US 20070208240A1

(19) **United States**
(12) **Patent Application Publication**
Nordstrom et al.
(10) **Pub. No.: US 2007/0208240 A1**
(43) **Pub. Date: Sep. 6, 2007**

(54) **TECHNIQUES FOR DETECTING HEART PULSES AND REDUCING POWER CONSUMPTION IN SENSORS**

(75) Inventors: **Brad Nordstrom**, Alameda, CA (US); **William Shea**, Livermore, CA (US); **Ethan Petersen**, Castro Valley, CA (US)

Correspondence Address:
Nellcor Puritan Bennett LLC
c/o Fletcher Yoder PC
P.O. BOX 692289
HOUSTON, TX 77269-2289 (US)

(73) Assignee: **Nellcor Puritan Bennett Inc.**, Pleasanton, CA

(21) Appl. No.: **11/650,861**

(22) Filed: **Jan. 8, 2007**

Related U.S. Application Data

(63) Continuation of application No. 10/787,851, filed on Feb. 25, 2004, now Pat. No. 7,162,288.

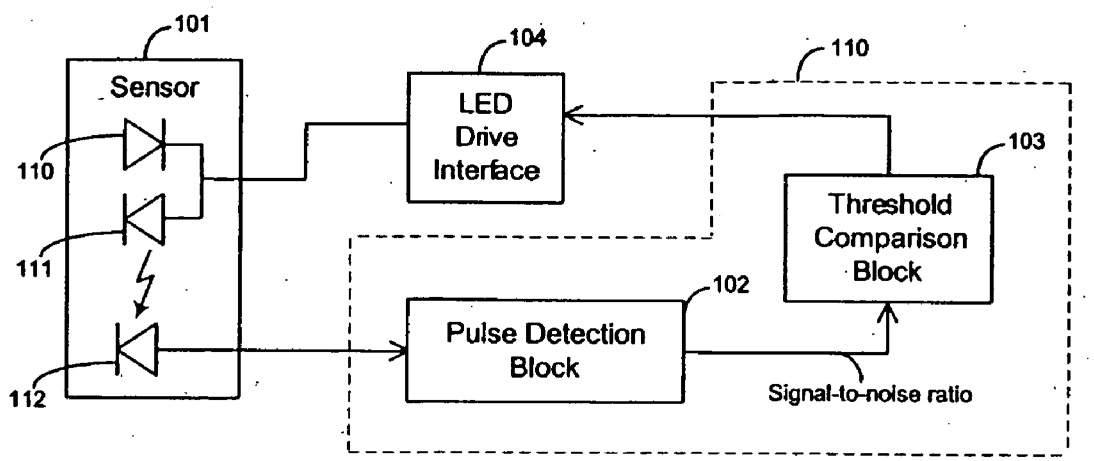
Publication Classification

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

(52) **U.S. Cl.** **600/323**; 600/336

(57) **ABSTRACT**

Low power techniques for sensing cardiac pulses in a signal from a sensor are provided. A pulse detection block senses the sensor signal and determines its signal-to-noise ratio. After comparing the signal-to-noise ratio to a threshold, the drive current of light emitting elements in the sensor is dynamically adjusted to reduce power consumption while maintaining the signal-to-noise ratio at an adequate level. The signal component of the sensor signal can be measured by identifying systolic transitions. The systolic transitions are detected using a maximum and minimum derivative averaging scheme. The moving minimum and the moving maximum are compared to the scaled sum of the moving minimum and moving maximum to identify the systolic transitions. Once the signal component has been identified, the signal component is compared to a noise component to calculate the signal-to-noise ratio.



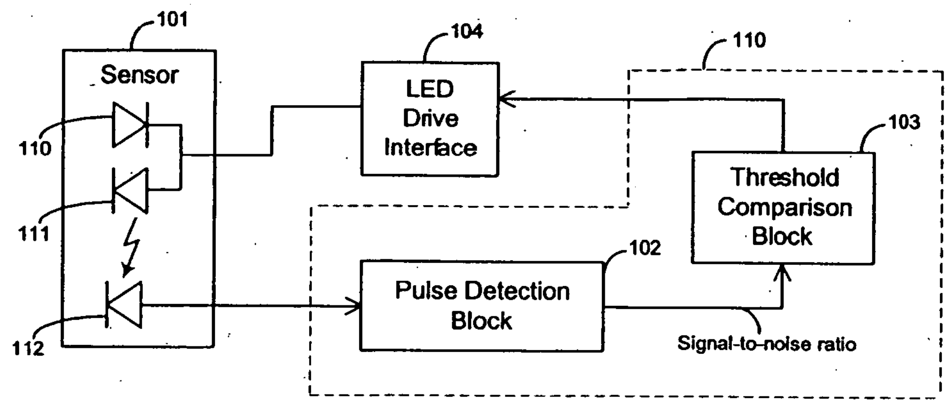

101
Sensor
110
111
112
104
LED
Drive
Interface
110
103
Threshold
Comparison
Block
102
Pulse Detection
Block
Signal-to-noise ratio

FIG. 1

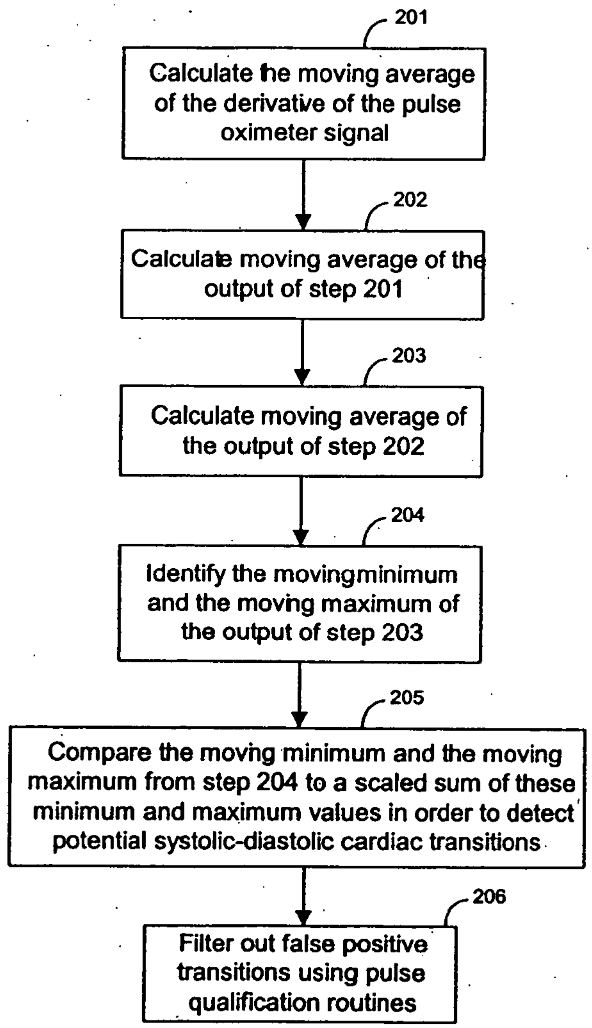

201
Calculate the moving average of the derivative of the pulse oximeter signal
202
Calculate moving average of the output of step 201
203
Calculate moving average of the output of step 202
204
Identify the movingminimum and the moving maximum of the output of step 203
205
Compare the moving minimum and the moving maximum from step 204 to a scaled sum of these minimum and maximum values in order to detect potential systolic-diastolic cardiac transitions
206
Filter out false positive transitions using pulse qualification routines

FIG. 2

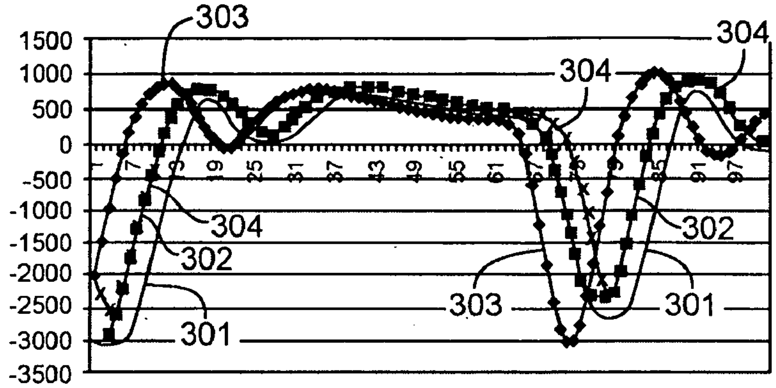


FIG. 3A

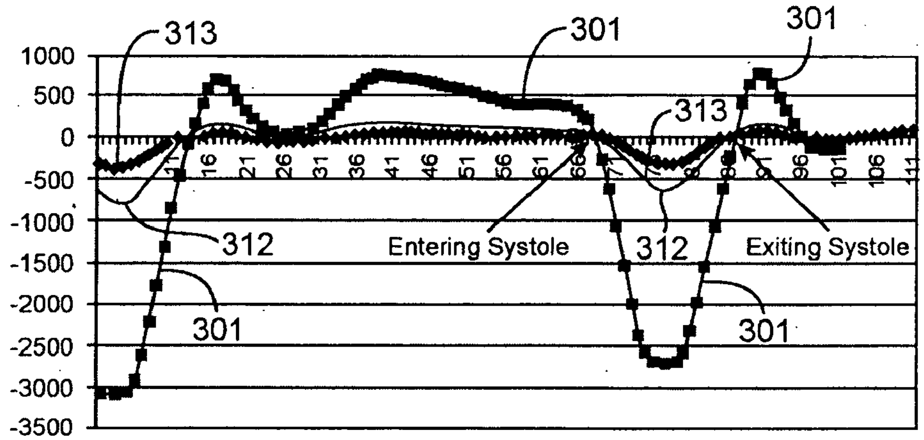


FIG. 3B

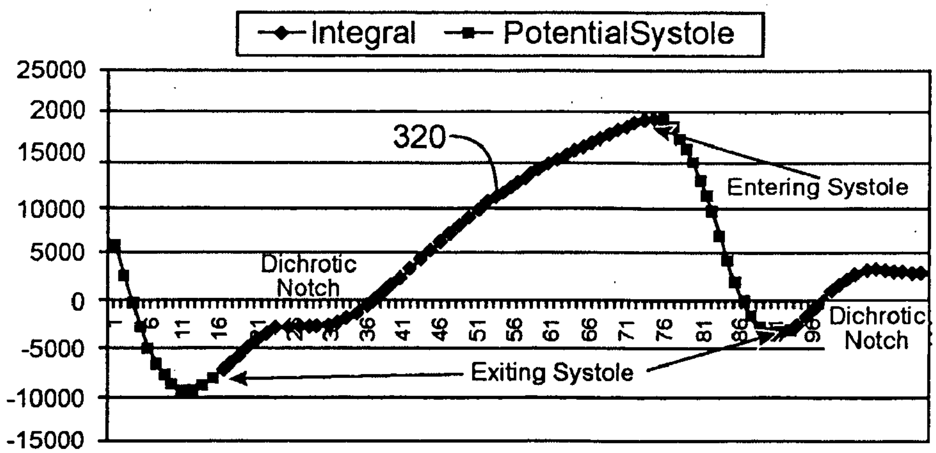


FIG. 3C

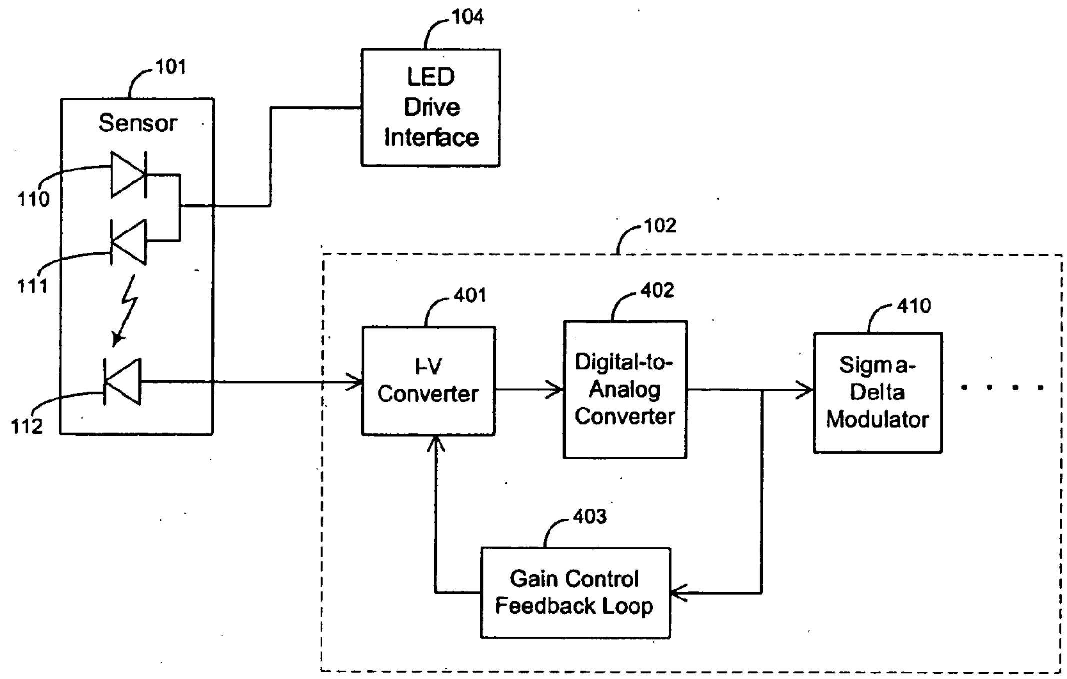

104
LED Drive Interface
101
Sensor
110
111
112
102
401
I-V Converter
402
Digital-to-Analog Converter
410
Sigma-Delta Modulator
403
Gain Control Feedback Loop

FIG. 4

TECHNIQUES FOR DETECTING HEART PULSES AND REDUCING POWER CONSUMPTION IN SENSORS

BACKGROUND OF THE INVENTION

[0001] The present invention relates to techniques for detecting heart pulses and reducing power consumption in sensors and oximeter systems, and more particularly, to techniques for distinguishing heart pulses in a sensor signal from noise and adjusting drive current provided to light emitting elements in response to a signal-to-noise ratio of the pulse in order to reduce power consumption.

[0002] Pulse oximetry is a technology that is typically used to measure various blood chemistry characteristics including, but not limited to, the blood-oxygen saturation of hemoglobin in arterial blood, the volume of individual blood pulsations supplying the tissue, and the rate of blood pulsations corresponding to each heartbeat of a patient.

[0003] Measurement of these characteristics has been accomplished by use of a non-invasive sensor. The sensor has a light source such as a light emitting diode (LED) that scatters light through a portion of the patient's tissue where blood perfuses the tissue. The sensor also has a photodetector that photoelectrically senses the absorption of light at various wavelengths in the tissue. The photodetector generates a pulse oximeter signal that indicates the amount of light absorbed by the blood. The amount of light absorbed is then used to calculate the amount of blood constituent being measured.

[0004] The light scattered through the tissue is selected to be of one or more wavelengths that are absorbed by the blood in an amount representative of the amount of the blood constituent present in the blood. The amount of transmitted light scattered through the tissue will vary in accordance with the changing amount of blood constituent in the tissue and the related light absorption.

[0005] For measuring blood oxygen level, oximeter sensors typically have a light source that is adapted to generate light of at least two different wavelengths, and with photodetectors sensitive to these wavelengths, in accordance with known techniques for measuring blood oxygen saturation. A typical pulse oximeter will alternately illuminate the patient with red and infrared light using two LEDs to obtain two different detector signals.

[0006] The pulse oximeter signal generated by the photodetector usually contains components of noise introduced by the electronics of the oximeter, by the patient, and by the environment. Noisy signals have a low signal-to-noise ratio. A pulse oximeter cannot accurately identify the blood oxygen saturation when the signal-to-noise ratio of the pulse oximeter signal is too low.

[0007] To improve the signal-to-noise ratio of the pulse oximeter signal, a pulse oximeter system will typically drive the LEDs with a large amount of current. A servo in the pulse oximeter will typically drive as much current as possible through the LEDs without causing the oximeter to be over-ranged (i.e., driven to full rail). The large drive current causes the LEDs to generate more light and to consume more power. Because the photodetector is able to sense more

[0008] Increasing the drive current of the LEDs to improve the signal-to-noise ratio of the pulse oximeter signal causes the system to consume an undesirably large amount of power. The large amount of power consumption can be a problem for oximeter systems that are battery operated.

[0009] It would therefore be desirable to provide pulse oximeter systems that consume less power without negatively compromising the signal-to-noise ratio of the pulse oximeter signal.

BRIEF SUMMARY OF THE INVENTION

[0010] The present invention provides CPU cycle efficient techniques for sensing heart pulses in a signal from a sensor. The sensor signal can be, for example, a pulse oximeter signal generated by a photodetector in a pulse oximeter sensor. The signal component of the sensor signal is measured by identifying potential systolic transitions of the cardiac cycle. The systolic transitions are detected using a derivative averaging scheme. The moving minimum and the moving maximum of the average derivative are compared to a scaled sum of the minimum and maximum to identify the systolic transitions. The systolic transitions correspond to a signal component of the sensor signal. The signal component is compared to a noise component to determine the signal-to-noise ratio of the signal.

[0011] The present invention also provides techniques for reducing power consumption in a sensor. After the signal-to-noise ratio of the pulse oximeter has been determined, the signal-to-noise ratio is compared to a threshold. In response to the output of the comparison, the drive current of light emitting elements in the sensor is dynamically adjusted to reduce power consumption and to maintain the signal-to-noise ratio at an adequate level for signal processing.

[0012] The present invention also provides techniques for sensing and adjusting the gain of a transimpedance amplifier to reduce the effect of ambient noise in a sensor. A gain control feedback loop senses the magnitude of the sensor signal when the light emitting elements are off. The gain control loop can include this information to effectively control the gain of the transimpedance amplifier.

[0013] For a further understanding of the nature and advantages of the invention, reference should be made to the following description taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] FIG. **1** illustrates a block diagram of a pulse oximeter system with reduced power consumption according to an embodiment of the present invention;

[0015] FIG. **2** is a flow chart that illustrates a process for identifying the systolic period of a pulse oximeter signal according to an embodiment of the present invention;

[0016] FIGS. **3**A-**3**C are graphs that illustrates how systolic transitions are identified in pulse oximeter signals according to embodiments of the present invention; and

[0017] FIG. **4** illustrates a portion of a pulse oximeter system with a transimpedance amplifier, a sigma-delta modulator, an analog-to-digital converter, and a gain control

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