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Rantala et al.

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(54) **PULSE OXIMETER**

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(73) Assignee: **GE Healthcare Finland OY** (FI)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **10/661,012**

(22) Filed: **Sep. 12, 2003**

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Related U.S. Application Data

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(51) **Int. Cl.**[7] **A61B 5/00**
(52) **U.S. Cl.** **600/322**; 600/330
(58) **Field of Search** 600/322–324, 600/330

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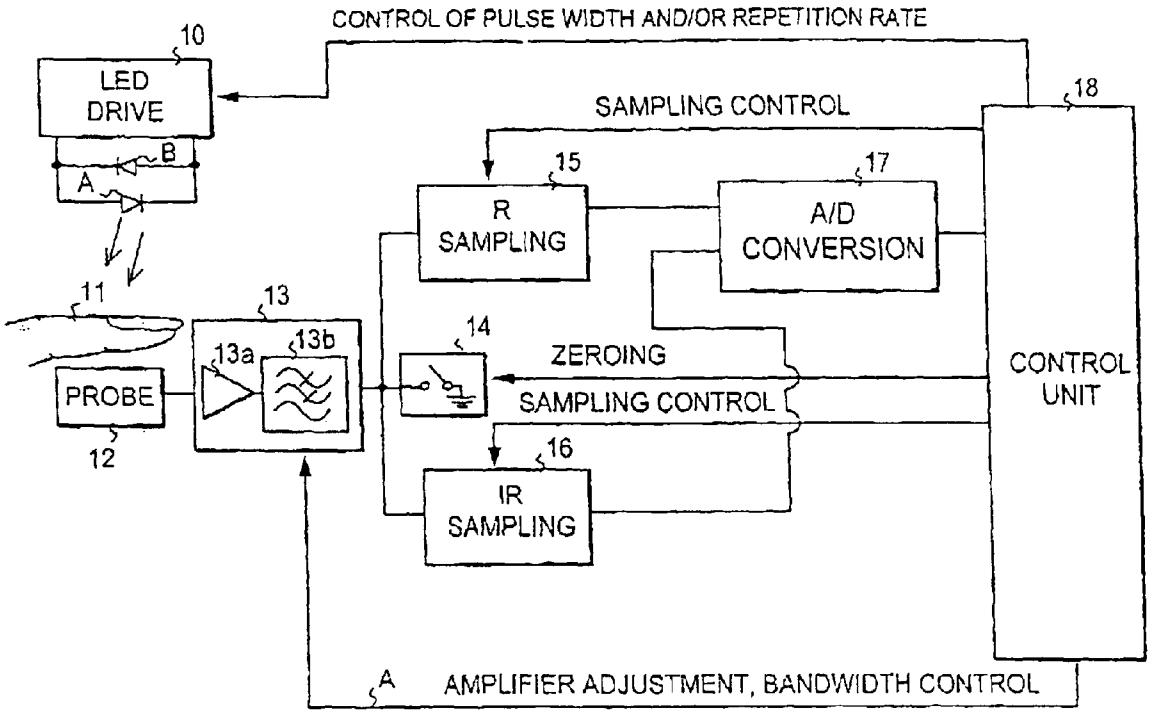
(57) **ABSTRACT**

The invention relates to pulsed oximeters used to measure blood oxygenation. The current trend towards mobile oximeters has brought the problem of how to minimize power consumption without compromising on the performance of the device. To tackle this problem, the present invention provides a method for controlling optical power in a pulse oximeter. The signal-to-noise ratio of the received baseband signal is monitored, and the duty cycle of the driving pulses is controlled in dependence on the monitored signal-to-noise ratio, preferably so that the optical power is minimized within the confines of a predetermined lower threshold set for the signal-to-noise ratio. In this way the optical power is made dependent on the perfusion level of the subject, whereby the power can be controlled to a level which does not exceed that needed for the subject.

32 Claims, 3 Drawing Sheets



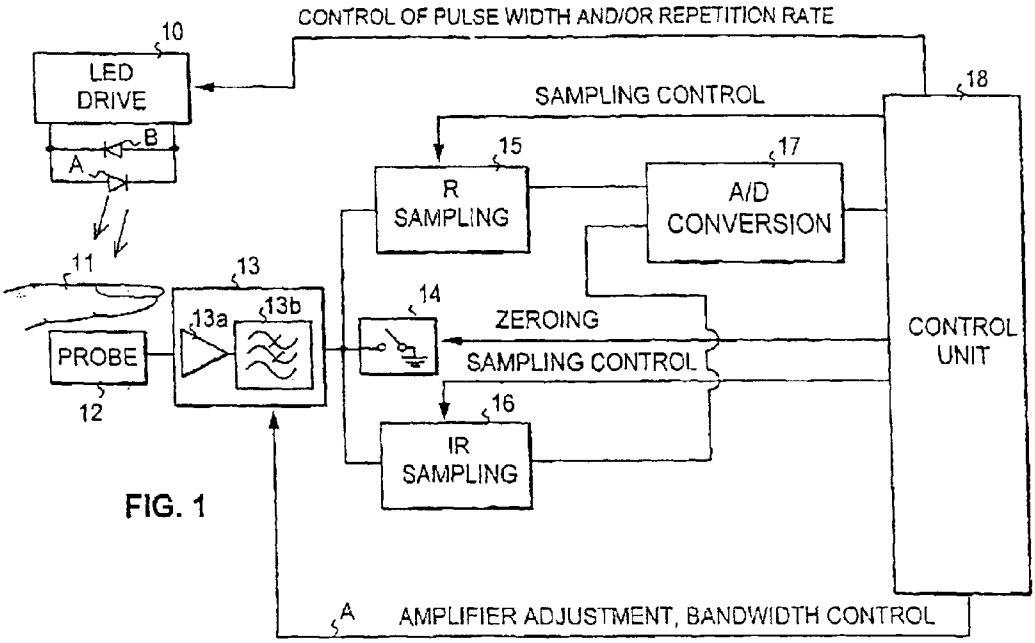


FIG. 1

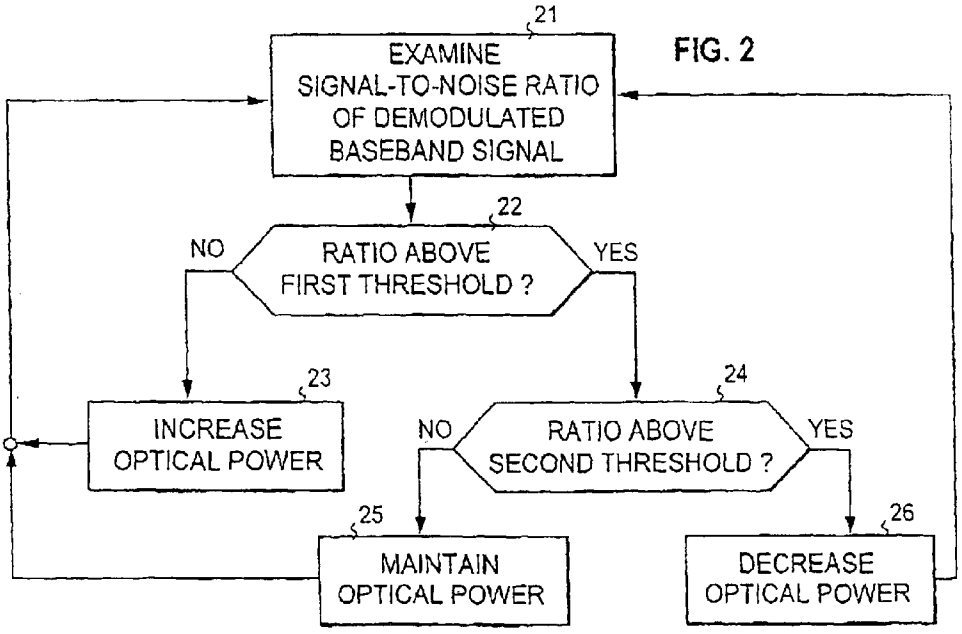


FIG. 2

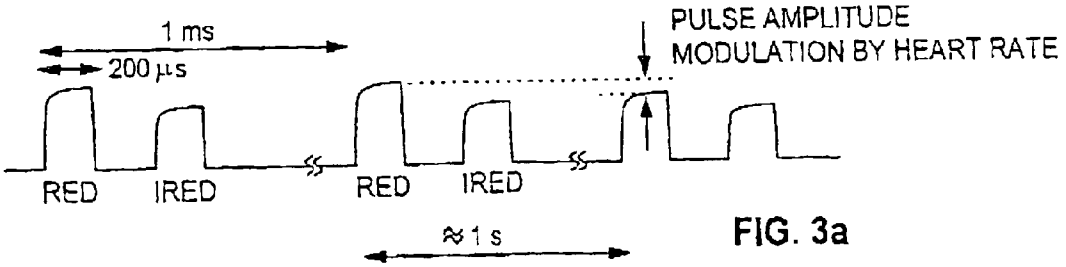


FIG. 3a

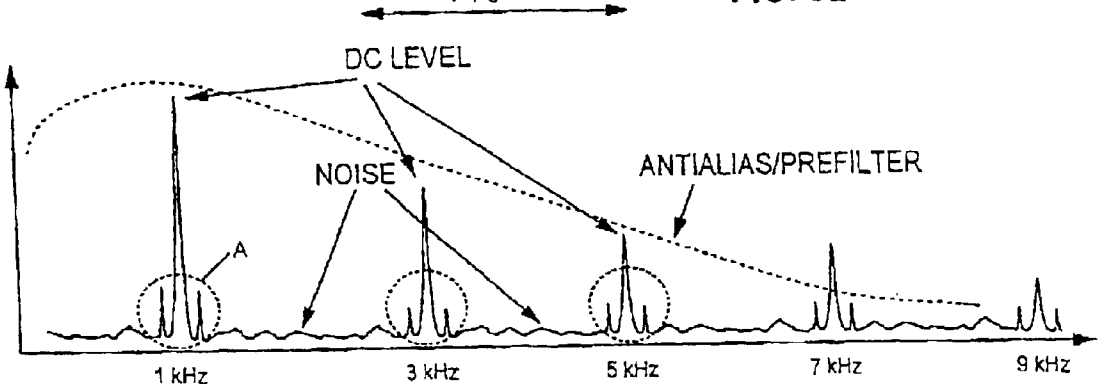


FIG. 3b

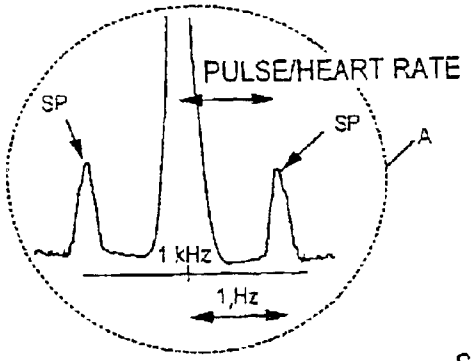


FIG. 3c

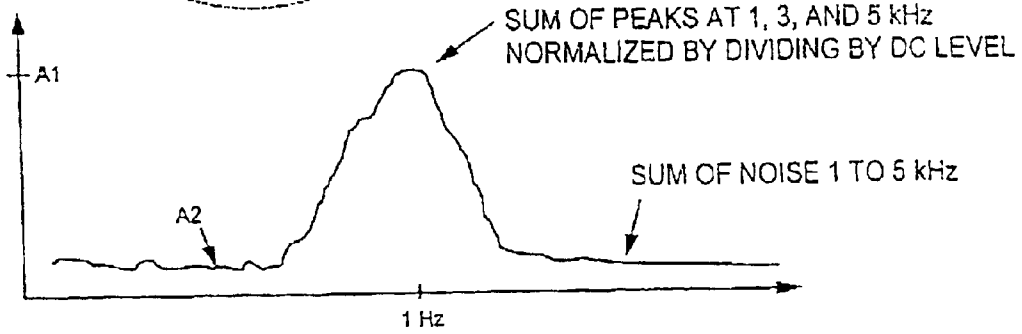


FIG. 3d

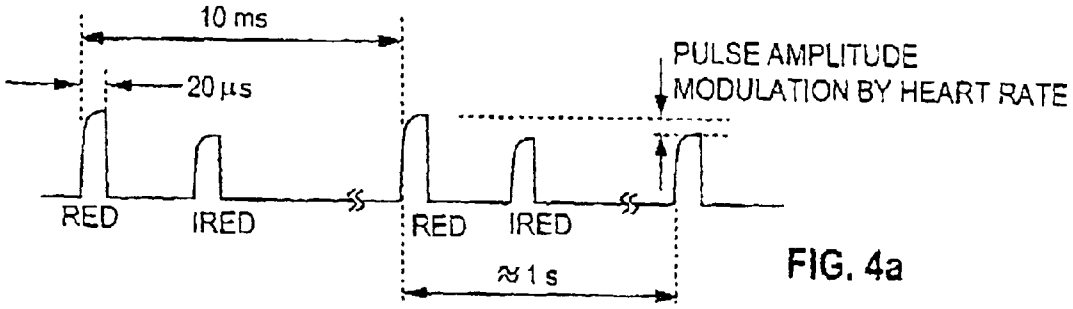


FIG. 4a

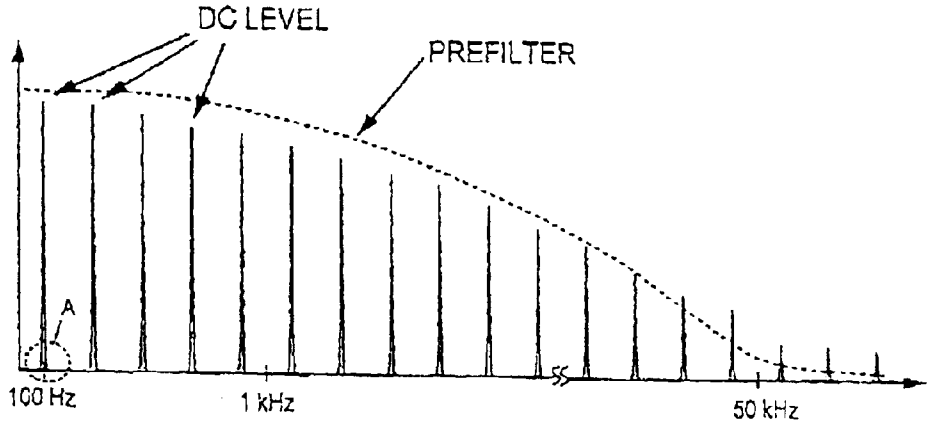


FIG. 4b

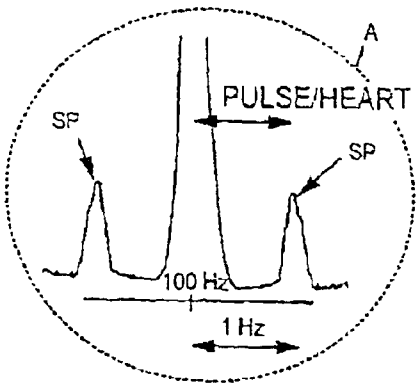


FIG. 4c

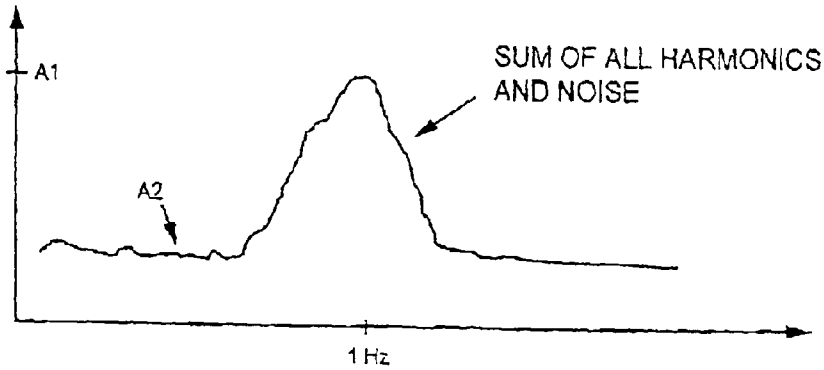


FIG. 4d

PULSE OXIMETER

RELATED APPLICATION

This application claims priority under 35 U.S.C. § 119 to prior U.S. Provisional Patent Application No. 60/410,526, filed Sep. 13, 2002, entitled "PULSE OXIMETER", the entire contents of which are incorporated herein as if set forth herein in full.

FIELD OF THE INVENTION

The invention relates generally to devices used for non-invasively determining the amount of at least one light absorbing substance in a subject. These devices are typically pulse oximeters used to measure the blood oxygenation of a patient. More specifically, the invention relates to the optimization of power consumption in such a device.

BACKGROUND OF THE INVENTION

Pulse oximetry is at present the standard of care for the continuous monitoring of arterial oxygen saturation (SpO_2). Pulse oximeters provide instantaneous in-vivo measurements of arterial oxygenation, and thereby provide early warning of arterial hypoxemia, for example.

A pulse oximeter comprises a computerized measuring unit and a probe attached to the patient, typically to his or her finger or ear lobe. The probe includes a light source for sending an optical signal through the tissue and a photo detector for receiving the signal after transmission through the tissue. On the basis of the transmitted and received signals, light absorption by the tissue can be determined. During each cardiac cycle, light absorption by the tissue varies cyclically. During the diastolic phase, absorption is caused by venous blood, tissue, bone, and pigments, whereas during the systolic phase, there is an increase in absorption, which is caused by the influx of arterial blood into the tissue. Pulse oximeters focus the measurement on this arterial blood portion by determining the difference between the peak absorption during the systolic phase and the constant absorption during the diastolic phase. Pulse oximetry is thus based on the assumption that the pulsatile component of the absorption is due to arterial blood only.

Light transmission through an ideal absorbing sample is determined by the known Lambert-Beer equation as follows:

$$I_{out}=I_{in}\epsilon^{-\epsilon DC}, \quad (1)$$

where I_{in} is the light intensity entering the sample, I_{out} is the light intensity received from the sample, D is the path length through the sample, ϵ is the extinction coefficient of the analyte in the sample at a specific wavelength, and C is the concentration of the analyte. When I_{in}, D, and ϵ are known and I_{out} is measured, the concentration C can be calculated.

In pulse oximetry, in order to distinguish between the two species of hemoglobin, oxyhemoglobin (HbO_2), and deoxyhemoglobin (RHb), absorption must be measured at two different wavelengths, i.e. the probe includes two different light emitting diodes (LEDs). The wavelength values widely used are 660 nm (red) and 940 nm (infrared), since the said two species of hemoglobin have substantially different absorption values at these wavelengths. Each LED is illuminated in turn at a frequency which is typically several hundred Hz.

The accuracy of a pulse oximeter is affected by several factors. This is discussed briefly in the following.

hemogiobin (CoHb), absorb light at the wavelengths used in the measurement. Pulse oximeters are set up to measure oxygen saturation on the assumption that the patient's blood composition is the same as that of a healthy, non-smoking individual. Therefore, if these species of hemoglobin are present in higher concentrations than normal, a pulse oximeter may display erroneous data.

Secondly, intravenous dyes used for diagnostic purposes may cause considerable deviation in pulse oximeter readings. However, the effect of these dyes is short-lived since the liver purifies blood efficiently.

Thirdly, coatings such as nail polish may in practice impair the accuracy of a pulse oximeter, even though the absorption caused by them is constant, not pulsatile, and thus in theory it should not have any effect on the accuracy.

Fourthly, the optical signal may be degraded by both noise and motion artifacts. One source of noise is the ambient light received by the photodetector. Many solutions have been devised with the aim of minimizing or eliminating the effect of the movement of the patient on the signal, and the ability of a pulse oximeter to function correctly in the presence of patient motion depends on the design of the pulse oximeter. One way of canceling out the motion artifact is to use an extra wavelength for this purpose.

One of the current trends in pulse oximetry is the aim towards lower power consumption, which is essential for battery-operated oximeters, for example. These oximeters are typically mobile and must therefore be used in various locations where both the characteristics of the patient and the surrounding measurement environment may vary. A problem related to these various measurement conditions is the optimization of power consumption without compromising the performance of the device, i.e. how to guarantee reliable measurement results even in difficult measurement conditions and still keep the battery life as long as possible.

The current straightforward solution for obtaining reliable measurement results under tough measurement conditions is to increase the driving power of the LEDs. This approach is based on the transmittance of the tissue: if the level of the signal transmitted through the tissue is not enough to guarantee reliable results, the level of the transmitted signal (i.e. the amplitude of the pulse train) is increased until the level of the signal received is sufficient. This is naturally contrary to the need to save power.

It is an objective of the invention to bring about a solution by means of which it is possible to dynamically optimize the power consumption in a pulse oximeter, especially in a portable battery-operated pulse oximeter, and to maintain good performance even in tough measurement conditions, where the transmittance and/or the perfusion level, as indicated by the normalized pulsatile component, are low.

SUMMARY OF THE INVENTION

These and other objectives of the invention are accomplished in accordance with the principles of the present invention by providing a power-saving scheme which allows the pulse oximeter to use no more power than that which is needed to drive the emitters while maintaining good performance of the oximeter. In this scheme, the signal-to-noise requirements are compromised in favor of power consumption, as long as this does not compromise measurement reliability.

According to the invention, the patient-specific effect of the tissue on the measurement result is taken into account, whereby the optical power, i.e. the power supplied to acti-

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