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(54) **DELTA-SIGMA MODULATOR FOR OUTPUTTING ANALOG REPRESENTATION OF PHYSIOLOGICAL SIGNAL**

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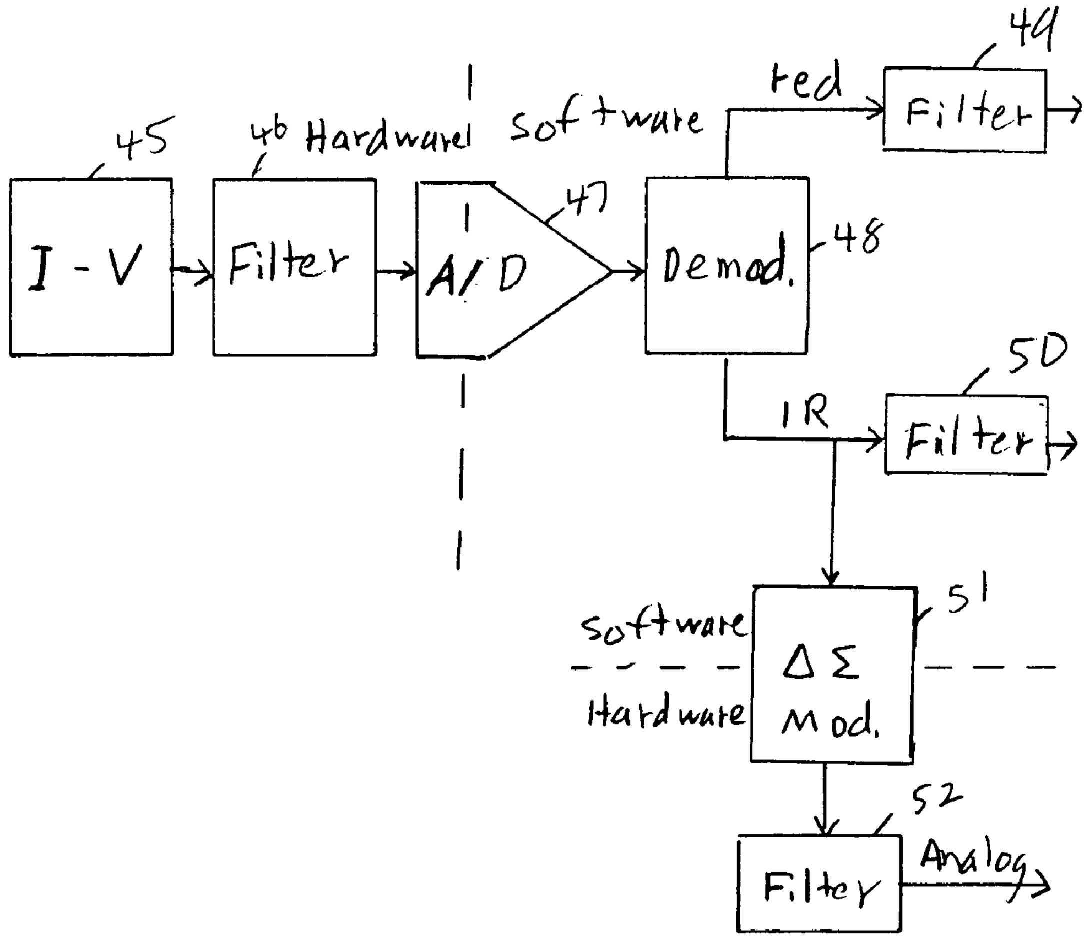
(52) **U.S. Cl.** **600/336**; 600/323

(57) **ABSTRACT**

A method and apparatus for providing a substantially real-time representation of an analog representation of a physiological signal. The waveform signal from the sensor is converted into digital form. A delta-sigma modulator is used as a simple Digital-to-analog Converter (ADC). The output can then be provided through a simple hardware filter to give an analog output signal in nearly real-time, which can be used for other instruments, synchronization, display, etc.



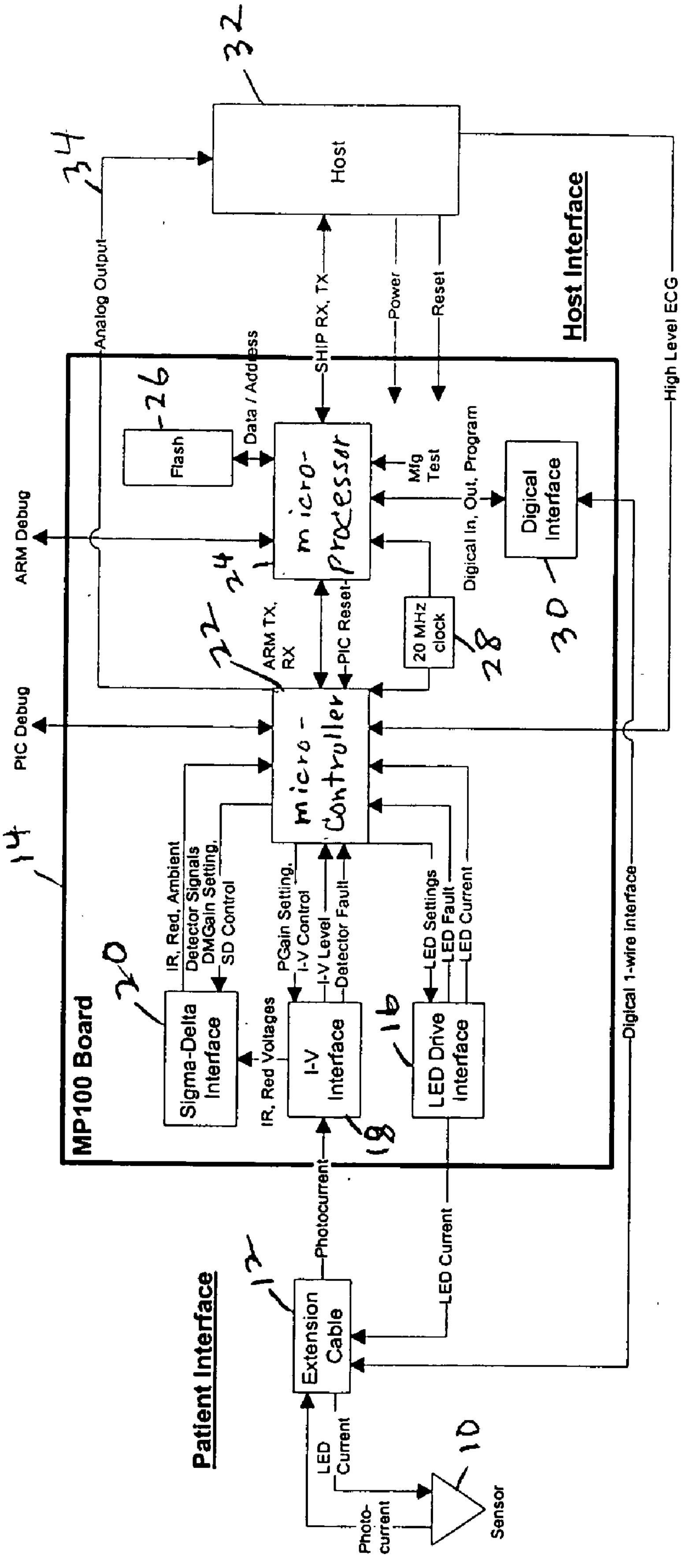

Host
Host Interface
Analog Output
SHIP RX, TX
Power
Reset
High Level ECG
Data / Address
Flash
micro-processor
Mfg Test
Digical In, Out, Program
Digical Interface
ARM Debug
ARM TX, RX
PIC Reset
20 MHz clock
PIC Debug
micro-controller
MP100 Board
IR, Red, Ambient Detector Signals
DMGain Setting,
SD Control
Sigma-Delta Interface
IR, Red Voltages
PGain Setting,
I-V Control
I-V Level
Detector Fault
I-V Interface
LED Settings
LED Fault
LED Current
LED Drive Interface
Digical 1-wire Interface
Photocurrent
LED Current
Extension Cable
Patient Interface
LED Current
Photo-current
Sensor
10
12
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FIG. 1

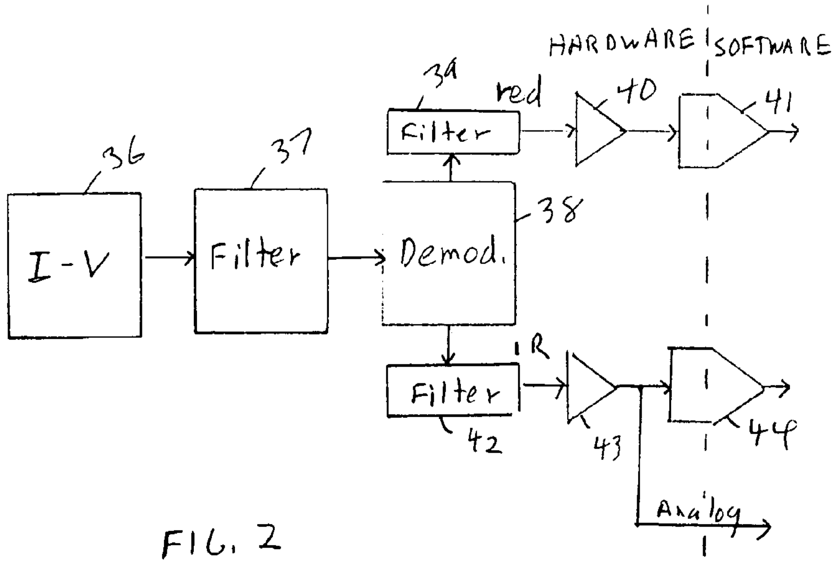

FIG. 2
PRIOR ART

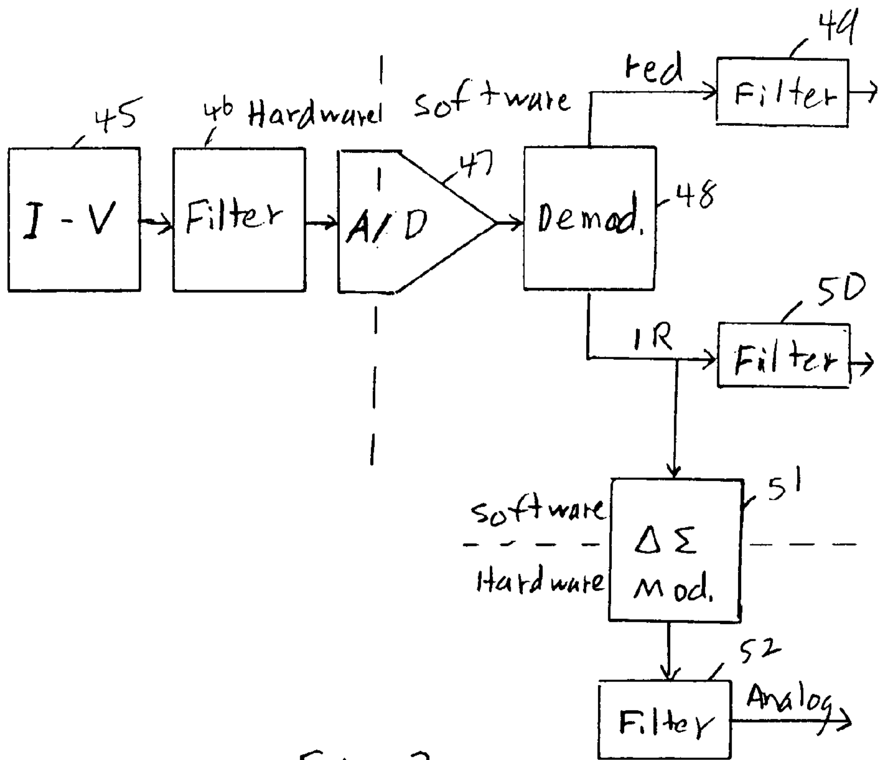

FIG. 3

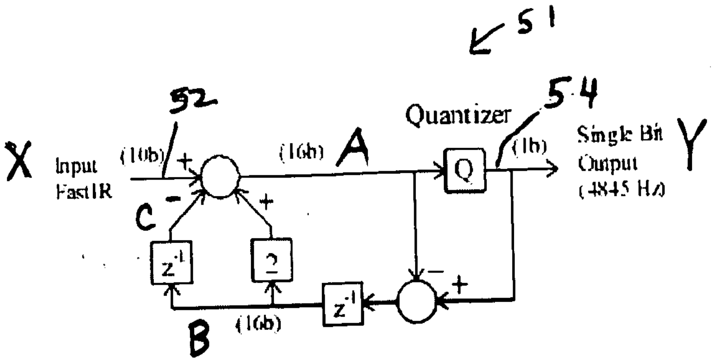

FIG. 4

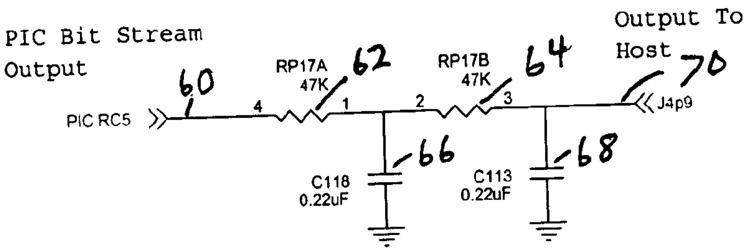

FIG. 5

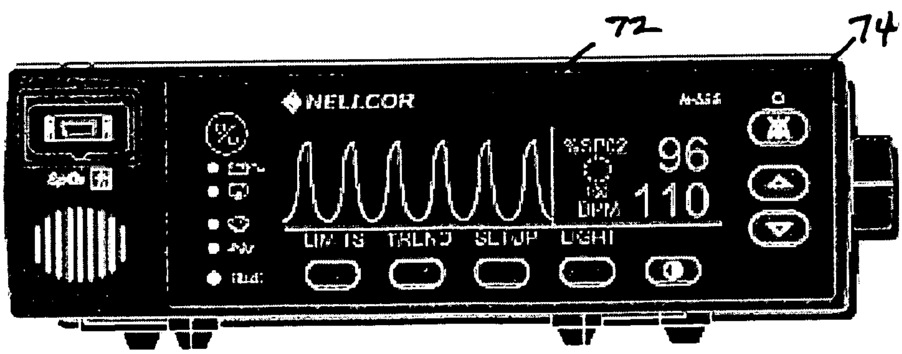

FIG. 6

DELTA-SIGMA MODULATOR FOR OUTPUTTING ANALOG REPRESENTATION OF PHYSIOLOGICAL SIGNAL

BACKGROUND OF THE INVENTION

[0001] The present invention relates to oximeters, and in particular to analog waveform displays in pulse oximeters.

[0002] Pulse oximetry 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. Measurement of these characteristics has been accomplished by use of a non-invasive sensor which scatters light through a portion of the patient's tissue where blood perfuses the tissue, and photoelectrically senses the absorption of light in such tissue. The amount of light absorbed at various frequencies is then used to calculate the amount of blood constituent being measured.

[0003] 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. For measuring blood oxygen level, such sensors have typically been provided with a light source that is adapted to generate light of at least two different wavelengths, and with photodetectors sensitive to both of those wavelengths, in accordance with known techniques for measuring blood oxygen saturation.

[0004] Known non-invasive sensors include devices that are secured to a portion of the body, such as a finger, an ear or the scalp. In animals and humans, the tissue of these body portions is perfused with blood and the tissue surface is readily accessible to the sensor.

[0005] Pulse oximeters, after processing the sensor data and calculating oxygen saturation, present that information to a display. In some pulse oximeters, it is also desirable to display the analog waveform itself. For example, U.S. Pat. No. 6,188,470 shows a signal for a display reflecting the waveform. U.S. Pat. No. 6,385,471 also discusses a waveform display, and sets forth that the data is first digitized, prefiltered, and then reconstructed for the display.

[0006] Nellcor Puritan Bennett, the assignee of the present invention, provides analog outputs in a number of its products. The analog outputs are used for such purposes as synchronizing to other instruments (e.g., EKG, multi-parameter monitor) as well as for a display, The analog waveforms are sometimes provided from the hardware pre-processing circuitry, to insure the analog signal is close in time to the actual patient waveform.

[0007] A problem with providing an analog waveform to a display after processing is that the processing takes some time, and thus the signal provided is delayed and not real-time.

BRIEF SUMMARY OF THE INVENTION

[0008] The present invention provides a method and apparatus for providing a substantially real-time representation of an analog representation of a physiological signal. The waveform signal from the sensor is converted into digital form. A delta-sigma modulator is used as a simple Digital-to-analog Converter (ADC). The output can then be provided through a simple hardware filter to give an analog output signal in nearly real-time, which can be used for other instruments, synchronization, display, etc.

[0009] The invention allows a waveform to be converted into digital form, and supplied to the software, while still allowing fast conversion back into hardware after initial processing in software. In particular, for a pulse oximeter that does demodulation in software, the digital IR signal can be obtained after this software demodulation, but before the much slower software filtering process used as part of the process to calculate oxygen saturation.

[0010] In one embodiment, in a first path the digital signal is processed, but a second path applies this digitized waveform to the delta-sigma modulator. The second path picks off the signal immediately after it is converted into digital form and demodulated. For a pulse oximeter, an IR signal is chosen for the analog output because it typically has less noise.

[0011] In one embodiment, the delta-sigma modulator is a software modulator which operates on the digitized version of the waveform. The delta-sigma modulator provides a single bit, serial output. This output is provided to a hardware RC filter, and then to the display.

[0012] 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

[0013] **FIG. 1** is a block diagram of an oximeter incorporating the present invention.

[0014] **FIG. 2** is a block diagram of a prior art circuit for generating an analog output signal.

[0015] **FIG. 3** is a block diagram of an embodiment of a circuit for generating an analog output signal according to the present invention.

[0016] **FIG. 4** is a block diagram of the software delta-sigma modulator according to an embodiment of the present invention.

[0017] **FIG. 5** is a circuit diagram of an embodiment of the hardware RC filter according to an embodiment of the present invention.

[0018] **FIG. 6** is a front view of a monitor showing an analog display according to an embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

[0019] Overall System

[0020] **FIG. 1** illustrates an embodiment of an oximetry system incorporating the present invention. A sensor **10** includes red and infrared LEDs and a photodetector. These are connected by a cable **12** to a board **14**. LED drive current is provided by an LED drive interface **16**. The received photocurrent from the sensor is provided to an I-V interface **18**. The IR and red voltages are then provided to a sigma-delta interface **20** incorporating the present invention. The output of sigma-delta interface **20** is provided to a micro-controller **22**. Microcontroller **22** includes flash memory for a program, and RAM memory for data. The oximeter also includes a microprocessor chip **24** connected to a flash memory **26**. Finally, a clock **28** is used and an interface **30** to a digital calibration in the sensor **10** is provided. A separate host **32** receives the processed information, as well as receiving an analog signal on a line **34** for providing an analog display.

[**0021**] Prior Art Demodulation in Hardware

[**0022**] **FIG. 2** shows an example of a prior art circuit for generating an analog output signal. A signal from a patient sensor is processed in hardware through a current-to-voltage converter (I-V) **36**, and a filter **37**. The red and IR signals are then demodulated in a demodulator **38**. A red signal is provided through a first channel of a filter **39** and an amplifier **40** to an ADC **41**. Similarly, the IR signal is provided through a second channel of filter **42**, amplifier **43** and ADC **44**. The analog output is obtained from the IR signal at the input of ADC **44**.

[**0023**] Demodulation in Software in the Present Invention

[**0024**] **FIG. 3** shows an embodiment of the present invention where demodulation isn't done in hardware, rather in software, so an analog IR signal simply is not available in hardware. A signal from a patient sensor is processed in hardware through a current-to-voltage converter **45** and a filter **46**, then is supplied to an ADC **47**. In software, a demodulator separates the red and IR signals. The red signal is then provided to a software filter **49** and further processing not shown. The IR signal is similarly provided through a software filter **50** and further processing not shown. Since the software filtering can cause a significant time delay, the IR signal before the filter **50** is converted back into analog form. A sigma-delta modulator **51** is used as a simple Digital-to-analog Converter (ADC). By using a sigma-delta modulator, the conversion process is simple and can be done quickly. The resulting analog signal then only needs to be filtered in a simple RC filter **52**.

[**0025**] Sigma-Delta Modulator and Filter for Simple DAC

[**0026**] **FIG. 4** is a block diagram of a delta-sigma modulator **51** of **FIG. 3** according to an embodiment of the invention. This modulator is preferably implemented in software running on microcontroller **22** of **FIG. 1**. An input on line **52** is the digitized sensor signal. In a preferred embodiment this signal is the infrared (IR) signal as opposed to the red signal. The infrared is chosen because it is typically a cleaner signal than the red signal. **FIG. 4** is a graphical representation of the difference equations implemented to create the second order noise shaping for the quintile signal. In one implementation, pseudocode that implements the difference equations is:

X is the input on line 52
Y is the output on line 54
A, B, and C are intermediate variables that store data from one iteration to the next loop every 206 μS

-continued

```
    A = X - C + (2 * B)
    C = B
    if A > ½ then
        Y = 1
    else
        Y = 0
    end if
    B = A - Y
end loop
```

[**0027**] This code is executed in a loop that executes every 206 μS, so the output (Y) is a 4845 bits/sec bit stream with an average value that is equal to the input (X).

[**0028**] The output on line **54** is preferably a 4845 Hz bitstream. This is provided to the input **60** of a hardware filter as shown in **FIG. 5**. This filter includes resistors **62** and **64** and capacitors **66** and **68**. This filter acts on the digital output signal to convert it into analog form to produce an output on line **70** that can be provided to a display. The filter is a passive, second order RC filter, without a buffer on the output. Any buffering could be done by the host system before displaying, if required.

[**0029**] **FIG. 6** shows an example of an analog display **72** on a pulse oximeter monitor **74**. The signal for this display is provided from line **70** of **FIG. 5**.

[**0030**] As will be understood by those of skill in the art, the present invention may be embodied in other specific forms without departing from the essential characteristics thereof. For example, the delta-sigma modulator could be of a different order than a second order. Some filtering could be done in software prior to the hardware filter, and a different configuration of the hardware filter could be used. Accordingly, the foregoing description is intended to be illustrative, but not limiting, of the scope of the invention which is set forth in the following claims.

What is claimed is:

1. A method for operating an physiological monitor comprising:

detecting a signal from a patient including a physiological waveform;

converting said waveform into digital form;

applying said waveform to a delta-sigma modulator; and

filtering said waveform to provide an analog waveform output.

2. The method of claim 1 further comprising demodulating said digital form of said waveform, wherein said delta-sigma modulator processes said waveform after said demodulation.

3. The method of claim 2 wherein said filtering is performed by a hardware filter coupled to an output of said delta-sigma modulator.

4. The method of claim 2 wherein said delta-sigma modulator provides a single bit output.

5. A method for operating an oximeter comprising:

detecting a signal from a patient including a pulse oximetry waveform;

converting said waveform into digital form;

demodulating said digital form of said waveform into red and IR signals;

applying one of said red and IR signals to a software delta-sigma modulator;

providing a single bit, serial output from said delta-sigma modulator;

filtering said single bit, serial output with a hardware filter.

6. An physiological monitor apparatus comprising:

an input for receiving from a patient a signal including a physiological waveform;

an analog-to-digital converter for converting said waveform into digital form;

a processor including a delta-sigma modulator configured to convert said waveform from digital into analog form;

a filter coupled to an output of said delta-sigma modulator for filtering said waveform.

7. The oximeter apparatus of claim 6 wherein said delta-sigma modulator is a software modulator that produces a serial, single bit output.

8. The oximeter apparatus of claim 6 wherein said filter is a hardware RC filter.

9. An oximeter apparatus comprising:

an input for receiving from a patient a signal including a pulse oximetry waveform;

an analog-to-digital converter for converting said waveform into digital form;

a processor including

a demodulator for separating said waveform into red and IR signals, and

a software delta-sigma modulator configured to convert one of said red and IR signals in digital form back into an analog signal by producing a serial, single bit output;

a hardware RC filter coupled to an output of said delta-sigma modulator for filtering said waveform.

* * * * *

专利名称(译)	Delta-sigma调制器，用于输出生理信号的模拟表示		
公开(公告)号	US20050187453A1	公开(公告)日	2005-08-25
申请号	US10/787853	申请日	2004-02-25
[标]申请(专利权)人(译)	内尔科尔普里坦贝内特公司		
申请(专利权)人(译)	NELLCOR PURITAN BENNETT INC.		
当前申请(专利权)人(译)	COVIDIEN LP		
[标]发明人	PETERSEN ETHAN SHEA WILLIAM CHEW BRADFORD B		
发明人	PETERSEN, ETHAN SHEA, WILLIAM CHEW, BRADFORD B.		
IPC分类号	A61B5/00 H03M7/32		
CPC分类号	A61B5/14551 H03M7/3042 H03M7/3028		
其他公开文献	US7212847		
外部链接	Espacenet USPTO		

摘要(译)

一种用于提供生理信号的模拟表示的基本上实时表示的方法和设备。来自传感器的波形信号被转换为数字形式。 Δ-Σ调制器用作简单的数模转换器（ADC）。然后可以通过简单的硬件滤波器提供输出，几乎实时地提供模拟输出信号，可用于其他仪器，同步，显示等。