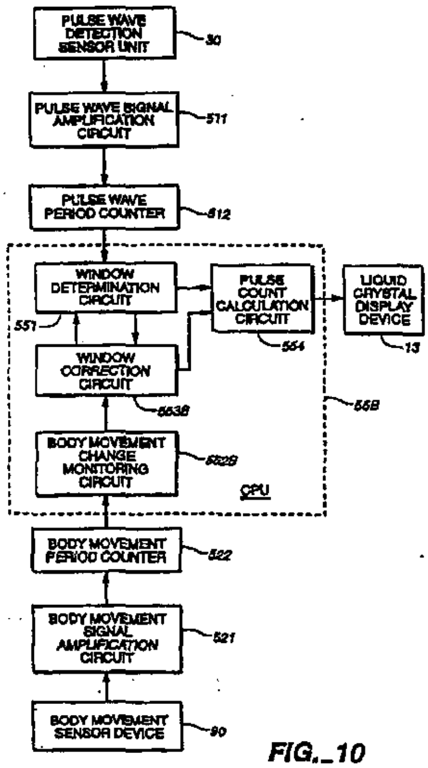


FIG._10

EP 0 730 843 A2

Description

The invention relates to a period and frequency measurement device used for determining pulse rate and pitch based on pulse signals and body movement signals detected by sensor means. More specifically, the invention relates to a technology for optimising the window for pulse rate and pitch.

When pulse waves and body movements are measured using sensors, and pulse rate and pitch are determined based on the measurement results, errors that occurred during the measurement may produce abnormal values for the pulse rate and pitch. Inclusion of these erroneous values in the determination of the subject's condition will lead to the wrong result. Therefore, this kind of measurement device uses as the reference value, the previously taken measurement value or the average of several measurement values taken immediately before as disclosed in Japanese patent publication No. 63-34731, multiplies this reference value by certain coefficients to set an upper and a lower margin, and determines whether or not the current measurement value is normal based on whether or not it is within the range (window) defined by these upper and lower margins.

However, a problem exists if a window is set up by merely multiplying the previous measurement (reference value) by certain coefficients to obtain an upper and a lower margin, as in conventional methods. That is, normal value can be differentiated from an abnormal value fairly accurately if changes in body movement are small, such as when the subject is at rest. However, because the pulse rate changes dramatically at the beginning of exercise, window correction cannot keep up with this degree of change. For example, in Fig. 18, the horizontal and vertical axes show elapsed time and pulse rate, respectively, and the change in pulse rate over time, before and after exercise, is plotted as polygonal line P. In this fig., window correction can keep up with the pulse rate change before the start of exercise (before time t1), but cannot keep up with the changes immediately after the start of exercise (immediately after time t1) due to the significant increase in pulse rate. Consequently, even if the measurement taken at this time is normal, it will be eliminated as being abnormal. As a result, such a value will not be displayed and window correction can never occur as long as such a value is judged to be abnormal.

Conversely, widening the window too far in an attempt to improve response to changes in pulse rate will defeat the original purpose of eliminating abnormal values.

These problems are also encountered by devices that measure running pitch which exhibits the same changes as pulse rate.

The object of this invention is to solve the above-mentioned problems and provide a cycle frequency measurement device that produces an appropriate window by making the window follow the changes even if pulse rate and pitch change dramatically.

In order to solve the above-mentioned problems, the present invention provides a cycle and frequency measurement device characterised by comprising; a sensor means for measuring pulse waves and body movements; a window determination means for setting a reference value based on the measurements previously taken by said sensor means and for determining whether or not the current measurement value taken by said sensor means falls within the window defined by the upper and lower margins relative to said reference value; and a window correction means that corrects the window to be used for the next measurement value to be taken by said sensor means, by applying a specified correction to the current measurement value if the determination result of said window determination means indicates that said current measurement value taken by said sensor means falls outside the current window.

The measurement previously taken by said sensor means may be the previous measurement value itself or multiple measurement values taken including the previous measurement value.

In other words, the cycle and frequency measurement device according to the invention solves the above-mentioned problems by changing the reference value of the window when the cycle and frequency signals of pulse waves and body movement fall outside the specified range (window), and instead of eliminating and ignoring rapid changes in cycle and frequency of pulse waves and body movement as abnormal signals, corrects the window based on the measurement value. Therefore, appropriate window determination can be made because the window follows large changes in pulse waves and body movement.

In this invention, said window correction means is preferably configured such that it increments the current measurement value and uses the result as a new reference value if the determination result of said window determination means indicates that the current measurement value exceeds the upper margin of said window; and such that it decrements the current measurement value and uses the result as a new reference value if the determination result of said window determination means indicates that the current measurement value falls below the lower margin of said window.

With such a configuration, if rapid changes occur in the cycle and frequency of the signal, the next measurement will be taken after the window correction means shifts the window based on the degree to which the signal deviates from the window (e.g., over the upper margin or below the lower margin). Therefore, even if cycle and frequency change dramatically, the excellent follow-up characteristic of the window allows the window to be correctly determined.

The invention may comprise a calculation means that calculates status values such as pulse rate and pitch based on the current measurement values if the determination result of said window determination means indicates that said current measurement values taken by said means fall within the window, and that calculates status values such as pulse rate and pitch based on the reference values generated from said measurement values by said window correction means if the determination result of said window determination means indicated that said current measurement values taken by said sensor means fall outside the window; and a display means that displays status values such as pulse rate and pitch calculated by said calculation means.

Here, said upper and lower margins may be set to be equal, in which case said reference value becomes the centre value of the window.

The cycle and frequency measurement device according to another embodiment of the invention is characterised by comprising; a body movement detection sensor means for sensing body movement; a pulse wave detection sensor means for sensing pulse waves; a window determination means that sets a reference value based on the measurements taken previously by one of said pulse wave detection sensor means or said body movement detection sensor means and that determines whether or not the current measurement value taken by one of said sensor means falls within the window defined by the upper and lower margins relative to said reference value; a change monitoring means for monitoring the change in the measurement value taken by the other sensor means; and a window correction means that corrects the window to be used for the current measurement value or the next measurement value to be taken by one of said sensor means, based on the monitoring result of said change monitoring means.

The measurement taken previously may be the previous measurement value itself or multiple measurement values taken including the previous measurement value. In other words, this embodiment is characterised in that window correction is performed based on the measurement value taken by another sensor means.

Here, when said pulse wave detection sensor means is used as said one of said sensor means, the cycle and frequency measurement device is configured as a pulse rateer; and in such a configuration, said other sensor means is said body movement detection sensor means, and said change monitoring means is a body movement change monitoring means that monitors body movement changes based on the measurement values taken by said body movement detection sensor means. If the configuration is reversed as will be described below, the cycle and frequency measurement device is configured as a pitch counter.

In this invention, said window correction means can be configured such that it corrects the window for the next measurement value to be taken by said pulse wave detection sensor means, by adjusting the current measurement value taken by said pulse wave detection sensor means in a sense corresponding to an increase in pulse rate and using the result as a new reference value if the determination result of said window determination means indicates that the current measurement value taken by said pulse wave detection sensor means falls outside the window and if the monitoring result of said boy movement change monitoring means shows that body movement has increased; and by adjusting the current measurement value taken by said pulse wave detection sensor means in a sense corresponding to a decrease in pulse rate and using the result as a new reference value if the determination result of said window determination means indicates that the current measurement value taken by said pulse wave detection sensor means falls outside the window and if the monitoring result of said body movement change monitoring means shows that body movement has decreased.

With such a configuration, the direction and magnitude of window reference value correction can be optimised by forecasting a rising or falling pulse rate trend based on body movement changes. Therefore, even at the start and finish of a run, or during a significant pitch change when pulse rate changes are temporarily large, the window can be appropriately corrected to follow those changes.

Furthermore, the invention may comprise a pulse rate calculation means that calculates pulse rate based on the current measurement value if the determination result of said window determination means indicates that said current measurement value taken by said pulse wave detection sensor means falls within the window, and that calculates pulse rate based on the reference value generated from said measurement values by said window correction means if the determination result of said window determination means indicates that said current measurement value taken by said pulse wave detection sensor means falls outside the window; and a display means that displays the pulse rate calculated by said pulse rate calculation means.

In this invention, said window correction means is preferably configured such that it makes corrections to the current measurement value taken by said pulse wave detection sensor means based on the rate of change of the amount of body movement, determined based on the monitoring result of said body movement change monitoring means.

Here again, said upper and lower margins may be set to be equal, in which case said reference value becomes the centre value of the window.

In this invention, another window correction means can be configured such that it corrects the window to be used for the current measurement value or the next measurement value to be taken by said pulse wave detection sensor means, by performing the first correction, i.e., widening a first margin corresponding to increased pulse rate, if the monitoring result of said body movement change monitoring means indicates increased body movement, and by performing a second correction, i.e, widening a second margin corresponding to decreased pulse rate, if the monitoring result of said body movement change monitoring means indicates decreased body movement.

With such a configuration, even when pulse rate changes drastically, window correction can sufficiently keep up with those changes because, by matching the body movement changes and pulse changes in an actual pattern, the upper margin of the window for pulse rate is widened as the first correction, when increased body movement is expected to accelerate the pulse; and the lower margin of the window for pulse rate is widened as the second correction, when decreased body movement is expected to decelerate the pulse. Therefore, the window can be appropriately determined.

In this case, said window correction means preferably makes said first margin wider in the first correction, immediately after the body movement increases, and subsequently narrows said first margin as time passes. Advantageously, the first margin can be returned to the pre-correction state as time passes.

Furthermore, said window correction means is preferably configured such that it narrows said second margin in the first correction, immediately after body movement increases; and narrows said first margin in the second correction, immediately after body movement decreases.

Additionally, said window correction means is preferably configured such that it performs the first correction if the monitoring result of said body movement change monitoring means indicates increased body movement and if the previous or the current measurement value taken by said pulse wave detection sensor means corresponds to a pulse rate below a specified value, and performs the second correction if the monitoring result of said body movement change monitoring means indicates decreased body movement and if the previous or the current measurement value taken by said pulse wave detection sensor means corresponds to a pulse rate above a specified value.

If the configuration of the invention is reversed such that said one of said sensor means is said body movement detection sensor means, the cycle and frequency measurement device is configured as a pitch counter. In this case, said other sensor means is said pulse wave detection sensor means, and said change monitoring means is a pulse change monitoring means that monitors pulse changes based on the measurement values taken by said pulse wave detection sensor means.

In this case again, said window correction means can be configured such that it corrects the window for the next measurement value to be taken by said body movement detection sensor means, by adjusting the current measurement value taken by said body movement detection sensor means in a sense corresponding to an increase in body movement and using the result as a new reference value if the determination result of said window determination means indicates that the current measurement value taken by said body movement detection sensor means falls outside the window and if the monitoring result of said pulse change monitoring means shows that the pulse has accelerated; and by adjusting the current measurement value taken by said body movement detection sensor means in a sense corresponding to a decrease in body movement and using the result as a new reference value if the determination result of said window determination means indicates that the current measurement value taken by said body movement detection sensor means falls outside the window and if the monitoring result by said pulse change monitoring means shows that the pulse has decelerated.

With such a configuration, the direction and magnitude of window reference value correction can be optimised by forecasting a rising or falling pitch trend based on pulse changes. Therefore, even at the start and finish of a run, or when pitch count changes are temporarily large, the window can be appropriately corrected to follow those changes.

Furthermore, the invention preferably comprises a pitch calculation means that calculates pitch based on the current measurement value if the determination result of said window determination means indicates that said current measurement value taken by said body movement detection sensor means falls within the window, and that calculates pitch based on the reference value generated from said measurement value by said window correction means if said current measurement value taken by said body movement detection sensor means falls outside the window; and a display means that displays the pitch calculated by said pitch calculation means.

Said window correction means is preferably configured such that it makes corrections to the current measurement value taken by said body movement detection sensor means based on the rate of change of the pulse rate, determined based on the monitoring result of said pulse change monitoring means.

In this case again, said upper and lower margins may be set to be equal, in which case said reference value becomes the centre value of the window.

In this invention, another window correction means can be configured such that it corrects the window to be used for the current measurement value or the next measurement value to be taken by said body movement detection sensor means, by performing the first correction, i.e., widening a first margin corresponding to increased body movement, if the monitoring result of said pulse wave change monitoring means indicates a faster pulse rate, and by performing the second correction, i.e., widening a second margin corresponding to decreased body movement, if the monitoring result of said pulse wave change monitoring means indicates a slower pulse rate.

With such a configuration, even when pitch changes drastically, window correction can sufficiently keep up with those changes because, by matching the body movement and pulse rate changes of an actual pattern, the upper margin of the window for pitch is widened as the first correction when a faster pulse rate is expected to raise the pitch; and the lower margin of the window for pitch is widened as the second correction, when a slower pulse rate is expected to lower the pitch. Therefore, the window can be appropriately determined.

In this case, said window correction means preferably makes said first margin wider in the first correction, immediately after the pulse rate accelerates, and subsequently narrows said first margin as time passes. Advantageously, the first margin is returned to the pre-correction state as time passes.

Furthermore, said window correction means is preferably configured such that it narrows said second margin in the first correction, immediately after the pulse rate accelerates; and narrows said first margin, in the second correction, immediately after the pulse rate decelerates.

Additionally, said window correction means is preferably configured such that if performs the first correction if the monitoring result of said pulse wave change monitoring means indicates a faster pulse rate and if the previous or the current measurement value taken by said body movement detection sensor means corresponds to a body movement rate below a specified value, and performs the second correction if the monitoring result of said pulse wave change monitoring means indicates a slower pulse rate and if the previous or the current measurement value taken by said body movement detection sensor means corresponds to a body movement rate above a specified value.

Embodiments of the invention will now be described by way of example only with reference to the accompanying diagrammatic figures in which;

Figs. 1A and 1B are general views showing the overall configuration and application of the cycle and frequency measurement device related to embodiment 1 of the invention.

Fig. 2 is a top view of the device main body of the cycle and frequency measurement device shown in Figs. 1.

Fig. 3 is a diagram of the device main body of the cycle and frequency measurement device shown in Figs. 1, viewed from the 3 o'clock direction of the watch.

Fig. 4 is a cross-section of the sensor unit used in the cycle and frequency measurement device shown in Figs. 1.

Fig. 5 is a diagram showing the configuration of the sensor and control area of the cycle an frequency measurement device related to embodiment 1 of the invention.

Fig. 6 is a block diagram showing the functions of the CPU used in the control area of the cycle and frequency measurement device shown in Fig. 5.

Fig. 7 is a flow chart showing the window correction process for pulse rate measurement performed by the cycle and frequency measurement device shown in Fig. 5.

Fig. 8 is a diagram showing the principle and content of the window correction performed by the cycle and frequency measurement device shown in Fig. 5.

Fig. 9 is a diagram showing the configuration of the sensor and control area of the cycle and frequency measurement device related to embodiment 2 of the invention.

Fig. 10 is a block diagram showing the functions of the CPU used in the control area of the cycle and frequency measurement device shown in Fig. 9.

Figs. 11A and 11B are a flow chart showing the window correction process for pulse rate measurement performed by the cycle and frequency measurement device shown in Fig. 9.

Fig. 12 is a block diagram showing the functions of the CPU used in the control area of the cycle and frequency measurement device related to embodiment 3 of the invention.

Fig. 13 is a diagram showing the configuration of the sensor and control area of the cycle and frequency measurement device related to embodiment 4 of the invention.

Fig. 14 is a block diagram showing the functions of the CPU used in the control area of the cycle and frequency measurement device shown in Fig. 13.

Figs. 15A and 15B are a flow chart showing the window correction process for pulse rate measurement performed by the cycle and frequency measurement device shown in Fig. 13.

Figs. 16A to 16C are diagrams showing the principle and content of the window correction performed by the cycle and frequency measurement device shown in Fig. 13.

Fig. 17 is a block diagram showing the functions of the CPU used in the control area of the cycle and frequency measurement device related to embodiment 5 of the invention.

Fig. 18 is a diagram showing the problems associated with a conventional window correction method.

The first embodiment of the invention is explained with references to drawings.

Embodiment 1

Overall configuration

Figs. 1 show the configuration of the cycle and frequency measurement device of the invention.

In Figs. 1A and 1B, the configuration of the cycle and frequency measurement device 1 (portable pulse rate/pulse wave measurement device) of the invention primarily comprises device main body 10 possessing a wristwatch structure, cable 20 connected to this device main body 10, and pulse wave detection sensor unit 30 (pulse wave measurement sensor means) installed on the tip of this cable 20. The tip of cable 20 is provided with connector piece 80 which is detachably attached to connector area 70 provided on the 6 o'clock side of device main body 10. Wristband 12, which is wrapped around the wrist from the 12 o'clock direction of the wristwatch and fastened in the 6 o'clock direction, is installed in device main body 10; and this wristband 12 allows device main body 10 to be easily put on or taken off from the wrist. Pulse wave detection sensor unit 30 is attached to the area between the base and the first joint of the index finger and is shielded from light by strap 40. Attaching pulse wave detection sensor unit 30 to the base of a finger in this way keeps cable 20 short and prevents it from getting in the way during running. Furthermore, taking into consideration the temperature distribution between the palm and finger tip in cold weather, the temperature at the finger tip falls substantially, while the temperature at the base of the finger falls relatively little. Therefore, attaching pulse wave detection sensor unit 30 at the base of the finger enables pulse rate (status value) to be accurately measured even during a run outside on a cold day.

Configuration of the device main body

Fig. 2 is a top view showing the main body of the cycle and frequency measurement device of the invention, with the wristband and cable removed; Fig. 3 is a side view of this cycle and frequency measurement device, obtained from the 3 o'clock direction.

In Fig. 2, device main body 10 is provided with plastic watch case 11 (body case), and the top side of this watch case 11 is provided with liquid crystal display device 13 (display device) with an electroluminescent (EL) backlight for displaying running time, pitch during walking, and pulse wave information such as pulse rate, in addition to current time and date. Liquid crystal display device 13 is provided with first segment display area 131 positioned on the upper left side of the display surface, second segment display area 132 positioned on the upper right side of the display surface, third segment display area 133 positioned on the lower right side of the display surface, and dot display area 134 which can graphically display various types of information positioned on the lower left side of the display.

Control area 5, which performs various types of control and data processing in order to determine the change in pulse rate based on the pulse wave signal measured by pulse wave detection sensor unit 30 and to display the result on liquid crystal display device 13, is provided inside watch case 11. Control area 5 is also provided with a timing circuit and thus can display normal time, lap time, split time, etc. on liquid crystal display device 13.

Button switches 111 through 115, which are used for external operations such as time adjustment and display mode switching, are provided on the perimeter of watch case 11. Additionally, larger button switches 116 and 117 are provided on the surface of the watch case.

Button-shaped small battery 59 contained inside watch case 11 is installed in cycle and frequency measurement device 1, and cable 20 supplies electrical power from battery 59 to pulse wave detection sensor unit 30 and at the same time inputs the detection result of pulse wave detection sensor unit 30 into control area 5 of watch case 11.

Device main body 10 also contains body movement sensor device 90 (body movement detection sensor means) which uses acceleration sensor 91 to detect body movement as body movement signals.

The size of device main body 10 must be increased as more functions are added to cycle and frequency measurement device 1. However, device main body 10 cannot be extended in the 6 or 12 o'clock directions of the watch because it must be worn around a wrist. Therefore, device main body 10 uses watch case 11 which is longer in the 3 and 9 o'clock directions than in the 6 and 12 o'clock directions. However, wristband 12 is connected eccentrically toward the 3 o'clock side, leaving extended area 101 in the 9 o'clock direction, viewed from wristband 12, but no such extended area in the 3 o'clock direction. Consequently, this structure, despite the use of long watch case 11, allows free wrist movement and eliminates the possibility of the back of the hand striking watch case 11.

Flat piezoelectric element 58 for a buzzer is positioned in the 9 o'clock direction, viewed from battery 59, inside watch case 11. Because battery 59 is heavier than piezoelectric element 58, the centre of gravity of device main body 10 is positioned eccentrically in the 3 o'clock direction. Because wristband 12 is connected to the side on which the centre of gravity is located, device main body 10 can be securely attached to the wrist. Furthermore, the positioning of battery 59 and piezoelectric element 58 in the planar direction allows device main body 10 to be thin; battery cover 118 installed on the back side as shown in Fig. 3 allows the user to easily replace battery 59.

Structure for attaching the device main body to the wrist

In Fig. 3, connecting area 105 for holding stopping pin 121 installed on the end of wristband 12 is formed in the 12 o'clock direction of watch case 11. Receiving area 106 is provided in the 6 o'clock direction of watch case 11, and said receiving area 106 is provided with fastener 122 for holding in place the middle point of wristband 12 wound around the wrist, in the long direction of the band.

In the 6 o'clock direction of device main body 10, the area from bottom surface 119 to receiving area 106 is formed as an integral part of watch case 11 and forms rotation stop area 108 which is positioned at approximately 115° from bottom surface 119. That is, when wristband 12 is used to attach device main body 10 to top area L1 (side of the back of the hand) of right wrist L (arm), bottom surface 119 of watch case 11 tightly contacts top area L1 of wrist L while rotation stop area 108 contacts side area L2 where radius R is located. In this state, bottom surface 119 of device main body 10 more or less straddles radius R and ulna U, while rotation stop area 108 and the area between bent area 109 of bottom surface 119 and rotation stop area 108 contact radius R. Because rotation stop area 108 and bottom surface 119 form an anatomically ideal angle of approximately 115° as explained above, device main body 10 will not turn around arm L even if an attempt is made to turn it in the direction of arrows A or B. Furthermore, because the rotation of device main body 10 is restricted only in two locations on the side of the arm by bottom surface 119 and rotation stop area 108, bottom surface 119 and rotation stop area 108 securely contact the arm even if it is thin, and provide a secure rotation stopping effect and comfortable fit even if the arm is thick.

Configuration of the pulse wave detection sensor unit

Fig. 4 shows a cross-section of the pulse wave detection sensor unit of this embodiment.

In this fig., component housing space 300 is formed between the casing of pulse wave detection sensor unit 30 and bottom lid 302 on the bottom side of sensor frame 36. Circuit board 35 is positioned inside component housing space 300. LED 31, phototransistor 32, and other electronic components are mounted on circuit board 35. One end of cable 20 is fastened to pulse wave detection sensor unit 30 by bushing 393, and various wires of cable 20 are soldered to various patterns on circuit board 35. Pulse wave detection sensor unit 30 is attached to the finger such that cable 20 is extended from the base of the finger toward device main body 10. Therefore, LED 31 and phototransistor 32 are arranged along the length of the finger, with LED 31 positioned on the finger tip side and phototransistor 32 positioned at the base of the finger. This configuration provides the effect of making it difficult for the ambient light to reach phototransistor 32.

In pulse wave detection sensor unit 30, a light transmission window is formed by translucent plate 34 which is made of a glass plate on the upper area of sensor frame 36, and the light-emitting surface and light-receiving surface of LED 31 and phototransistor 32, respectively, are oriented toward said translucent plate 34. Because of this configuration, when a finger surface is pressed onto external surface 341 of translucent plate 34, LED 31 emits light toward the finger surface and phototransistor 32 can receive part of the light emitted by LED 31 that is reflected by the finger. Note that external surface 341 of translucent plate 34 protrudes farther than surrounding area 361 in order to improve its contact with the finger surface.

In this embodiment, an InGaN (indium-gallium-nitrogen) blue LED is used as LED 31, and its emission spectrum possesses a peak at 450 nm and its emission wavelength ranges from 350 to 600 nm. To match with LED 31 possessing such characteristics, a GaAsP (gallium-arsenic-phosphorus) phototransistor is used as phototransistor 32, and the light-receiving wavelength of the element itself ranges from 300 to 600 nm, with some sensitive areas also at or below 300 nm.

When pulse wave detection sensor unit 30 thus configured is attached to the base of the finger by sensor-fastening strap 40 and light is emitted from LED 31 toward the finger, the light reaches blood vessels, and part of the light is absorbed by haemoglobin in the blood and part of it is reflected. The light reflected by the finger (blood) is received by phototransistor 32, and the change in the amount of received light corresponds to the change in the blood volume (pulse wave in the blood). That is, because the reflected light becomes weak when the blood volume is high and becomes strong when the blood volume is low, data such as pulse rate can be measured by optically detecting the intensity of the reflected light as a pulse wave signal.

This embodiment uses LED 31 with an emission wavelength range of between 350 and 600 nm and phototransistor 32 with a light-receiving wavelength range of between 300 and 600 nm, and vital information is displayed based on the results taken in the overlapping wavelengths of between approximately 300 and approximately 600 nm, i.e., wavelengths of approximately 700 nm or shorter. When such pulse wave detection sensor unit 30 is used, even if the ambient light strikes the exposed part of the finger, lights with wavelengths of 700 nm or shorter contained in the ambient light do not use the finger as a light guide to reach phototransistor 32 (light-receiving area). The reason for this is as follows. Because lights with wavelengths of 700 nm or shorter contained in the ambient light do not easily penetrate the finger, the ambient light reaching the area of the finger not covered by the sensor fastening strap 40 will not penetrate the finger to reach phototransistor 32. In contrast, if an LED possessing an emission peak at around 880 nm and a silicon phototransistor are used, a light-receiving wavelength range of between 350 and 1,200 nm will result. In such a case, changes in the ambient light level tend to cause measurement errors because pulse waves will be detected using a light with 1 μm wavelength which can use the finger as a light guide to easily reach phototransistor 32.

Furthermore, because pulse wave information is obtained using lights with approximately 700 nm or shorter wavelengths, the S/N ratio of the pulse wave signal based on blood volume change is high. The reason for this is as follows.

The absorption coefficient of haemoglobin in the blood for lights with wavelengths of between 300 and 700 nm is several times to approximately one hundred or more times larger than the absorption coefficient for a light with wavelength of 800 nm which has been conventionally used as the detection light. As a result, lights with wavelengths of between 300 and 700 nm change sensitively to blood volume changes, producing higher pulse wave detection rate (S/N ratio) based on blood volume change.

Configuration of the control area

Fig. 5 shows the configurations of individual sensors and control area 5. In pulse wave detection sensor unit 30, the light emitted from LED 31 passes into the body and the reflected light is modulated according to the volume change in the blood vessel, and after the resulting optical change is converted to electrical current by phototransistor 32, a voltage output (pulse wave signal) is obtained by a collector resistor R_1. Pulse wave signal amplification circuit 511 comprising three steps, an AC amplifier (A) (step 1), a low pass filter (LPF) (step 2), and a Schmitt trigger comparator (TR) for square wave conversion (step 3) is provided after pulse wave detection sensor unit 30, and pulse wave cycle counter 512 is provided after this amplification circuit. Based on the clock signal from reference clock 550, pulse wave cycle counter 512 measures the time between the edges of square waves that are output from pulse wave signal amplification circuit 511, and outputs the counter value K to CPU 55A.

CPU 55A also runs based on the clock signal from reference clock 550, performs calculations using RAM 562 as the operation memory and based on the program stored in ROM 561, and displays the calculation result (pulse rate) on liquid crystal display device 13.

Fig. 6 is a block diagram showing the functions of CPU 55A. As evident from this fig., the output of pulse wave detection sensor unit 30 is detected and amplified by pulse wave signal amplification circuit 511, and the cycle is counted by pulse wave cycle counter (or pulse wave period counter) 512 which is a cycle counting means. Whether or not the output of said pulse wave cycle counter 512 falls within the specified window is first judged by window determination area 551 (window determination means) provided in CPU 55A. Here, the window is defined by certain upper and lower margins relative to the reference value determined based on the previous measurement value. In this embodiment, the reference value is equivalent to the centre value because the upper and lower margins are equal.

If the window determination result indicates that the current output (current measurement value) of pulse wave cycle counter 512 falls within the window, this value is sent to pulse rate calculation area 554 (pulse rate calculation means) as is. Pulse rate calculation area 554 converts the cycle that is output by pulse wave cycle counter 512 to pulse rate, and the resulting value is displayed as a pulse rate on liquid crystal display device 13.

In contrast, if the current output (current measurement value) of pulse wave cycle counter 512 falls outside the window, a value that is corrected by window correction area 553A (window correction means) is sent to pulse rate calculation area 554. Therefore, pulse rate calculation area 554 converts the output of pulse wave cycle counter 512 that has been corrected by window correction area 553A to pulse rate, and the resulting value is display as a pulse rate on liquid crystal display device 13.

Furthermore, if the current output (current measurement value) of pulse wave cycle counter 512 falls outside the window, the window centre value is corrected by window correction area 553A, and thus window correction area 553A is in effect correcting the centre value of the window for the next measurement result.

The method of processing measurement results will be explained in detail with reference to the control flow in Fig. 7.

First, S_{old} which becomes the centre value of the next window determination is calculated based on counter value K fetched from pulse wave cycle counter 512 (step ST601). The actual measurement now begins, and after calculating pulse cycle S by fetching counter value K of pulse wave cycle counter 512 again (step ST602), window determination area 551 calculates the lower margin Low which is 20% lower than window determination reference value S_{old} and upper margin High which is 20% higher than reference value S_{old} (steps ST603 and ST604). Note that because pulse wave cycle and pulse rate are different in dimension, upper margin High and lower margin Low correspond to the lower and upper margins of the pulse rate window, respectively.

Next, whether or not the current measurement of cycle S falls within the window defined by lower margin Low and upper margin High is determined (steps ST605 and ST606). These steps are performed by window determination area 551 (window determination means).

If pulse wave cycle S is below the window width, a value that is 2% smaller than the window determination reference value S_{old} (centre value) is used as the next reference value S_{old} (step ST607). In contrast, if pulse wave cycle S is above the window width, a value that is 2% larger than the window determination reference value S_{old} (centre value) is used as the next reference value S_{old} (step ST608).

Window correction area 553A (window correction means) in effect performs window correction for the next measurement value as explained below, because it corrects reference value S_{old} based on the window determination result for the current measurement value as described above.

Next, if cycle S is within the window, this cycle S is assigned to pulse rate calculation variable J as is (step ST609), and if cycle S is outside the window, a corrected reference value S_{old} is assigned to pulse rate calculation variable J (step ST610). Next, pulse rate calculation variable J is converted to pulse rate M in step ST611. These steps are performed by pulse rate calculation area 554 (pulse rate calculation means).

Next, in step ST612, window correction for the next measurement value is performed by assigning pulse rate calculation variable J to reference value S_{old} for the next window determination.

Then in step ST613, an instruction is issued for displaying a pulse rate on liquid crystal display device 13, and pulse rate M is displayed on liquid crystal display device 13.

The steps so far described constitute one cycle, and the steps beginning with ST602 are repeated for the next measurement and display.

Fig. 8 shows an example of measuring pulse rate using such a processing method under a condition involving rapid pulse rate changes, such as during exercise. In this fig., the horizontal and vertical axes show elapsed time and pulse rate, respectively. Here, Mn (where n is an integer) indicates each pulse rate measurement value, which results when pulse wave cycle Sn obtained by the average pulse rate cycle calculation routine is converted to pulse rate.

First, reference value S_{old} (centre value) and the window width (the range indicated by the up and down arrows in the fig.) are determined by the initial value M0. In Fig. 8, cycle Sn and reference value S_{old} are shown as Mn and M_{old} after conversion to pulse rates, in order to maintain dimensional consistency.

Next, if measurement value M1 is within the window possessing value M_{old} as its centre, measurement value M1 is displayed as is, and the reference value (window centre value) for the next window is set based on measurement value M1. The same steps are taken for M2 measured subsequently. In this example, exercise was started after measurement value M2 was obtained but before measurement value M3 was obtained, resulting in a rapid increase in pulse rate.

If value M3 measured falls outside the window, reference value M_{old} of the window is corrected upward, and a corrected value is displayed. Furthermore, this corrected value is set as the reference value (window centre value) for the next window. Although measurement values M4, M5, and M6 are also outside the window, reference value M_{old} of the window is gradually corrected, and as a result measurement value M7 falls inside the window. Therefore, unless the pulse rate changes abruptly at a later time, the true pulse rate (where Mn falls inside the window) can be displayed.

Although it is possible that the pulse rate will fluctuate according to a different pattern, normal pulse rate stays within a certain range, i.e., the lower limit of pulse rate ranges between 30 and 100 pulses/minute and the upper limit between 150 and 240 pulses/minute, and thus window reference value (centre value) correction can always keep up with pulse rate changes, and the pulse rate eventually falls within an appropriate zone. Therefore, although a reading containing an error will be temporarily displayed when the pulse rate changes rapidly, the erroneous display is not locked in and the duration of the erroneous display can be minimised. In conclusion, in this example, abnormal values can be eliminated from cycle measurement and at the same time the window can follow rapid changes in measurement values.

It is of course possible to display "ERROR" when a measurement value is outside the window, to clearly indicate that the pulse rate obtained is not true. Furthermore, although pulse rate was obtained in this example, it is possible to obtain pitch, in which case a similar process can be applied to the measurement results of body movement sensor device 90 instead of pulse wave detection sensor unit 30.

Embodiment 2

Because the configuration of the cycle and frequency measurement device in this example is identical to that of embodiment 1, the same symbols are used to represent the same areas, with their explanations omitted.

Fig. 9 shows the configurations of individual sensors and control area 5 of cycle and frequency measurement device 1 of this example. In pulse wave detection sensor unit 30, the light emitted from LED 31 passes into the body and the reflected light is modulated according to the volume change in the blood vessel, and after the resulting optical change is converted to electrical current by phototransistor 32, a voltage output (pulse wave signal) is obtained by a collector resistor. Pulse wave signal amplification circuit 511 is provided behind pulse wave detection sensor unit 30, and pulse wave cycle counter 512 is provided behind this amplification circuit. Based on the clock signal from reference clock 550, pulse wave cycle counter 512 measures the time between the edges of square waves that are output from pulse wave signal amplification circuit 511, and outputs the counter value K to CPU 35B.

This example is also provided with body movement sensor device 90. Said body movement sensor device 90 comprises a pre-amplifier consisting of acceleration sensor 91 which acts as a body movement sensor, a discharging resistor, and a FET. Body movement signal amplification circuit 521 comprising an AC amplifier (A_2), a low pass filter (LPF_2), and a Schmitt trigger comparator (TR_2) for square wave conversion is provided with the output signal of body movement sensor device 90, and body movement cycle counter 522 is provided with the output signal of this amplification circuit. Based on the clock signal from reference clock 550, body movement cycle counter 522 measures the time between edges of square waves that are output from body movement signal amplification circuit 521, and outputs the counter value T to CPU 55B.

CPU 55B also runs based on the clock signal from reference clock 550, performs calculations using RAM 562 as the operation memory and based on the program stored in ROM 561, and displays the calculation result (pulse rate) on liquid crystal display device 13.

Fig. 10 is a block diagram showing the functions of CPU 55B. The output of pulse wave detection sensor unit 30 is detected and amplified by pulse wave signal amplification circuit 511, and the cycle is counted by pulse wave cycle counter 512. Whether or not the output of said pulse wave cycle counter 512 falls within the specified window is judged by window determination area 551 provided in CPU 55B. Here, the window is defined by certain upper and lower margins relative to the reference value determined based on the previous measurement value. In this embodiment, the reference value is equivalent to the centre value because the upper and lower margins are equal.

If the window determination result indicates that the current measurement value falls within the window, this value is sent to pulse rate calculation area 554 as is. In contrast, if the current output value falls outside the window, the current value is corrected by window correction area 553B (window correction means).

Because this configuration is the same as that in embodiment 1, detailed explanations will be omitted. The main characteristic of this embodiment is the fact that window correction area 553B determines how to correct the current measurement value by measuring the changes in the body movement detected.

In other words, the output of body movement sensor device 90 is detected and amplified by body movement signal amplification circuit 521 and the cycle is measured by body movement cycle counter 522. The trend in body movements is determined based on this cycle, the resulting value is stored in body movement change monitoring area 552B (body movement change monitoring means/change trend storage means). Based on the change trend stored here, window correction area 553B determines by how much the reference value, which will become the centre value of the window, should be increased or decreased.

The method of processing measurement results will be explained in detail with reference to the control flow diagram shown in Fig. 11.

First, S_{old} which becomes the centre value of the next window determination is calculated based on counter value K fetched from pulse wave cycle counter 512 (step ST901). The actual measurement now begins, and cycle S is determined by fetching counter value K of cycle counter 512 again (step ST902).

Next, body movement change monitoring area 552B (body movement change monitoring means) determines the change trend of body movement cycle. In this processing, count value T of body movement cycle counter 522 is fetched into SM (step ST903). Next, three adjoining body movement cycle points (SMn, SMn-1, and SMn-2) stored in RAM 562 are updated to the three points from SM fetched above (steps ST904, ST905, and ST906). Next, the differences between SMn-2 through SMn which change over time are determined, and the sum total of these differences, Deff, is obtained (step ST907).

Next, based on the value of Deff, correction magnitudes "up" and "down" are determined from the conversion table shown in Table 1 (step

[Table 1]

Deff (msec)	up	down
< -200	0.01	0.08
-200 to -100	0.01	0.04
-100 to 100	0.02	0.02
100 to 200	0.04	0.01
200 <	0.08	0.01

Note that when the value of Deff is positive, it indicates that the body movement is increasing, i.e., the running pitch is accelerating. Consequently, the load on the heart increases, and as a result the pulse rate increases in most cases. Therefore, as shown in Table 1, the correction magnitude "up" is set larger when Deff is positive and as its absolute value increases. Conversely, when the value of Deff is negative, it indicates that the running pitch is decelerating or the subject has stopped. Consequently, the load on the heart decreases, and as a result the pulse rate decreases in most cases. Therefore, as shown in Table 1, the correction magnitude "down" is set larger when Deff is negative and as its absolute value increases.

With these settings, if the processing (steps ST909, ST910, ST911, and ST912) by window determination area 551 (window determination means) shows that the pulse rate falls below the window, reference value S_{old} (centre value) for the next window determination is corrected in step ST913, and during this step, appropriate correction is made using a "down" value that is set based on an expected downward trend in the pulse rate. In contrast, if the pulse rate is above the window, reference value S_{old} (centre value) for the next window determination is corrected in step ST914 using an "up" value based on an expected upward trend in the pulse rate. Since such processing corrects reference value S_{old} for the next measurement value, as explained below, it is equivalent to the processing by window correction area 553B (window correction means).

As in embodiment 1, in the processing steps (ST915, ST916, and ST917) by pulse rate calculation area 554 (pulse rate calculation means), cycle S that has gone through the determination by window determination area 551 or the value S_{old} that has been corrected by the correction process in window correction area 553B is converted to pulse rate M per minute (step ST917). Furthermore, in step ST918, pulse rate calculation variable J (cycle) is assigned to variable S_{old} as the reference value of the next window.

Next, the pulse rate M that has been determined is displayed (step ST919), and the next measurement is then taken.

As explained above, in this example, the direction and amount of correction of the window reference value (centre value) in window correction area 553B are optimized by forecasting the rising or falling trend of the pulse rate based on body movement changes, allowing pulse rate to be measured with excellent response characteristics even when the pulse rate temporarily changes rapidly, such as at the start or end of a run, or when the pitch fluctuates dramatically.

Embodiment 3

In embodiment 3, during displaying of a pulse rate, the change trend of body movement cycles was determined for optimizing the amount of correction for the window. In contrast, in this embodiment, the amount of correction needed when the body movement cycle (e.g., running pitch) deviates from the window is optimized based on the change trend of the pulse wave cycle. That is, the fact that correlation exists between the change trend of the body movement cycle and the change trend of the pulse rate cycle is utilized. The example utilizes the fact that when the pulse rate is increasing, the running pitch is also increasing; and when the pulse rate is decreasing, the running pitch is also decreasing in most cases.

As shown in the block diagram in Fig. 12, the configuration necessary for such processing requires only that the areas for measuring pulse wave cycle (pulse rate) be replaced with the areas for measuring pitch (body movement), and thus only brief explanations will be provided on their configurations. Furthermore, because the details of the processing performed in this example are the same as those shown in the flow chart in Fig. 11, except that the processing for pulse wave cycle (pulse rate) is replaced with that for pitch (body movement), their explanations are omitted.

In the example shown in Fig. 12, after the output of body movement sensor device 90 is amplified by body movement signal amplification circuit 521, edge-to-edge cycle is measured by body movement cycle counter 522. Likewise, after the output of pulse wave detection sensor unit 30 is amplified by pulse wave signal amplification circuit 511, edge-to-edge cycle is measured by pulse wave cycle counter 512. Next, the change trend of pulse cycle is calculated and stored by pulse change monitoring area 552C (pulse change monitoring means) provided in CPU 55C. The cycle determined by body movement cycle counter 522 is judged to be normal or abnormal through window determination by window determination area 551; and if the body movement cycle falls within the window, the current measurement of body movement cycle is judged to be normal and is converted to a pitch by pitch calculation area 574 (pitch calculation means).

In contrast, if the current body movement cycle measured falls outside the window, window correction area 522C (window correction means) corrects the reference value (centre value) for the next window determination. Note that the amount of correction to be made to the current measurement value is optimized based on the monitoring result of pulse change monitoring area 552C. Pitch calculation area 574 then converts the corrected reference value to a pitch.

The pitch thus calculated by pitch calculation area 574 is then displayed on liquid crystal display device 13.

Embodiment 4

Because the basic configuration of the cycle and frequency measurement device in this example is identical to that of embodiment 1, the same symbols are used to represent the same areas, with their explanations omitted.

Configuration of the control area

As shown in Fig. 13, the configurations of individual sensors and control area 5 of cycle and frequency measurement device 1 of this example are the same as those of embodiment 3. That is, in pulse wave detection sensor unit 30, the light emitted from LED 31 passes into the body and the reflected light is modulated according to the volume change in the blood vessel, and after the resulting optical change is converted to electrical current by phototransistor 32, a voltage output (pulse wave signal) is obtained by a collector resistor. Pulse wave signal amplification circuit 511 comprising an AC amplifier (A), a lowpass filter (LPF), and a Schmitt trigger comparator (TR) for square wave conversion is provided with the output signal of pulse wave detection sensor unit 30, and pulse wave cycle counter 512 is provided with the output signal of this amplification circuit. Based on the clock signal from reference clock 550, pulse wave cycle counter 512 measures the time between the edges of square waves that are output from pulse wave signal amplification circuit 511, and outputs the counter value K to CPU 55D.

This example is also provided with body movement sensor device 90. Body movement signal amplification circuit 521 comprising an AC amplifier (A_2), a lowpass filter (LPF_2), and a Schmitt trigger comparator (TR_2) for square wave conversion and body movement cycle counter 522 are provided with the output signal of said body movement sensor device 90. Based on the clock signal from reference clock 550, body movement cycle counter 522 also measures the time between edges of square waves that are output from body movement signal amplification circuit 521, and outputs the counter value T to CPU 55D.

Fig. 14 is a block diagram showing the functions of CPU 55D. CPU 55D is provided with window determination area 551 which sets a specified reference value based on the previous detection result of pulse wave detection sensor unit 30 and which determines whether or not the current detection result obtained by pulse wave detection sensor unit 30 falls within the effective window defined by the upper and lower margins relative to this reference value; and with pulse rate calculation area 554 which calculates pulse rate based on the detection result if the result of window determination area 551 indicates that the current detection result obtained by pulse wave detection sensor unit 30 falls within the window.

CPU 55D is also provided with body movement change monitoring area 552D (body movement change monitoring means) which monitors whether or not the body movement has increased, based on the detection result of body movement sensor device 90; and with window correction area 553D (window correction means) which performs the first correction, i.e., widening the upper margin of the window, if the monitoring result of body movement change monitoring means 552D indicates increased body movements, and subsequently performs the second correction, i.e., widening the lower margin, if the monitoring result of said body movement change monitoring means 552D indicates decreased body movements.

Note that window correction area 553D is configured such that it makes said upper margin the widest in the first correction, immediately after body movement increases, and subsequently returns the upper margin to the pre-correction state as time passes. Furthermore, window correction area 553D is configured such that it narrows the lower margin in the first correction, immediately after body movement increases, and narrows the upper margin, in the second correction, immediately after body movement decreases. Additionally, window correction area 553D is configured such that it performs the first correction when the monitoring result of body movement change monitoring means 552D indicates increased body movements and if the previous or the current pulse rate measurement is smaller than a specified value, and subsequently performs the second correction when the monitoring result of body movement change monitoring means 552D indicates decreased body movements and if the previous or the current pulse rate measurement is larger than a specified value.

Window determination and correction

ROM 561 contains programs that correspond to pulse rate calculation area 554, window determination area 551, window correction area 553D, and body movement change monitoring area 552D; and its control flow is shown in Fig. 15.

First, counter value K (previous measurement value) is fetched from pulse wave cycle counter 512 for determining reference value Sold of the current window, and the various variables to be used for setting the pulse wave cycle window, etc. are initialized (step ST1). That is, variable Run used for setting the width of the window for pulse wave cycle is set to "0", and coefficient Rmax for specifying the upper margin (this corresponds to the lower margin in the window for pulse rate because of the dimensional difference between pulse wave cycle and pulse rate) of the window for pulse wave cycle is set to "1.2", and coefficient Rmin for specifying the lower margin (this corresponds to the upper margin in the window for pulse rate because of the dimensional difference between pulse wave cycle and pulse rate) of the window for pulse wave cycle is set to "0.8".

Next, in order to initialize the window, the upper margin of the window is set by multiplying reference value S_{old} to which the previous measurement value has been assigned, by "1.2" of coefficient Rmax, and the lower margin of the window is set by multiplying reference value S_{old}, by "0.8" of coefficient Rmin (steps ST2 and ST3). That is, the window is set within the range of ±20% of the previous measurement value.

Actual measurement now begins, and pulse wave cycle S is determined by fetching counter value K of pulse wave cycle counter 512 (step ST4).

Next, body movement change monitoring area 552D determines the change trend of body movement cycle. In this process, counter value T of body movement cycle counter 522 is first fetched into SM as a converted pitch value, and at the same time three adjoining points (SMn, SMn-1, and SMn-2) stored in RAM 562 are updated to the three points including SM fetched above (step ST5). Next, the differences between SMn-2 through SMn which change over time are determined, and the sum total of these differences, Deff, is obtained (step ST6).

Next, whether or not variable Run for setting the window is "0" is determined (step ST7). This is performed in order to decide whether or not the upper and lower margins of the window have already been corrected because of a large body movements.

If variable Run is "0", whether or not variable Deff for determining the change trend of body movement cycles is equal to or larger than the threshold value SMth (SMth is a positive integer) on the positive side is determined (step ST8). If variable Deff is larger than the threshold value SMth on the positive side, it indicates that the body movement has increased.

In step ST8, even when variable Deff is positive, if its absolute value is equal to or smaller than threshold value SMth, body movements are not present or small enough with little pitch change, and thus the load on the heart does not change much. Therefore, the initially set window is used as is since pulse wave cycle (pulse rate) should not change much. In other words, window determination area 551 determines whether or not the current pulse wave cycle S measurement is smaller than lower margin Low (step ST9), and determines whether or not the current pulse wave cycle S measurement is larger than upper margin High (step ST10). That is, whether or not the current pulse wave cycle S measurement falls within the window is determined.

If the current pulse wave cycle S measurement is judged to fall within the window, pulse rate calculation area 554 assigns the current pulse wave cycle S measurement to pulse rate calculation variable J (step ST11) and then calculates pulse rate M (step ST12). Next, after pulse rate calculation variable J is assigned to reference value S_{old} of the window (step ST13), i.e., after the pulse wave cycle S measurement is assigned to reference value S_{old}, pulse rate M that is obtained is displayed on liquid crystal display device 13 (step ST14), and then the pulse wave measurement results for the next 4 seconds are processed, and pulse wave cycle S is determined by again fetching counter value K of pulse wave cycle counter (step ST4).

In contrast, if the current pulse wave cycle S measurement is judged not to be within the window in steps ST9 or ST10, reference value S_{old} of the window, i.e., the previous pulse wave cycle, instead of the current pulse wave cycle, S measurement, is assigned to pulse rate calculation variable J (step ST15). Pulse rate M is then calculated based on this value (step ST12). Next, after pulse rate calculation variable J is assigned to reference value S_{old} of the window (step ST13), i.e., after the previously measured pulse wave cycle is assigned to reference value S_{old} as is, pulse rate M that is obtained is displayed on liquid crystal display device 13 (step ST14). Then, the pulse wave measurement results for the next 4 seconds are processed, and pulse wave cycle S is determined by again fetching counter value K of pulse wave cycle counter (step ST4).

In step ST8, if variable Deff for determining the change trend of body movements is larger than the positive threshold value SMth, and then if pulse wave cycle S is judged to be larger than pulse wave cycle K120 at pulse rate of 120/minute, i.e., pulse rate is confirmed to be equal to or less than 120/minute, in step ST16, window correction area 553D first increments variable Run by "1" (step ST17), and then obtains from the data in Table 2, coefficient Rmax for specifying the upper margin of the window and coefficient Rmin for specifying the lower margin of the window, when variable Run is "1" (step ST18).

Then, a new upper margin High and a new lower margin Low of the window are determined (steps ST19 and ST20).

Next, whether or not the current pulse wave cycle S measurement falls within the new window is determined (steps ST9 and ST10). Then, the processing in steps ST11 through ST15 are performed.

As explained above, variable Run is "1" and not "0" after the first window correction. If variable Run is not "0", step ST21 determines whether or not variable Run is "4". If it is not "4", step ST22 determines whether or not variable Run is "5". If variable Run is not "5", variable Run is incremented by "1" (step ST17), and then coefficient Rmax for specifying the upper margin of the window and coefficient Rmin for specifying the lower margin of the window, for the current value of variable Run (step ST18), are obtained from the data in Table 2.

Then, a new upper margin High and a new lower margin Low of the window are determined (steps ST19 and ST20).

Next, whether or not the current pulse wave cycle S measurement falls within the new window is determined (steps ST9 and ST10). Then, the processing in steps ST11 through ST15 are performed.

This process is performed until variable Run reaches "4", and because each time variable Run is incremented by "1" (step ST17), new coefficients Rmax and Rmin are determined from the table 2 data (step ST18) and window correction is performed (steps ST19 and ST20).

As explained above, window correction area 553D makes the upper margin widest immediately after body movement increases, and subsequently returns the upper margin to the pre-correction state as time passes. This is the first correction.

After variable Run reaches "4", the pulse rate should remain high. Therefore, if step ST21 determines that variable Run is "4", steps ST17 to ST20 are omitted and whether or not the current pulse wave cycle S measurement falls within the new window is determined (steps ST9 and ST10). Thus, the window is determined based on coefficients Rmax and Rmin when variable Run is "4".

Note however that if variable Deff used for determining the change trend of body movements is equal to or less than the threshold on the negative side, -SMth, in step ST23, it indicates that body movement is decreasing, i.e., the pitch is slowing down and the load on the heart is decreasing, and thus the pulse rate is also decreasing. In this case, step ST24 determines whether or not pulse wave cycle S is smaller than pulse wave cycle K150 at pulse rate of 150/minute, i.e., whether or not pulse rate is larger than 150/minute, and if pulse rate is confirmed to be higher than 150/minute, increments variable Run by "1" to "5" (step ST17), and then obtains from the data in Table 2, coefficient Rmax for specifying the upper margin of the window and coefficient Rmin for specifying the lower margin of the window, when variable Run is "5" (step ST18).

Then, a new upper margin High and a new lower margin Low of the window are determined (steps ST19 and ST20).

Next, whether or not the current pulse wave cycle S measurement falls within the new window is determined (steps ST9 and ST10). Then, the processing in steps ST11 through ST15 are performed.

Content of window correction

During the process described above, coefficients Rmax and Rmin are set as shown in the data in Table 2, in this example. Since coefficient Rmax sets the upper margin of the pulse wave cycle window, it sets the lower margin of the pulse rate window. Conversely, since coefficient Rmin sets the lower margin of the pulse wave cycle window, it sets the upper margin of the pulse rate

Table 2

Variable Run	Specific state	Lower margin Rmin of pulse wave cycle	Upper margin Rmax of pulse wave cycle
0	Initial setting	x 0.8	x 1.2
1	First 4 seconds after body movements increase	x 0.2	x 1.1
2	Next 4 seconds	x 0.4	x 1.1
3	Next 4 seconds	x 0.6	x 1.1
4	Afterwards	x 0.8	x 1.1
5	After body movements decrease	x 0.9	x 1.6

As shown in Table 2 and Fig. 16A, variable Run begins at "0" and sets the lower margin of pulse wave cycle 20% longer than the previous measurement value and sets the upper margin of pulse wave cycle 20% shorter than the previous measurement value. When expressed in terms of pulse rate, the upper margin of pulse rate is set 20% larger than the previous measurement value and the lower margin of pulse rate is set 20% smaller than the previous measurement value.

Then, as shown in Fig.s 16B and C, when body movements become larger, variable Run is "1" for the following 4 seconds, and the lower margin of pulse wave cycle is set 80% wider than the previous measurement value and the upper margin of pulse wave cycle is set 10% narrower than the previous measurement value. When expressed in terms of pulse rate, the upper margin of pulse rate is set 80% wider than the previous measurement value and the lower margin of pulse rate is set 10% narrower than the previous measurement value.

For the next 4 seconds, variable Run is "2" and the lower margin of pulse wave cycle is set 60% wider than the previous measurement value and the upper margin of pulse wave cycle is set 10% narrower than the previous measurement value. When expressed in terms of pulse rate, the upper margin of pulse rate is set 60% wider than the previous measurement value and the lower margin of pulse rate is set 10% narrower than the previous measurement value.

For the next 4 seconds, variable Run is "3" and the lower margin of pulse wave cycle is set 40% wider than the previous measurement value and the upper margin of pulse wave cycle is set 10% narrower than the previous measurement value. When expressed in terms of pulse rate, the upper margin of pulse rate is set 40% wider than the previous measurement value and the lower margin of pulse rate is set 10% narrower than the previous measurement value.

After that, variable Run is "4" and the lower margin of pulse wave cycle is set 20% wider than the previous measurement value and the upper margin of pulse wave cycle is set 10% narrower than the previous measurement value, and measurements continue with this window width. When expressed in terms of pulse rate, the upper margin of pulse rate is set 20% wider than the previous measurement value and the lower margin of pulse rate is set 10% narrower than the previous measurement value.

In this embodiment, when the variable Run is "4" the lower margin of pulse wave cycle is set 20% wider than the previous measurement value, the same as when variable Run is "0". This is not essential, the lower margin of pulse wave cycle when variable Run is "4" can be greater or less than the margin when variable Run is "0". For example, Rmin could be 0.7 when variable Run is "0".

The correction performed when variable Run is "1", "2", "3", or "4" is the first correction.

Note that when body movement subsequently decreases, variable Run is "5", and the lower margin of pulse wave cycle is set 10% wider than the previous measurement value and the upper margin of pulse wave cycle is set 60% narrower than the previous measurement value. When expressed in terms of pulse rate, the upper margin of pulse rate is set 10% wider than the previous measurement value and the lower margin of pulse rate is set 60% narrower than the previous measurement value.

The correction performed when variable Run is "5" is the second correction.

Effects of Embodiment 4

As explained above, window correction area 553D widens the upper margin of the window, as the first correction, *when larger body movements are expected to accelerate the pulse; and widens the lower margin of the window,* as the second correction, when smaller body movements are expected to decelerate the pulse, by matching the body movement changes and pulse changes of an actual pattern. Therefore, even when the pulse rate changes greatly, the window can be appropriately determined because it can keep up with the changes. Furthermore, in the first correction, the lower margin of the window is narrowed instead of widening the upper margin, and in the second correction, the lower margin of the window is widened instead of narrowing the upper margin, resulting in higher window determination precision.

Additionally, in the first correction, the upper margin is made widest immediately after body movement increases, and subsequently the upper margin is narrowed as time passes, by matching the actual change pattern. Advantageously, the upper margin may be returned to the pre-correction state as time passes. Therefore, the window need not be made unnecessarily wide, resulting in appropriate window determination.

Furthermore, because a slow pulse rate is confirmed before widening the upper margin of the window during the first correction, and a high pulse rate is confirmed before widening the lower margin of the window during the second correction, the window is always corrected in the right direction.

Another configuration of the body movement change monitoring area

In this example, the fact that the pitch changes as shown in Fig.s 16B and C is utilized by body movement change monitoring area 552D for monitoring changes in body movements. However, since the amplitude of the signal that is output from body movement sensor device 90 also changes when body movements change as shown in Fig.s 16B and C, it is possible to correct the window by recognizing body movement changes based on the changes in the amplitude of the signal that is output from body movement sensor device 90.

Embodiment 5

In embodiment 4, the window for the pulse rate measured by the pulse rateer was corrected based on pitch trend. Instead, it is also possible to correct the window for pitch measured by the pitch counter, based on the pulse trend. In such a case, the processing detail of the window correction is the same as the flow chart shown in Fig. 15, except that pitch (body movement) and pulse wave cycle (pulse rate) are swapped and that the upper and lower margins of the window are set to the specified conditions. Therefore, their explanations are omitted. Fig. 17 shows the configurations of the control area, etc. that are required for the above-mentioned process.

In Fig. 17, the cycle and frequency measurement device is first provided with pulse wave detection sensor unit 30 for detecting pulse wave signals, pulse wave signal amplification circuit 511 for amplifying the pulse wave signals output by said unit, and pulse wave cycle counter 512 for counting the time between the edges of the square waves output by said amplification circuit. The cycle and frequency measurement device is also provided with body movement sensor device 90 for detecting body movement signals, body movement signal amplification circuit 521 for amplifying the body movement signals output by said sensor device, and body movement cycle counter 522 for counting the time between edges of the square waves output by said amplification circuit. The cycle and frequency measurement device is further provided with window determination area 551 that sets a specified reference value based on the previous detection result of body movement sensor device 90 and that determines whether or not the current detection result of body movement sensor device 90 falls within the window defined by the upper and lower margins relative to said reference value, and pitch calculation area 574 that calculates a pitch based on the current detection result of body movement sensor device 90 if this current detection result is within the window.

CPU 55E is provided with pulse change monitoring area 552E (pulse change monitoring means) which monitors whether or not the pulse has accelerated, based on the detection result of pulse wave detection sensor unit 30; and with window correction area 553E (window correction means) which performs the first correction, i.e., widening the upper margin of the window for pitch and narrowing the lower margin, if the monitoring result of pulse change monitoring means 552E indicates faster pulses, and subsequently performs the second correction, i.e., widening the lower margin (to which the first correction was applied earlier) and narrowing the upper margin (to which the first correction was applied earlier), if the monitoring result of the pulse change monitoring means 552E indicates slower pulses. In such a configuration, the lower margin of the window is narrowed instead of widening the upper margin in the first correction, and the upper margin of the window is narrowed instead of widening the lower margin in the second correction, by matching the pitch change pattern, enabling appropriate window correction.

Note that window correction area 553E can be configured such that it makes said upper margin widest, in the first correction, immediately after the pulse accelerates, and subsequently narrows the upper margin as time passes. Advantageously, the upper margin can be returned to the pre-correction state as time passes. With such a configuration, the upper margin of the window can be corrected by matching the actual pitch change pattern. Therefore, the window need not be made unnecessarily wide, resulting in appropriate window determination.

Furthermore, window correction area 553E can be configured such that it performs the first correction if the monitoring result of pulse change monitoring area 552E indicates that the pulse has accelerated and if the previous or the current measured pitch is smaller than a specified value, and performs the second correction if the monitoring result of pulse change monitoring area 552E indicates that the pulse has decelerated and if the previous or the current measured pitch is larger than a specified value. With such a configuration, incorrect window correction can be prevented because a slow pitch is confirmed before widening the upper margin of the window, and a fast pitch is confirmed before widening the lower margin of the window.

Another configuration of the pulse wave data processing area

For measuring pulse rate, it is possible to first use an operational amplifier to amplify the analog signal that is output by pulse wave detection sensor unit 30, then output the result to an A/D converter via a sample hold circuit, perform frequency analysis (high-speed Fourier transformation: FFT processing) on the pulse wave data that has been converted into a digital signal by the A/D converter, and then to measure pulse rate from the resulting spectrum, instead of measuring the time between edges of the square waves that are output by pulse wave signal amplification circuit 511. Furthermore, for measuring and monitoring pitch, it is possible to first use an operational amplifier to amplify the analog signal that is output by body movement sensor device 90, then output the result to an A/D converter via a sample hold circuit, perform frequency analysis (high-speed Fourier transformation: FFT processing) on the pulse wave data that has been converted into a digital signal by the A/D converter, and then to measure pitch from the resulting spectrum, instead of measuring the time between the edges of the square waves that are output by body movement signal amplification circuit 521.

Although the cycle measuring means (pulse or body movement) in the above example is configured to obtain the cycle of the cycle signal (pulse or body movement), it can also be configured to obtain frequency which is the inverse of cycle. Since cycle and frequency correspond univocally to each other, it is possible to select whichever is more convenient in terms of calculation, etc.

It is also possible to treat the one measurement taken immediately before as the current measurement value (pulse rate or pitch), or to treat the average of several measurements taken, including the current one, as the current measurement value (pulse rate or pitch).

Furthermore, in embodiments 4 and 5, window correction areas 553D and 553E correct the window for the current measurement value because they correct the window before the window for the current measurement value is determined. However, instead of such a configuration, it is possible to perform window correction after the window for the current measurement value is determined. In this case, window correction areas 553D and 553E correct the window for the next measurement value.

Effects of the invention

As described above, the cycle and frequency measurement device related to the invention is characterized in that it is provided with a window correction means for reconciling abnormal value elimination by a window determination means with the responsiveness to rapid cycle fluctuations. Therefore, according to the invention, both reliability and accuracy in measurement during exercise can be achieved at the same time.

In particular, when the amount of correction for the window reference value is optimized by forecasting the rising or falling trend of the pulse rate (or body movement) based on the monitoring result of the body movement change monitoring means (pulse change monitor means), the window can be corrected with appropriate responsiveness to changes even when the pulse rate (body movement) temporarily changes rapidly, such as at the start or end of a run, or when the pitch fluctuates greatly. Therefore, appropriate window determination can be performed. As a result, the reliability of pulse rate measurement during exercise and running pitch measurement is greatly increased, and pulse rateers and pitch counters that enables safe and effective training can be provided in the field of sports science.

According to the invention, the upper margin of the window for pulse rate is widened, as the first correction, when increased body movement is expected to accelerate the pulse; the lower margin of the window for pulse rate is widened, as the second correction, when decreased body movement is expected to decelerate the pulse, by matching the body movement changes and pulse changes of an actual pattern, and thus window determination can be appropriately performed because window correction can keep up with the changes even when the pulse rate changes greatly.

Furthermore, when the configuration makes the upper margin widest, in the first correction, immediately after body movement increases, and subsequently narrows the upper margin as time passes, the window can be corrected by matching the actual change pattern, enabling appropriate window determination. Advantageously, the upper margin can be returned to the pre-correction state as time passes.

Additionally, when the lower margin of the window is narrowed, instead of widening the upper margin, as the first correction, and the upper margin of the window is narrowed, instead of widening the lower margin, as the second correction, window determination can be appropriately performed

Furthermore, when a slow pulse rate is confirmed before widening the upper margin of the window, as the first correction, and a fast pulse rate is confirmed before widening the lower margin of the window, as the second correction, incorrect window correction can be prevented.

When the window for pitch is corrected in the same manner as described above by matching the changes in pulse, for pitch measurement, the same effects can be obtained.

The aforegoing description has been given by way of example only and it will be appreciated by a person skilled in the art that modifications can be made without departing from the scope of the present invention.

Claims

1. *A cycle and frequency measurement device (1) characterized by comprising;*

   a sensor means (30, 90) for measuring pulse waves and body movements;
   a window determination means (551) for setting a reference value based on the measurements previously taken by said sensor means and for determining whether or not the current measurement value taken by said sensor means falls within the window defined by the upper and lower margins relative to said reference value; and
   a window correction means (553) that corrects the window to be used for the next measurement value to be taken by said sensor means, by applying a specified correction to the current measurement value if the determination result of said window determination means indicates that said current measurement value taken by said sensor means falls outside the current window.

2. The cycle and frequency measurement device according to Claim 1 and further characterized in that;

   said window correction means is configured such that it increments the current measurement value and uses the result as a new reference value if the determination result of said window determination means indicates that the current measurement value exceeds the upper margin of said window; and
   such that it decrements the current measurement value and uses the result as a new reference value if the determination result of said window determination means indicates that the current measurement value falls below the lower margin of said window.

3. The cycle and frequency measurement device according to Claim 1 or Claim 2 and further characterized by com-

prising;

a calculation means (554) that calculates status values such as pulse rate and pitch based on the current measurement values if the determination result of said window determination means indicates that said current measurement values taken by said sensor means fall within the window, and that calculates status values such as pulse rate and pitch based on the reference values generated from said measurement values by said window correction means if the determination result of said window determination means indicates that said current measurement values taken by said sensor means fall outside the window; and
a display means (13) that displays status values such as pulse rate and pitch calculated by said calculation means.

4. The cycle and frequency measurement device according to any of Claims 1 through 3 and further characterized in that;
said upper and lower margins are equal.

5. A cycle and frequency measurement device (1) characterized by comprising;

a body movement detection sensor means (90) for sensing body movements;
a pulse wave detection sensor means (30) for sensing pulse waves;
a window determination means (551) that sets a reference value based on the measurements previously taken by one of said pulse wave detection sensor means or said body movement detection sensor means and that determines whether or not the current measurement value taken by said one of said sensor means falls within the window defined by upper and lower margins relative to said reference value;
a change monitoring means (552) for monitoring the change in the measurement value taken by the other sensor means;
and a window correction means (553) that corrects the window to be used for the current measurement value or the next measurement value to be taken by said one of said sensor means, based on the monitoring result of said change monitoring means.

6. The cycle and frequency measurement device according to Claim 5 and further characterized in that;
said one of said sensor means is said pulse wave detection sensor means, said other sensor means is said body movement detection sensor means, and said change monitoring means is a body movement change monitoring means that monitors body movement changes based on the measurement values of said body movement detection sensor means.

7. A cycle and frequency measurement device according to Claim 6 and further characterized in that;

said window correction means is configured such that it corrects the window for the next measurement value to be taken by said pulse wave detection sensor means, by adjusting the current measurement value taken by said pulse wave detection sensor means in a sense corresponding to an increase in pulse rate and using the result as a new reference value if the determination result of said window determination means indicates that the current measurement value taken by said pulse wave detection sensor means falls outside the window and if the monitoring result by said body movement change monitoring means shows that body movement has increased; and
by adjusting the current measurement value taken by said pulse wave detection sensor means in a sense corresponding to a decrease in pulse rate and using the result as a new reference value if the determination result of said window determination means indicates that the current measurement value taken by said pulse wave detection sensor means falls outside the window and if the monitoring result by said body movement change monitoring means shows that body movement has decreased.

8. The cycle and frequency measurement device according to Claim 7 and further characterized by comprising;

a pulse rate calculation means (554) that calculates pulse rate based on the current measurement value if the determination result of said window determination means indicates that said current measurement value taken by said pulse wave detection sensor means falls within the window, and that calculates pulse rate based on the reference value generated from said measurement values by said window correction means if the determination result of said window determination means indicates that said current measurement value taken by said pulse wave detection sensor means falls outside the window; and a display means (13) that displays the pulse rate calculated by said pulse rate calculation means.

9. The cycle and frequency measurement device according to Claims 7 or 8 and further characterized in that;
said window correction means is configured such that it makes corrections to the current measurement value taken by said pulse wave detection sensor means based on the rate of change of the amount of body movement, determined based on the monitoring result of said body movement change monitoring means.

10. The cycle and frequency measurement device according to any of Claims 5 through 9 and further characterized in that;
said upper and lower margins are equal.

11. The cycle and frequency measurement device according to Claim 6 and further characterized in that;
said window correction means is configured such that it corrects the window to be used for the current measurement value or the next measurement value to be taken by said pulse wave detection sensor means, by performing a first correction, i.e., widening a first margin corresponding to increased pulse rate, if the monitoring result of said body movement change monitoring means indicates increased body movement, and by performing a second correction, i.e., widening a second margin corresponding to decreased pulse rate, if the monitoring result of said body movement change monitoring means indicates decreased body movement.

12. The cycle and frequency measurement device according to Claim 11 and further characterized in that;
said window correction means makes said first margin wider in the first correction, immediately after body movement increases, and subsequently narrows said first margin as time passes.

13. The cycle and frequency measurement device according to Claim 11 or Claim 12 and further characterized in that;
said window correction means is configured such that it narrows said second margin, in the first correction, immediately after body movement increases; and narrows said first margin, in the second correction, immediately after body movement decreases.

14. The cycle and frequency measurement device according to any of Claims 11 through 13 and further characterized in that;
said window correction means is configured such that it performs the first correction when the monitoring result of said body movement change monitoring means indicates increased body movement and the previous or the current measurement value taken by said pulse wave detection sensor means corresponds to a pulse rate below a specified value, and performs the second correction when the monitoring result of said body movement change monitoring means indicates decreased body movement and the previous or the current measurement value taken by said pulse wave detection sensor means correspnds to a pulse rate above a specified value.

15. The cycle and frequency measurement device according to Claim 5 and further characterized in that;
said one of said sensor means is said body movement detection sensor means, said other sensor means is said pulse wave detection sensor means, and said change monitoring means is a pulse change monitoring means that monitors pulse changes based on the measurement values taken by said pulse wave detection sensor means.

16. The cycle and frequency measurement device according to Claim 15 and further characterized in that;

said window correction means is configured such that it corrects the window for the next measurement value to be taken by said body movement detection sensor means, by adjusting the current measurement value taken by said body movement detection sensor means in a sense corresponding to an increase in body movement and using the result as a new reference value if the determination result of said window determination means indicates that the current measurement value taken by said body movement detection sensor means falls outside the window and if the monitoring result by said pulse change monitoring means shows that the pulse rate has accelerated; and
by adjusting the current measurement value taken by said body movement detection sensor means in a sense corresponding to a decrease in body movement and using the result as a new reference value if the determination result of said window determination means indicates that the current measurement value taken by said body movement detection sensor means falls outside the window and if the monitoring result by said pulse change monitoring means shows that the pulse rate has decelerated.

17. The cycle and frequency measurement device according to Claim 16 and further characterized by comprising;

a pitch calculation means (574) that calculates pitch based on the current measurement value if the determination result of said window determination means indicates that said current measurement value taken by said body movement detection sensor means falls within the window, and that calculates pitch based on the reference value generated from said measurement value by said window correction means if the determination result of said window determination means indicates that said current measurement value taken by said body movement detection sensor means falls outside the window; and
a display means (13) that displays the pitch calculated by said pitch calculation means.

18. The cycle and frequency measurement device according to Claims 16 or 17 and further characterized in that;
said window correction means is configured such that it makes corrections to the current measurement value taken by said body movement detection sensor means based on the rate of change of the pulse rate, determined based on the monitoring result of said pulse change monitoring means.

19. The cycle and frequency measurement device according to any of Claims 16 through 18 and further characterized in that;
said upper and lower margins are equal.

20. The cycle and frequency measurement device according to Claim 15 and further characterized in that;
said window correction means is configured such that it corrects the window to be used for the current measurement value or the next measurement value to be taken by said body movement detection sensor means, by performing the first correction, i.e., widening a first margin corresponding to increased body movement, if the monitoring result of said pulse wave change monitoring means indicates a faster pulse rate, and by performing the second correction, i.e., widening a second margin corresponding to decreased body movement, if the monitoring result of said pulse wave change monitoring means indicates a slower pulse rate.

21. The cycle and frequency measurement device according to Claim 20 and further characterized in that;
said window correction means makes said first margin wider in the first correction, immediately after the pulse rate accelerates; and subsequently narrows said first margin as time passes.

22. The cycle and frequency measurement device according to Claims 20 or 21 and further characterized in that;
said window correction means is configured such that it narrows said second margin in the first correction, immediately after the pulse rate accelerates; and narrows said first margin in the second correction, immediately after the pulse rate decelerates.

23. The cycle and frequency measurement device according to any of Claims 20 through 22 and further characterized in that;
said window correction means is configured such that it performs the first correction if the monitoring result of said pulse wave change monitoring means indicates a faster pulse rate and if the previous or the current measurement value taken by said body movement detection sensor means corresponds to a body movement rate below a specified value, and performs the second correction if the monitoring result of said pulse wave change monitoring means indicates a slower pulse rate and if the previous or the current measurement value taken by said body movement detection sensor means corresponds to a body movement rate above a specified value.

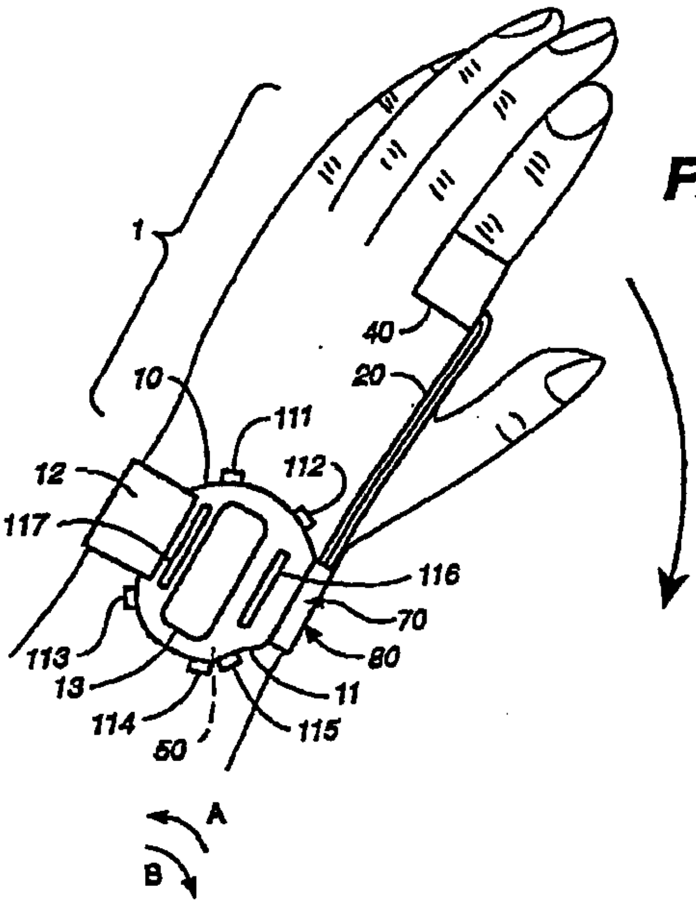


FIG._1A

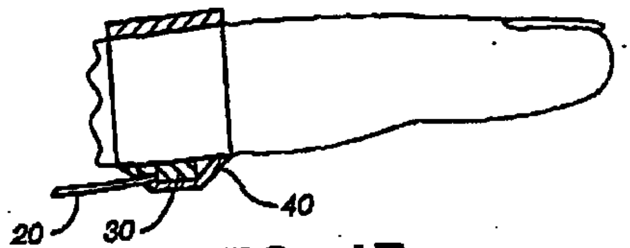
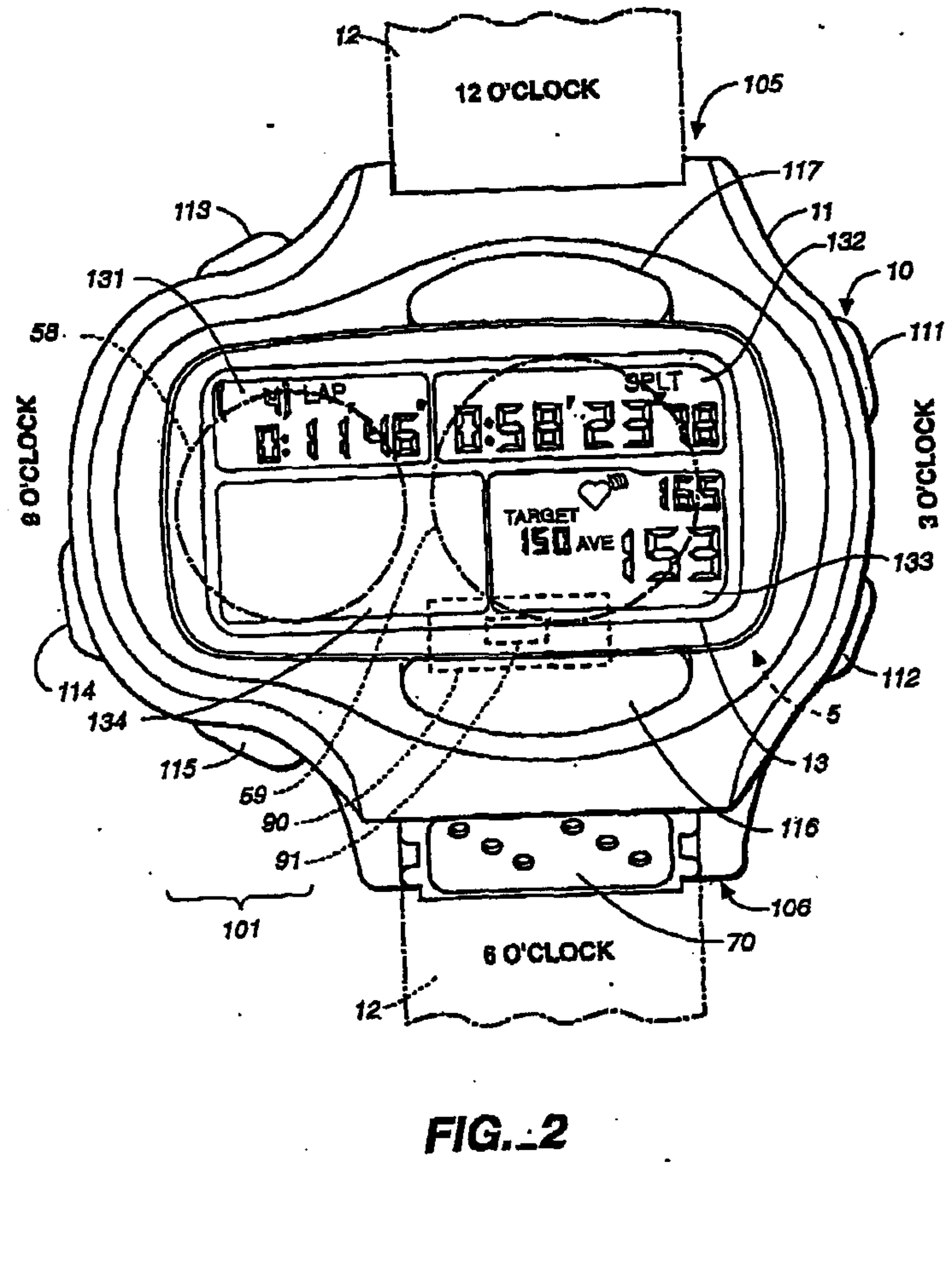


FIG._1B



12
12 O'CLOCK
105
117
113
11
132
10
131
111
58
SPLT
LAP
9 O'CLOCK
3 O'CLOCK
TARGET
150 AVE
165
153
133
114
112
134
5
13
115
59
116
90
91
106
101
70
6 O'CLOCK
12

FIG._2

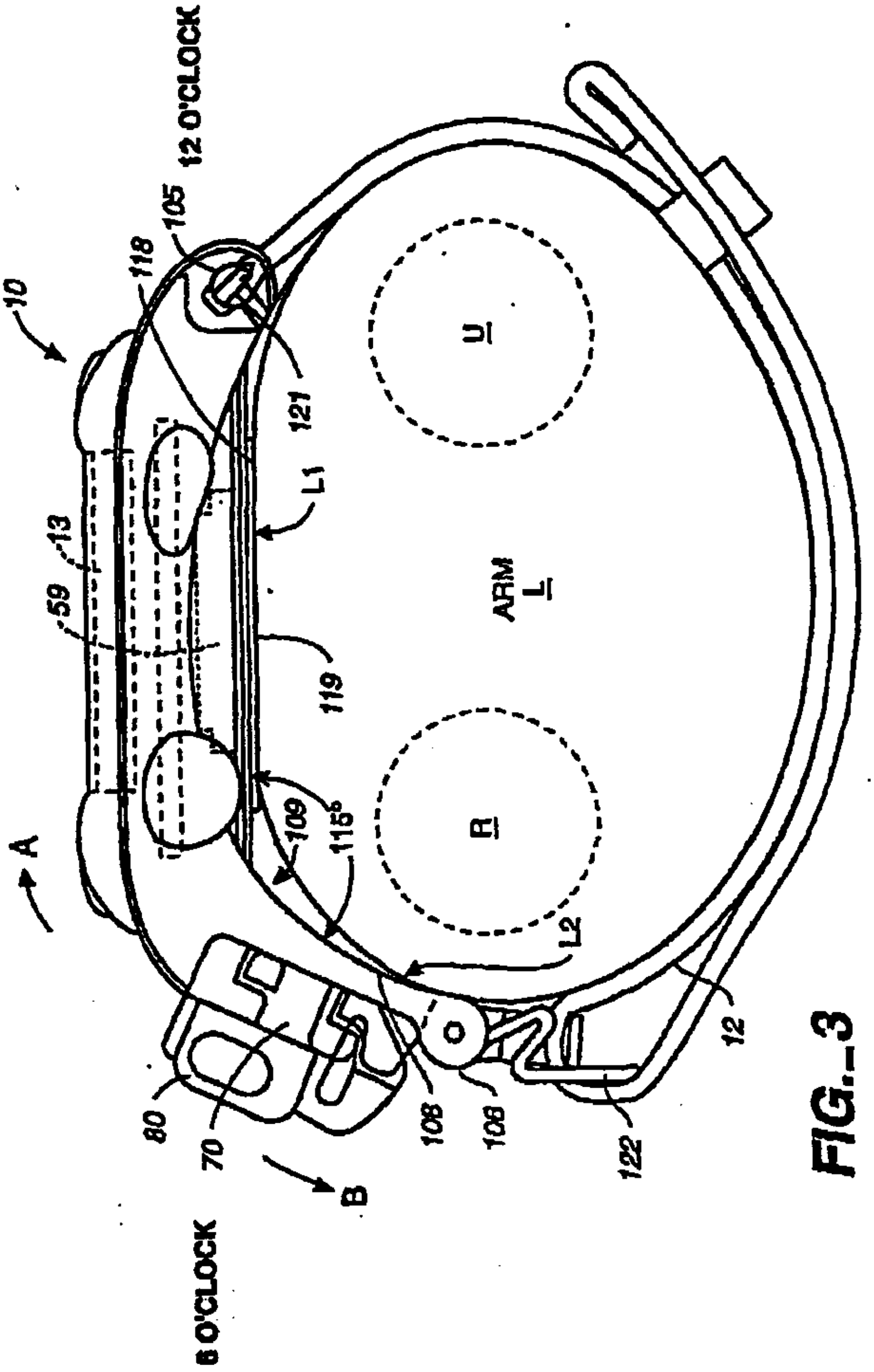

10
12 O'CLOCK
105
118
121
U
L1
13
59
ARM
L
119
R
109
115b
A
L2
12
122
108
108
70
80
B
6 O'CLOCK

FIG._3

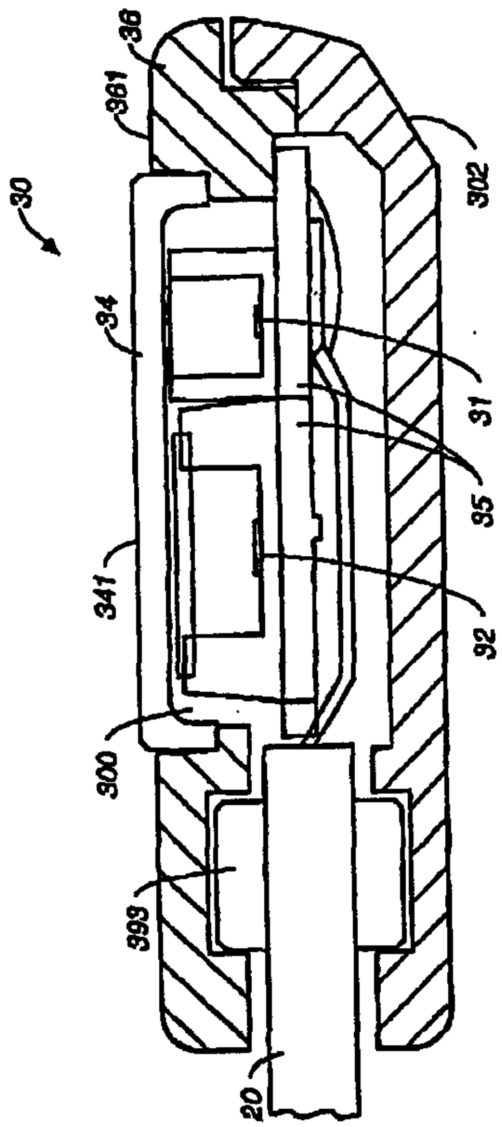
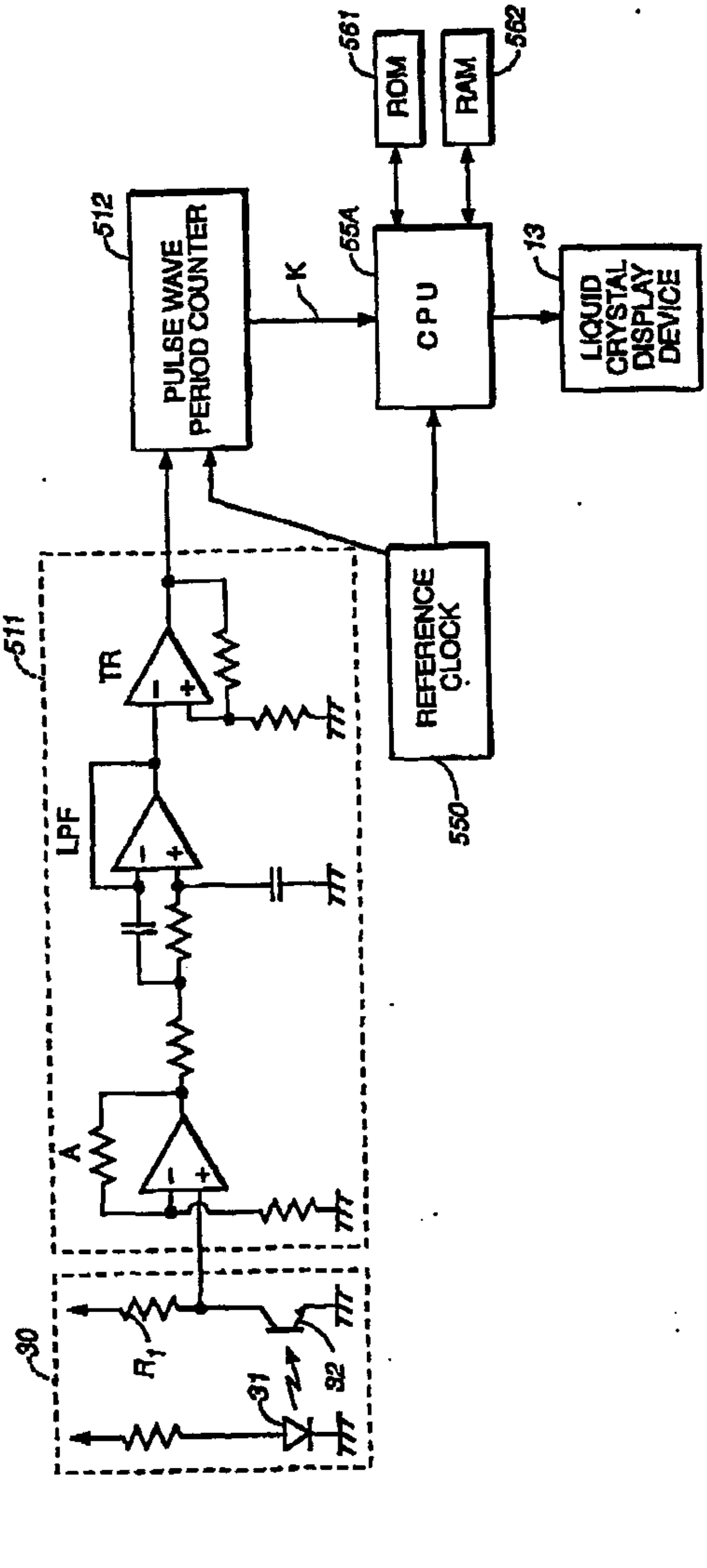


FIG._4



561
ROM
562
RAM
512
PULSE WAVE
PERIOD COUNTER
K
55A
CPU
13
LIQUID
CRYSTAL
DISPLAY
DEVICE
511
TR
LPF
A
REFERENCE
CLOCK
550
30
R1
31
32

FIG._5

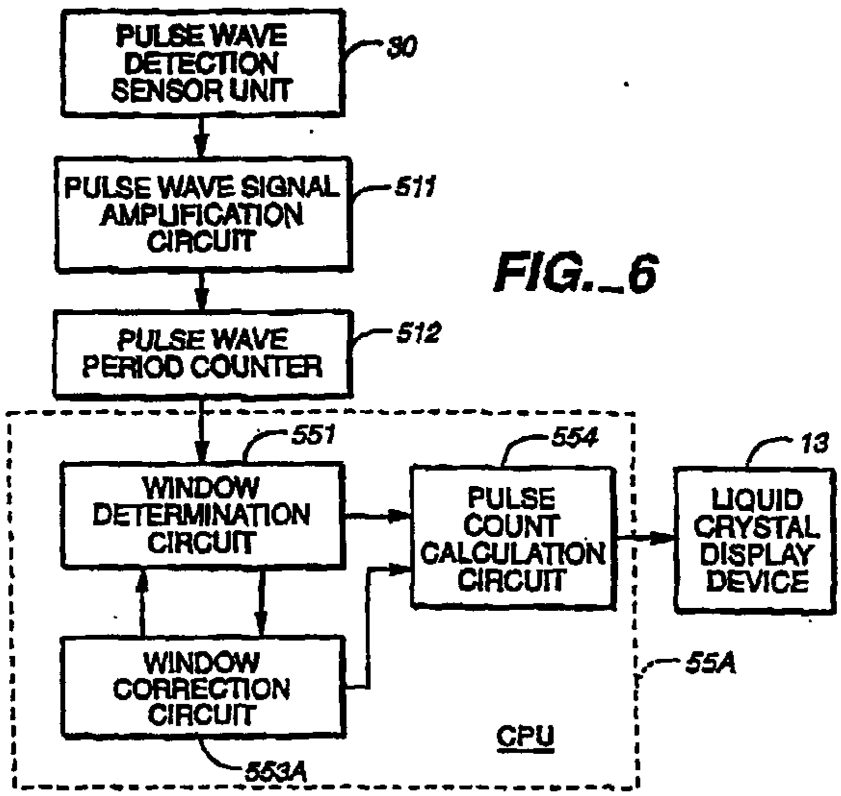

PULSE WAVE DETECTION SENSOR UNIT
30
PULSE WAVE SIGNAL AMPLIFICATION CIRCUIT
511
PULSE WAVE PERIOD COUNTER
512
551
WINDOW DETERMINATION CIRCUIT
554
PULSE COUNT CALCULATION CIRCUIT
13
LIQUID CRYSTAL DISPLAY DEVICE
WINDOW CORRECTION CIRCUIT
553A
CPU
55A

FIG._6

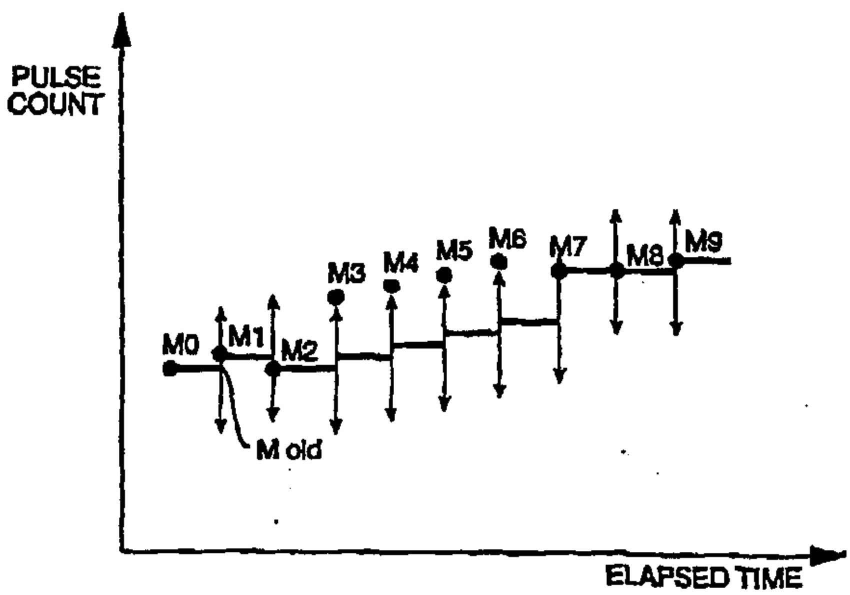
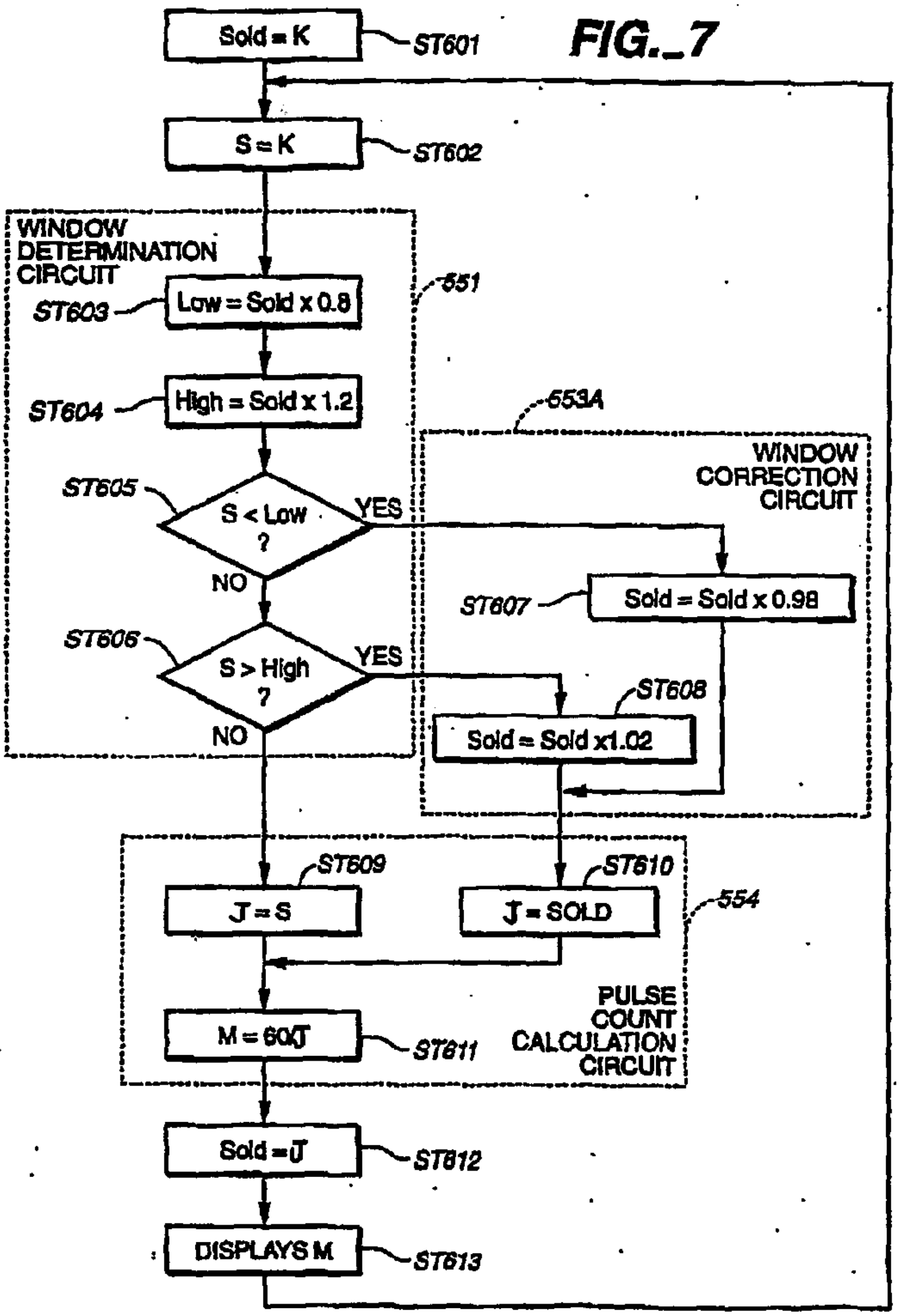

PULSE COUNT
M0
M1
M2
M3
M4
M5
M6
M7
M8
M9
M old
ELAPSED TIME

FIG._8

FIG._7


Sold = K
ST601
S = K
ST602
WINDOW DETERMINATION CIRCUIT
551
ST603
Low = Sold x 0.8
ST604
High = Sold x 1.2
553A
WINDOW CORRECTION CIRCUIT
ST605
S < Low ?
YES
NO
ST607
Sold = Sold x 0.98
ST606
S > High ?
YES
NO
ST608
Sold = Sold x1.02
ST609
ST610
554
J = S
J = SOLD
PULSE COUNT CALCULATION CIRCUIT
M = 60/J
ST611
Sold = J
ST612
DISPLAYS M
ST613

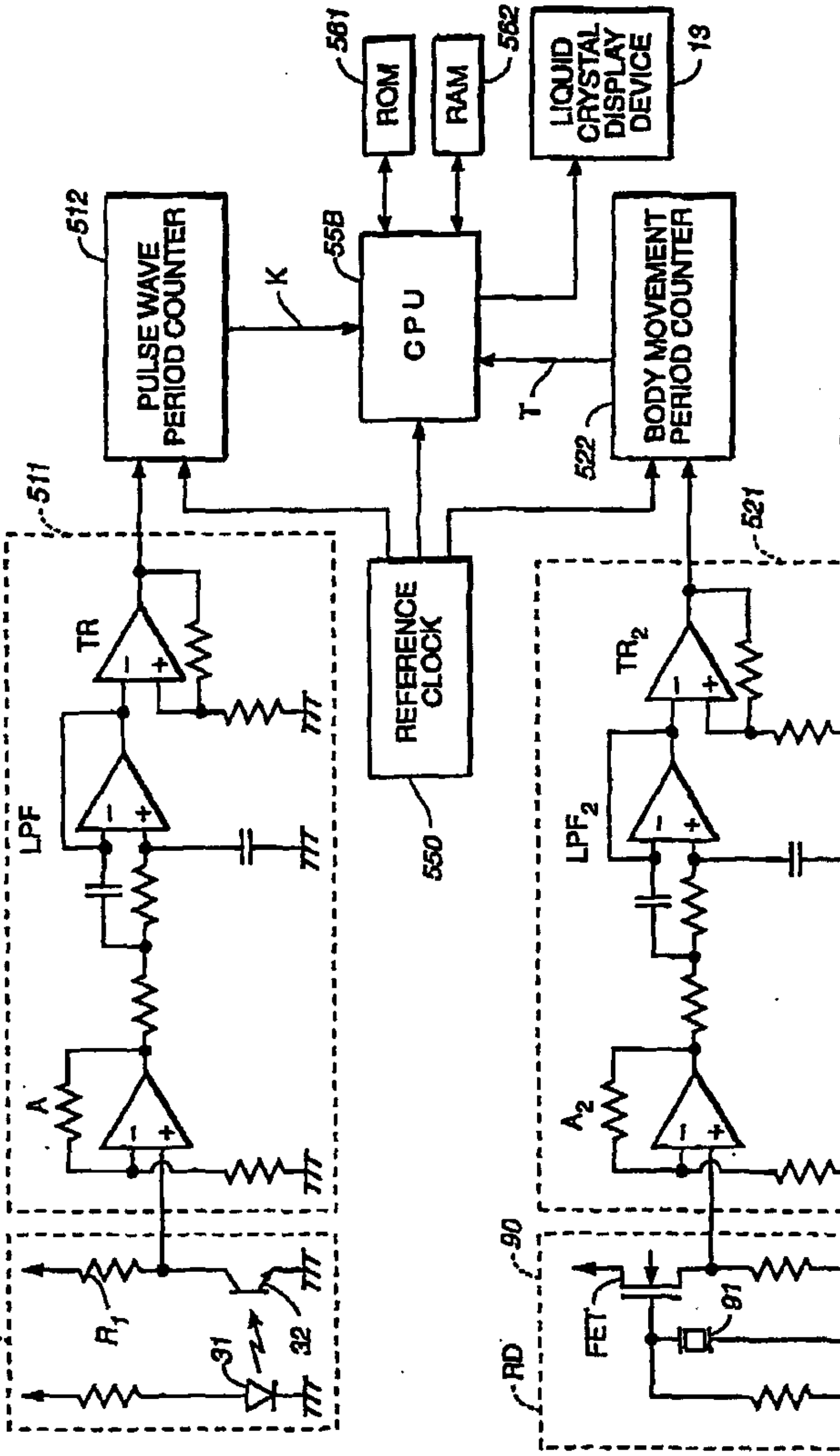

PULSE WAVE PERIOD COUNTER
512
K
CPU
55B
ROM
581
RAM
582
LIQUID CRYSTAL DISPLAY DEVICE
13
T
BODY MOVEMENT PERIOD COUNTER
522
REFERENCE CLOCK
550
511
521
30
R1
31
32
A
LPF
TR
90
RD
FET
91
A2
LPF2
TR2

FIG._9

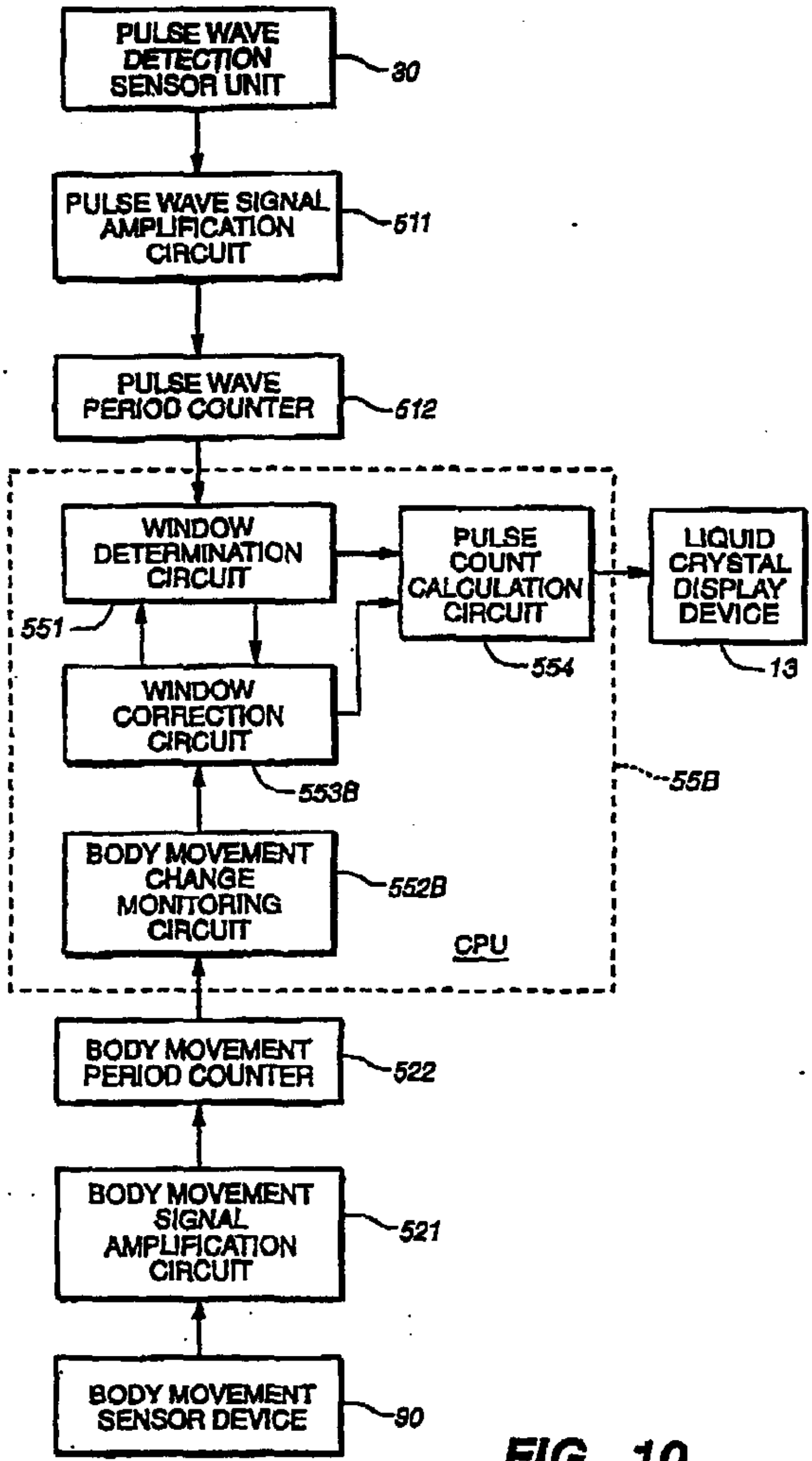
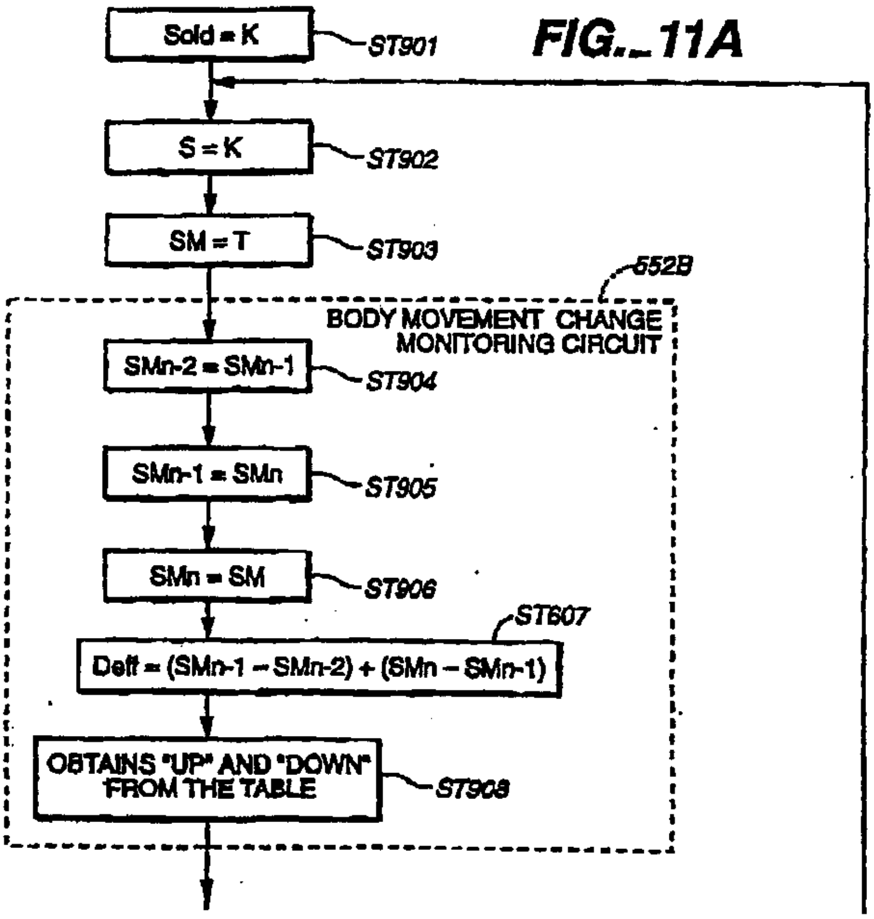

PULSE WAVE DETECTION SENSOR UNIT
30
PULSE WAVE SIGNAL AMPLIFICATION CIRCUIT
511
PULSE WAVE PERIOD COUNTER
512
WINDOW DETERMINATION CIRCUIT
551
PULSE COUNT CALCULATION CIRCUIT
554
LIQUID CRYSTAL DISPLAY DEVICE
13
WINDOW CORRECTION CIRCUIT
553B
55B
BODY MOVEMENT CHANGE MONITORING CIRCUIT
552B
CPU
BODY MOVEMENT PERIOD COUNTER
522
BODY MOVEMENT SIGNAL AMPLIFICATION CIRCUIT
521
BODY MOVEMENT SENSOR DEVICE
90

FIG._10

FIG._11

FIG._11A



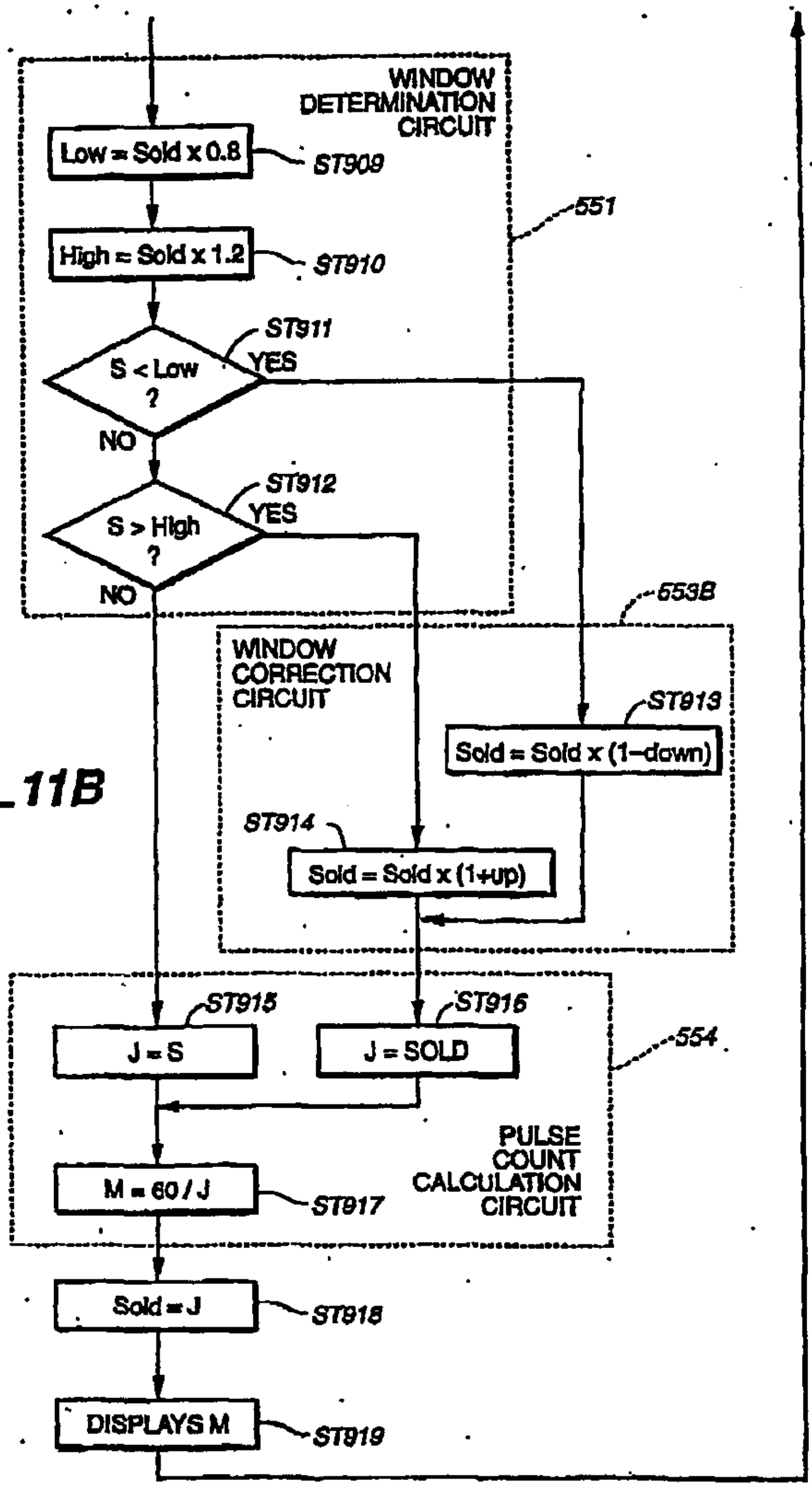

WINDOW DETERMINATION CIRCUIT
Low = Sold x 0.8
ST909
551
High = Sold x 1.2
ST910
ST911
S < Low ?
YES
NO
ST912
S > High ?
YES
NO
653B
WINDOW CORRECTION CIRCUIT
ST913
Sold = Sold x (1−down)
ST914
Sold = Sold x (1+up)
ST915
J = S
ST916
J = SOLD
554
PULSE COUNT CALCULATION CIRCUIT
M = 60 / J
ST917
Sold = J
ST918
DISPLAYS M
ST919

FIG._11B

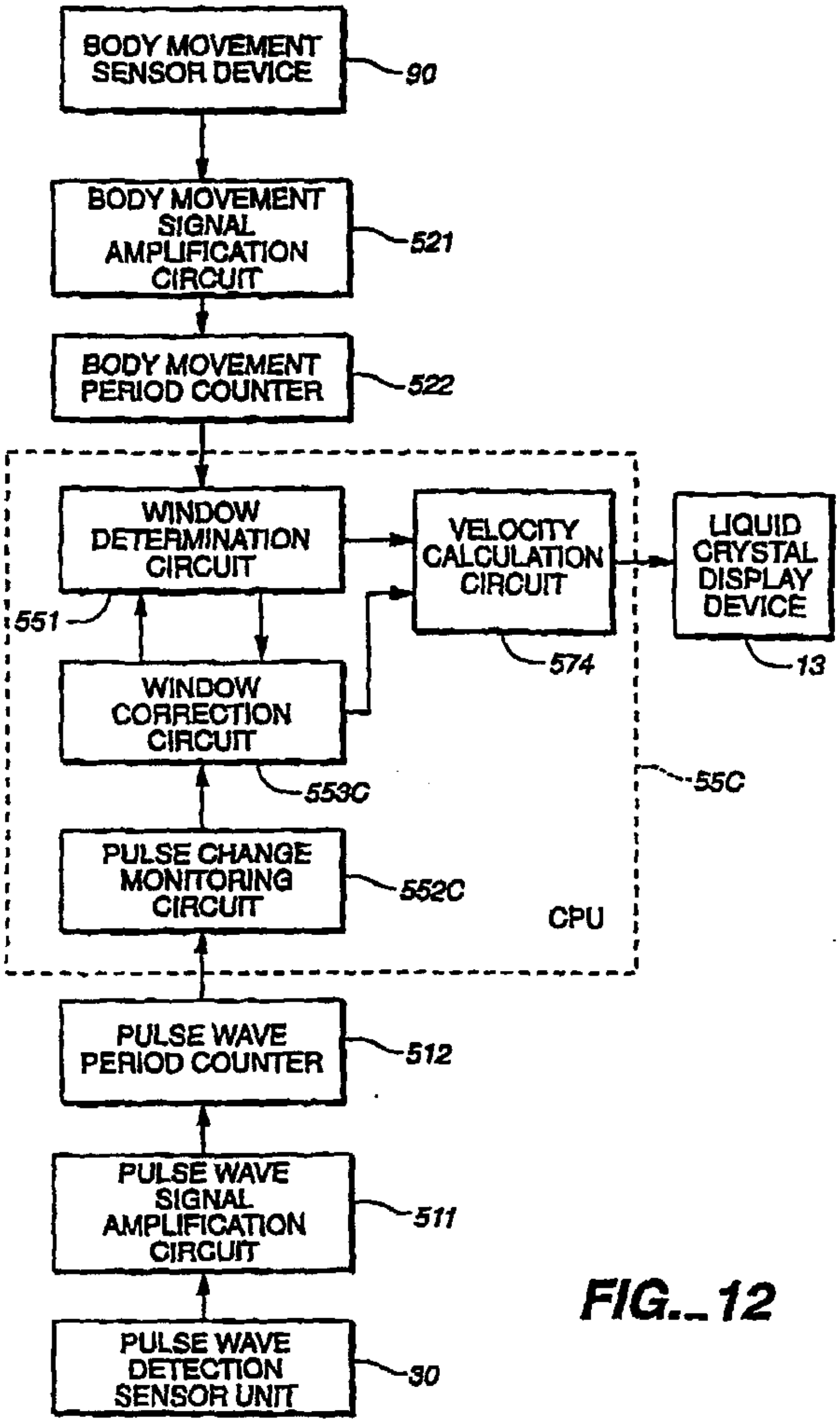

BODY MOVEMENT SENSOR DEVICE
90
BODY MOVEMENT SIGNAL AMPLIFICATION CIRCUIT
521
BODY MOVEMENT PERIOD COUNTER
522
WINDOW DETERMINATION CIRCUIT
551
VELOCITY CALCULATION CIRCUIT
574
LIQUID CRYSTAL DISPLAY DEVICE
13
WINDOW CORRECTION CIRCUIT
553C
55C
PULSE CHANGE MONITORING CIRCUIT
552C
CPU
PULSE WAVE PERIOD COUNTER
512
PULSE WAVE SIGNAL AMPLIFICATION CIRCUIT
511
PULSE WAVE DETECTION SENSOR UNIT
30

FIG._12

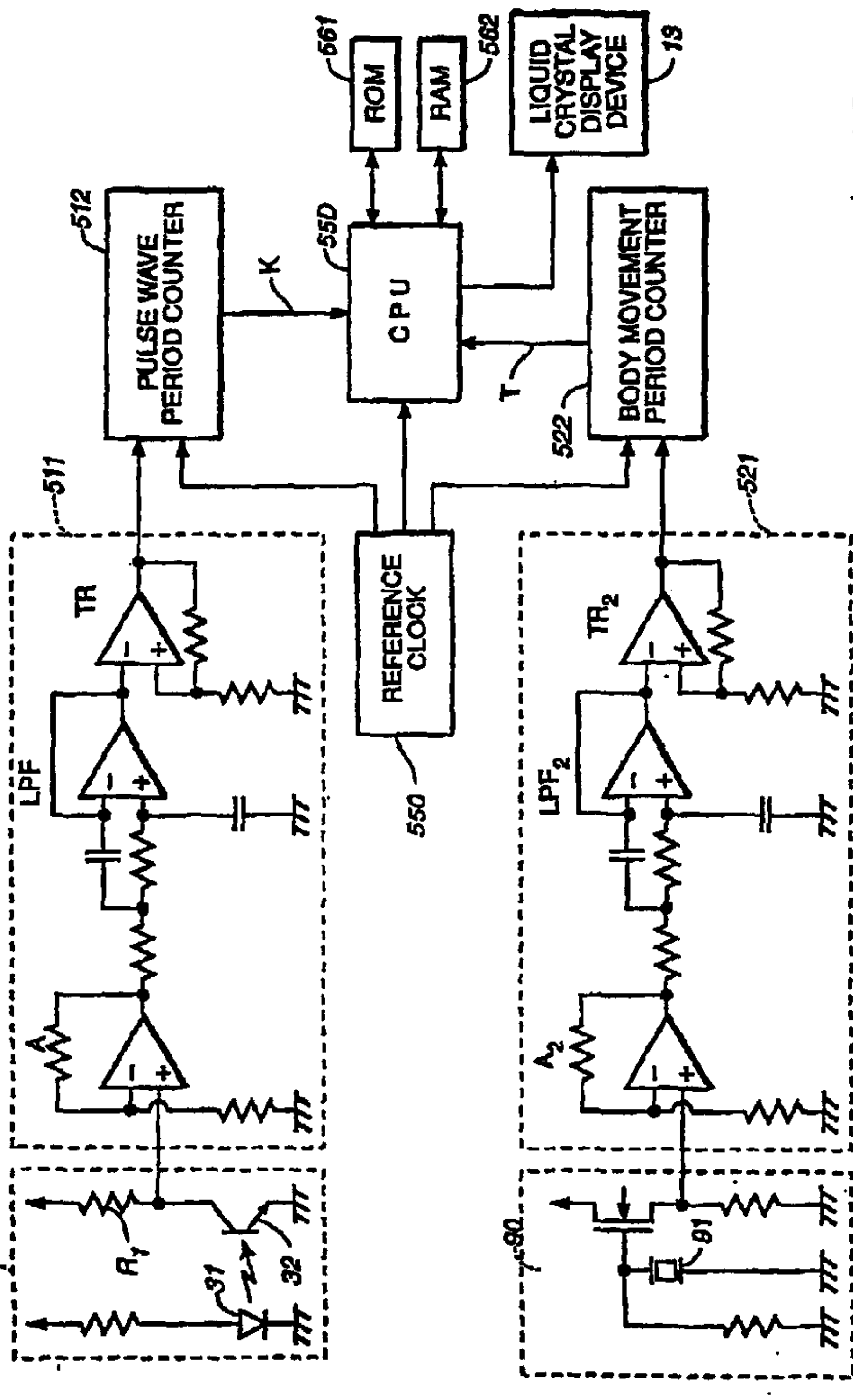

PULSE WAVE PERIOD COUNTER
512
K
55D
C P U
ROM
561
RAM
562
LIQUID CRYSTAL DISPLAY DEVICE
19
T
BODY MOVEMENT PERIOD COUNTER
522
REFERENCE CLOCK
550
511
521
TR
TR_2
LPF
LPF_2
A
A_2
30
R_1
31
32
90
91

FIG._13

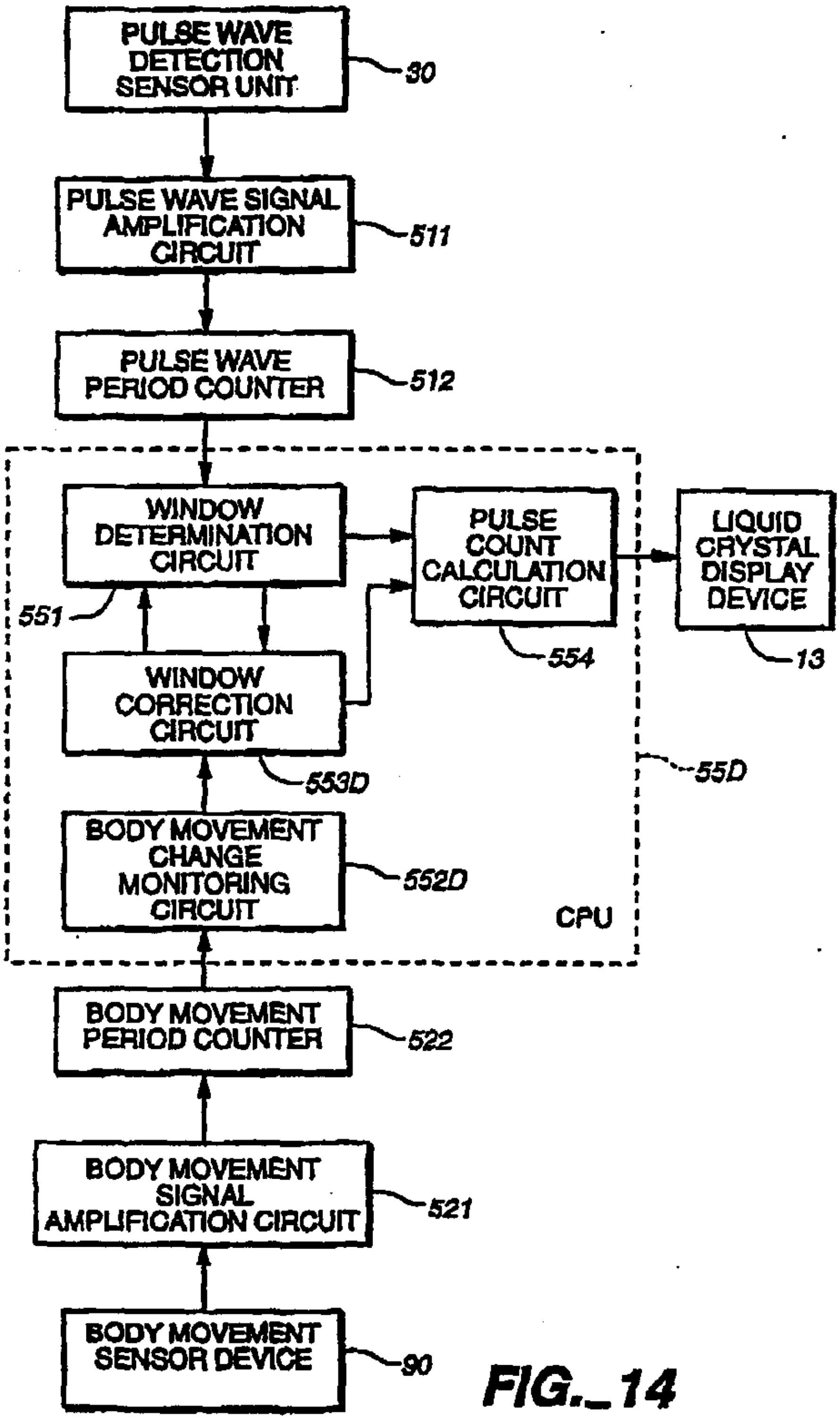

PULSE WAVE DETECTION SENSOR UNIT
30
PULSE WAVE SIGNAL AMPLIFICATION CIRCUIT
511
PULSE WAVE PERIOD COUNTER
512
WINDOW DETERMINATION CIRCUIT
551
PULSE COUNT CALCULATION CIRCUIT
554
LIQUID CRYSTAL DISPLAY DEVICE
13
WINDOW CORRECTION CIRCUIT
553D
55D
BODY MOVEMENT CHANGE MONITORING CIRCUIT
552D
CPU
BODY MOVEMENT PERIOD COUNTER
522
BODY MOVEMENT SIGNAL AMPLIFICATION CIRCUIT
521
BODY MOVEMENT SENSOR DEVICE
90

FIG._14

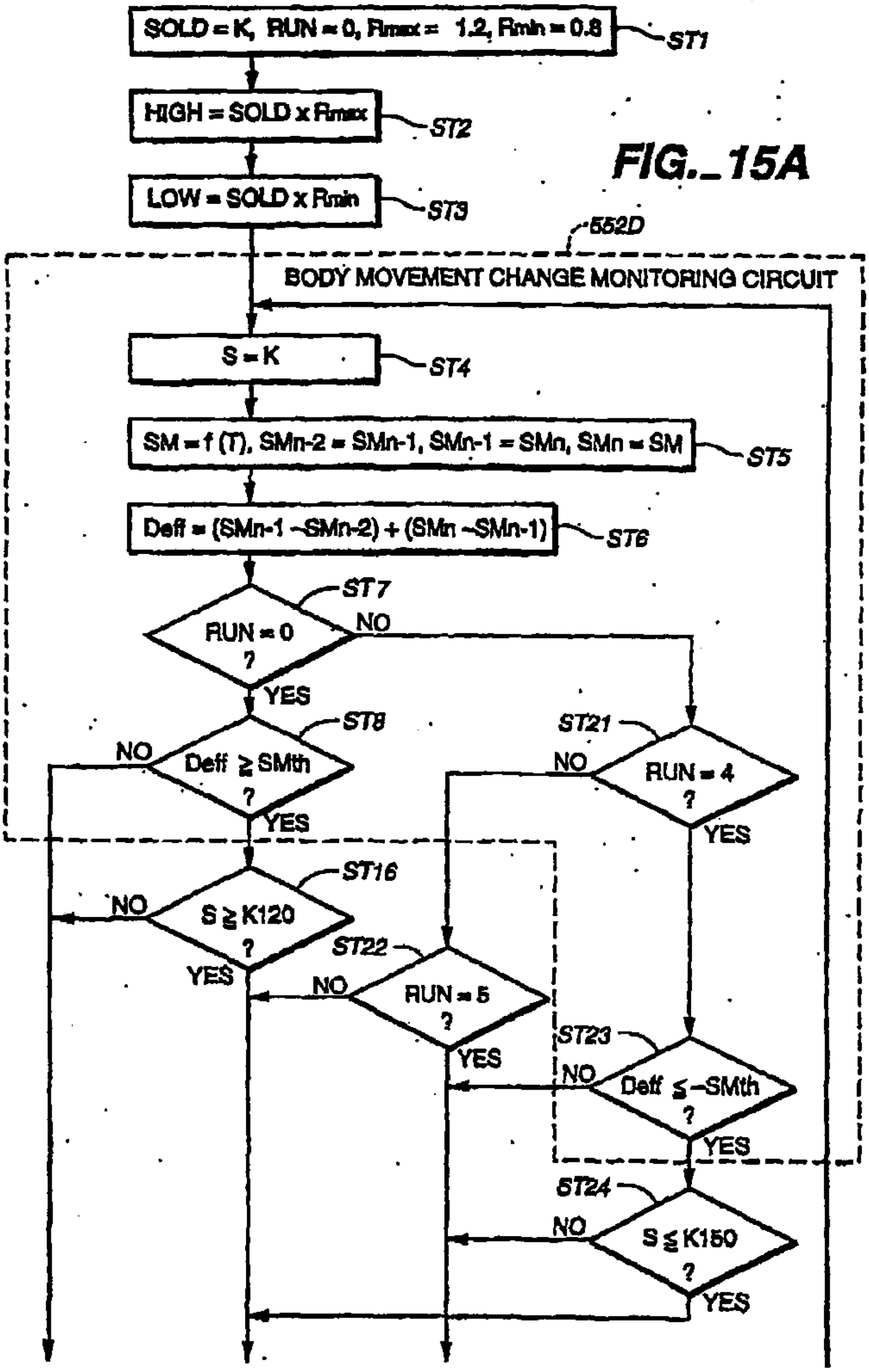

SOLD = K, RUN = 0, Rmax = 1.2, Rmin = 0.8
ST1
HIGH = SOLD x Rmax
ST2
LOW = SOLD x Rmin
ST3
552D
BODY MOVEMENT CHANGE MONITORING CIRCUIT
S = K
ST4
SM = f (T), SMn-2 = SMn-1, SMn-1 = SMn, SMn = SM
ST5
Deff = (SMn-1 -SMn-2) + (SMn -SMn-1)
ST6
ST7
RUN = 0 ?
NO
YES
ST8
Deff ≧ SMth ?
NO
YES
ST21
RUN = 4 ?
NO
YES
ST16
S ≧ K120 ?
NO
YES
ST22
RUN = 5 ?
NO
YES
ST23
Deff ≦ -SMth ?
NO
YES
ST24
S ≦ K150 ?
NO
YES

FIG._15A

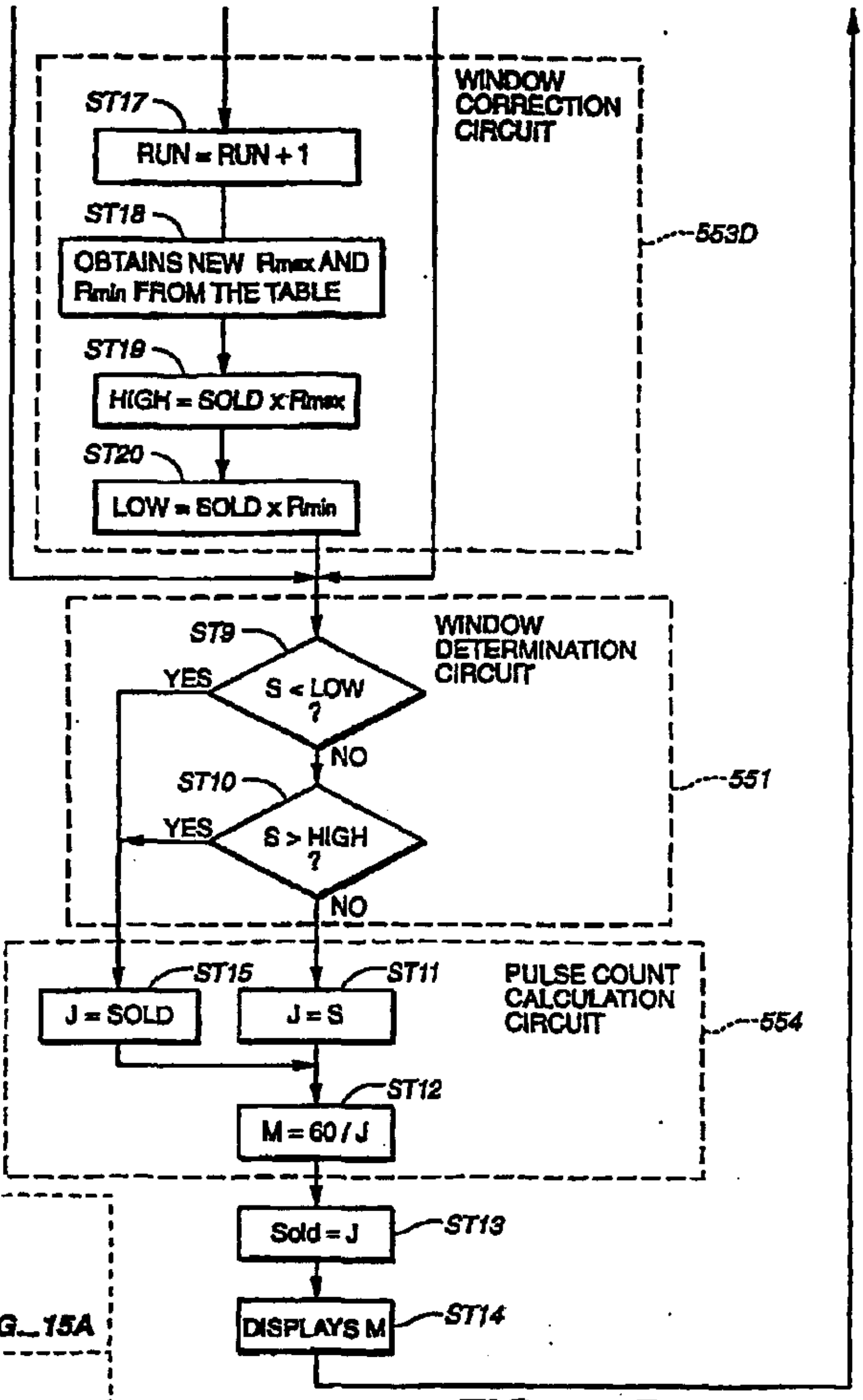


FIG._15B

FIG._15

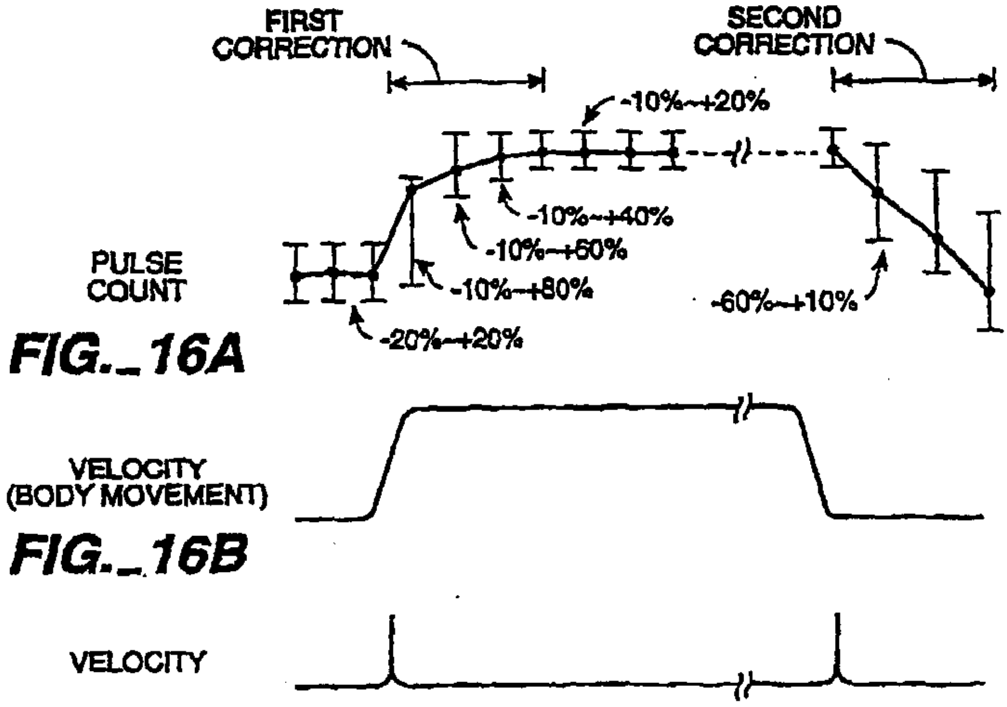


FIG._16A

FIG._16B

FIG._16C

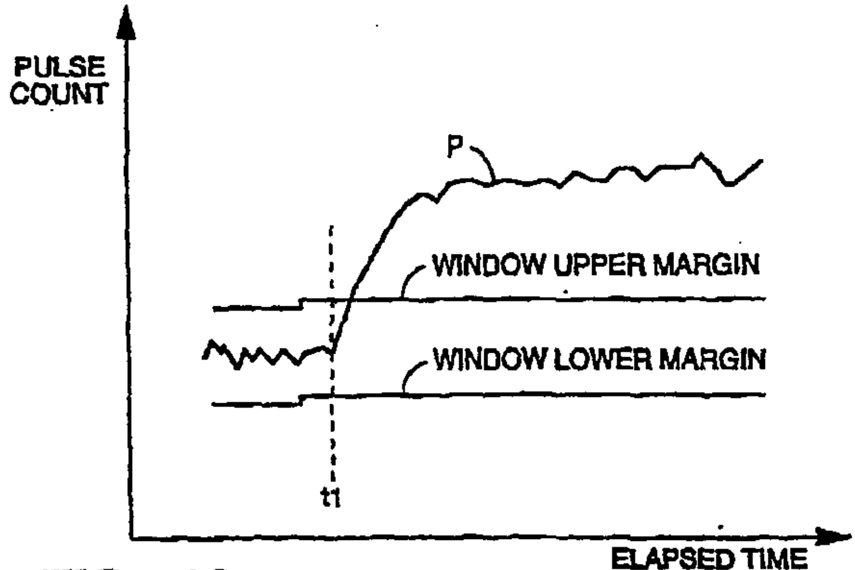


FIG._18

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 96 30 1110

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
A	US 5 337 753 A (G. LEKHTMAN) * column 3, line 55 - column 4, line 35; figures 1-9 * ---	1-5	A61B5/024 A61B5/22 G01R23/15
A	EP 0 614 070 A (SEIKO INSTRUMENTS INC.) * abstract; figures 1-13 * ---	1,5,15	
A	US 4 202 350 A (C.A. WALTON) * the whole document * ---	1,5,15	
A	WO 93 14815 A (VITATRON MEDICAL B.V.) * abstract; figures 1-18 * ---	1,5	
A	US 4 407 295 A (R.R. STEUER ET AL.) * the whole document * -----	1,5	
			TECHNICAL FIELDS SEARCHED (Int.Cl.6)
			A61B G01R

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	12 September 1997	Hunt, B

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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A : technological background
O : non-written disclosure
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T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)

專利摘要　　　：

目標

提供循環及頻率量度設備，透過使窗口根隨轉變(即使當脈沖率或音高大幅轉變)可執行適當的窗口確定。

解決問題的方法

在量度脈沖率的裝置中，首先，用於量度結果的上邊際被設定爲大於上一量度值的 20%而下邊際則被設定爲小於上一量度值的 20%。其後，當身體移動增加時，在此後的 4 秒，上邊際會由上一量度值擴闊 80%，而下邊際則收窄 10%。此後，上邊際被收窄至+60%，+40%及+20%。應注意的是，若身體移動減少，上邊際會由上一量度值擴闊 10%，與此同時，下邊際則被設定爲上一量度值的-60%。