(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 1 286 619 B1

(12) EUROPEAN PATENT SPECIFICATION

(45) Date of publication and mention of the grant of the patent:
20.04.2011 Bulletin 2011/16

(21) Application number: **01946090.6**

(22) Date of filing: **05.06.2001**

(51) Int Cl.:
A61B 5/00 *(2006.01)* ***H03H 17/00*** *(2006.01)*

(86) International application number:
PCT/US2001/018168

(87) International publication number:
WO 2001/093757 (13.12.2001 Gazette 2001/50)

(54) VARIABLE MODE AVERAGER

VARIABLER MODENMITTLER

MOYENNEUR A MODE VARIABLE

(84) Designated Contracting States:
DE FR GB

(30) Priority: **05.06.2000 US 586845**

(43) Date of publication of application:
05.03.2003 Bulletin 2003/10

(73) Proprietor: **Masimo Corporation**
Irvine, CA 92618 (US)

(72) Inventors:
- **WEBER, Walter, M.**
  Laguna Hills, CA 92653 (US)
- **AL-ALI, Ammar**
  Tustin, CA 92782 (US)

(74) Representative: **Vossius & Partner**
Siebertstrasse 4
81675 München (DE)

(56) References cited:
US-A- 5 018 088 **US-A- 5 056 052**
US-A- 5 136 267 **US-A- 5 511 042**
US-A- 5 632 272 **US-A- 5 856 934**
US-A- 5 957 866 **US-A- 6 041 290**

Note: Within nine months of the publication of the mention of the grant of the European patent in the European Patent Bulletin, any person may give notice to the European Patent Office of opposition to that patent, in accordance with the Implementing Regulations. Notice of opposition shall not be deemed to have been filed until the opposition fee has been paid. (Art. 99(1) European Patent Convention).

EP 1 286 619 B1

Printed by Jouve, 75001 PARIS (FR)

Description

Field of the Invention

[0001] The present invention is directed to the field of signal processing, and, more particularly, is directed to systems and methods for signal averaging.

Background of the Invention

[0002] Digital signal processing techniques are frequently employed to enhance a desired signal in a wide variety of applications, such as health care, communications and avionics, to name a few. Signal enhancement includes smoothing, filtering and prediction. These processing techniques each operate on a block of input signal values in order to estimate the signal at a specific point in time. FIG.1 illustrates that smoothing, filtering and prediction can be distinguished by the time at which an output value is generated relative to input values. Shown in FIG.**1** is a time axis **100** and a block **101** of input signal values depicted in this example as occurring within a time window between points t^{min} and t^{max}. SperificaHy, the block **101** includes a set of discrete input values $\{v_i; i = 1, 2, ... n\}$ occurring at a corresponding set of time points $\{t_i; i = 1, 2, ... n\}$. A smoother operates on the block **101** of input values to estimate the signal at a time point, t, **102** between t^{min} and t^{max}. That is, a smoother generates an output value based upon input values occurring before and after the output value. A filter operates on the block **101** of input values to estimate the signal at a time t_i **104,** corresponding to the most recently occurring input value in the block **101.** That is, a filter generates a forward filtered output value at the time t_t based upon input values occurring at, and immediately before, the output value. A filter also operates on the block **101** to estimate the signal at a time t_b **105** at the beginning of the block **101** to generate a backward filtered value. A forward predictor operates on the block of input values **101** to estimate the signal at time t_{pt} **106**, which is beyond the most recently occurring value in the block **101.** That is, a forward predictor generates a forward predicted output value based upon input values occurring prior to the output value. A backward predictor operates on the block **101** of input values to estimate the signal at time t_{pb} **108,** which is before the earliest occurring value in the block **101.** That is, a backward predictor generates a backward predicted output value based upon input values occurring after the output value.

[0003] Document WO-A-96/12435 describes various methods of determining an oxygen saturation in the presence of patient motion.

[0004] Document WO-A-95/02288 describes a telephone communication system which determines a gain multiplicative factor for each frequency component based on a noise confidence level.

Summary of the Invention

[0005] The invention is defined by the features of the claims. A common smoothing technique uses an average to fit a constant, v^A, to a set of data values, $\{v_i, i = 1, 2, ..., n\}$:

$$v^A = \frac{1}{n} \cdot \sum_{i=1}^{n} v_i \tag{1}$$

[0006] A generalized form of equation (1) is the weighted average

$$v^{WA} = \frac{\sum_{i=1}^{n} w_i \cdot v_i}{\sum_{i=1}^{n} w_i} \tag{2}$$

[0007] Here, each value, v_i, is scaled by a weight, w_i, before averaging. This allows data values to be emphasized and de-emphasized relative to each other. If the data relates to an input signal, for example, values occurring during periods of low signal confidence can be given a lower weight and values occurring during periods of high signal confidence can be given a higher weight.

[0008] **FIG. 2A** illustrates the output of a constant mode averager, which utilizes the weighted average of equation (2) to process a discrete input signal, $\{v_i, i \text{ an integer}\}$ **110.** The input signal **110** may be, for example, a desired signal corrupted by noise or a signal having superfluous features. The constant mode averager suppresses the noise and unwanted features, as described with respect to FIG. 5, below. A first time-window **132** defines a first set, $\{v_i; i=1, 2, \ldots, n\}$, of signal values, which are averaged together to produce a first output value, z_1 **122.** A second time-window **134,** shifted from the previous window **132,** defines a second set $\{v_i, i\text{-}2, 3, \ldots, n+1\}$ of signal values, which are also averaged together to produce a second output value $\boldsymbol{z_2}$ **124.** In this manner, a discrete output signal, $\{z_j; j$ an integer$\}$ **120** is generated from a moving weighted average of a discrete input signal $\{v_i; i$ an integer$\}$ **110**, where:

$$z_j = \sum_{i=j}^{n+j-1} w_i v_i \Big/ \sum_{i=j}^{n+j-1} w_i \quad (3)$$

[0009] A common filtering technique computes a linear fit to a set of data values, $\{v_i; i=1, 2, \ldots, n\}$:

$$\hat{v}_i = \alpha \cdot t_i + \beta \quad (4)$$

where α and β are constants and t_i is the time of occurrence of the i^{th} value. **FIG. 2B** illustrates the output of a linear mode averager, which uses the linear fit of equation (4) to process a discrete input signal, $\{v_i; i$ an integer$\}$ **110.** The input signal **110** may be, for example, a desired signal with important features corrupted by noise. The linear mode averager reduces the noise but tracks the important features, as described with respect to FIG. **6** below. A first time-window **132** defines a first set, $\{v_i; i=1, 2, \ldots, n\}$, of signal values. A linear fit to these n values is a first line **240,** and the value along this line at $\max\{t_1, t_2, \ldots, t_n\}$ is equal to a first output value, z_1, **222.** A second time-window **134** shifted from the previous window **132** defines a second set, $\{v_i; i = 2, 3, \ldots, n+1\}$, of signal values. A linear fit to these n values is a second line **250,** and the value along this line at $\max\{t_2, t_3, \ldots, t_{n+1}\}$ is equal to a second output value, z_2 **224.** In this manner, a discrete output signal, $\{z_j; j$ an integer$\}$ **220** is generated from a moving linear fit of a discrete input signal $\{v_i; i$ an integer$\}$, where:

$$z_j = \alpha_j \cdot t_{n+j-1}^{MAX} + \beta_j \quad (5a)$$

$$t_{n+j-1}^{MAX} = \max\left\{t_j, t_{j+1}, \cdots, t_{n+j-1}\right\} \quad (5b)$$

[0010] In general, the time windows shown in FIGS. **2A-2B** may be shifted from each other by more than one input value, and values within each time window may be skipped, i.e., not included in the average. Further, the t_i's may not be in increasing or decreasing order or uniformly distributed, and successive time windows may be of different sizes. Also, although the discussion herein refers to signal values as the dependent variable and to time as the independent variable to facilitate disclosure of the present invention, the concepts involves are equally applicable where the variables are other than signal values and time. For example, an independent variable could be a spatial dimension and a dependent variable could be an image value.

[0011] The linear mode averager described with respect to FIG. **2B** can utilize a "best" linear fit to the input signal, calculated by minimizing the mean-squared error between the linear fit and the input signal. A weighted mean-squared error can be described utilizing equation (4) as:

$$\varepsilon(\alpha,\beta) = \sum_{i=1}^{n} w_i (v_i - \hat{v}_i)^2 \Big/ \sum_{i=1}^{n} w_i \quad (6a)$$

$$\varepsilon(\alpha,\beta) = \sum_{i=1}^{n} w_i [v_i - (\alpha \cdot t_i + \beta)]^2 \Big/ \sum_{i=1}^{n} w_i \quad (6b)$$

[0012] Conventionally, the least-mean-squared (LMS) error is calculated by setting the partial derivatives of equation

(6b) with respect to a and β to zero:

$$\frac{\partial}{\partial\alpha}\varepsilon(\alpha,\beta)=0 \qquad (7a)$$

$$\frac{\partial}{\partial\beta}\varepsilon(\alpha,\beta)=0 \qquad (7b)$$

[0013] Substituting equation (6b) into equation (7b) and taking the derivative yields:

$$-2\sum_{i=1}^{n}w_i[v_i-(\alpha\cdot t_i+\beta)]\Big/\sum_{i=1}^{n}w_i=0 \qquad (8)$$

[0014] Solving equation (8) for β and substituting the expression of equation (2) yields:

$$\beta=\frac{\sum_{i=1}^{n}w_i\cdot v_i}{\sum_{i=1}^{n}w_i}-\alpha\frac{\sum_{i=1}^{n}w_i\cdot t_i}{\sum_{i=1}^{n}w_i} \qquad (9a)$$

$$\beta=v^{WA}-\alpha\cdot t^{WA} \qquad (9b)$$

where the weighted average time, t^{WA}, is defined as:

$$t^{WA}=\frac{\sum_{i=1}^{n}w_i\cdot t_i}{\sum_{i=1}^{n}w_i} \qquad (10)$$

[0015] Substituting equation (9b) into equation (4) gives:

$$\hat{v}_i=\alpha(t_i-t^{WA})+v^{WA} \qquad (11)$$

[0016] Substituting equation (11) into equation (6a) and rearranging terms results in:

$$\varepsilon(\alpha,\beta)=\sum_{i=1}^{n}w_i[(v_i-v^{WA})-\alpha\cdot(t_i-t^{WA})]^2\Big/\sum_{i=1}^{n}w_i \qquad (12)$$

[0017] Changing variables in equation (12) gives:

$$\varepsilon(\alpha,\beta)=\sum_{i=1}^{n}w_i(v_i'-\alpha\cdot t_i')^2\Big/\sum_{i=1}^{n}w_i \qquad (13)$$

where:

$$v_i' = v_i - v^{WA} \tag{14a}$$

$$t_i' = t_i - t^{WA} \tag{14b}$$

[0018] Substituting equation (13) into equation (7a) and taking the derivative yields

$$-2\sum_{i=1}^{n} w_i t_i'(v_i' - \alpha \cdot t_i') \Big/ \sum_{i=1}^{n} w_i = 0 \tag{15}$$

[0019] Solving equation (15) for α gives:

$$\alpha = \frac{\sum_{i=1}^{n} w_i v_i' t_i' \Big/ \sum_{i=1}^{n} w_i}{\sum_{i=1}^{n} w_i t_i'^2 \Big/ \sum_{i=1}^{n} w_i} \tag{16}$$

[0020] Substituting equations (14a, b) into equation (16) results in:

$$\alpha = \frac{\sum_{i=1}^{n} w_i (v_i - v^{WA})(t_i - t^{WA}) \Big/ \sum_{i=1}^{n} w_i}{\sum_{i=1}^{n} w_i (t_i - t^{WA})^2 \Big/ \sum_{i=1}^{n} w_i} \tag{17a}$$

$$\alpha = \frac{{\sigma_{vt}}^2}{{\sigma_{tt}}^2} \tag{17b}$$

where:

$${\sigma_{vt}}^2 = \sum_{i=1}^{n} w_i (v_i - v^{WA})(t_i - t^{WA}) \Big/ \sum_{i=1}^{n} w_i \tag{18a}$$

$${\sigma_{tt}}^2 = \sum_{i=1}^{n} w_i (t_i - t^{WA})^2 \Big/ \sum_{i=1}^{n} w_i \tag{18b}$$

[0021] Finally, substituting equation (17b) into equation (11) provides the equation for the least-mean-square (LMS) linear fit to $\{v_i; i = 1,2,\ldots,n\}$:

$$\hat{v}_i = \frac{{\sigma_{vt}}^2}{{\sigma_{tt}}^2}(t_i - t^{WA}) + v^{WA} \tag{19}$$

[0022] FIG. **3** provides one comparison between the constant mode averager, described above with respect to FIG. **2A** and equation (2), and the linear mode averager, described above with respect to FIG. **2B** and equation (19). Shown in FIG. **3** are input signal values $\{v_i;\ i = 1, 2, ..., n\}$ **310.** The constant mode averager calculates a constant **320** for these values **310,** which is equal to v^{WA}, the weighted average of the input values v_i. Thus, the constant mode averager output **340** has a value v^{WA}. For comparison to the linear mode averager, the constant mode averager output can be conceptualized as an estimate of the input values **310** along a linear fit **350,** evaluated at time t^{WA}. The linear mode averager may be thought of as calculating a LMS linear fit, $\hat{v}_i$ **330** to the input signal values, $\boldsymbol{v_i}$ **310.** The linear mode averager output **350** has a value, v^{WLA}. The linear mode averager output is an estimate of the input values **310** along the linear fit **330,** described by equation (19), evaluated at an index i such that $t_i = t^{MAX}$:

$$v^{WLA} = \frac{\sigma_{vt}^{\ 2}}{\sigma_{tt}^{\ 2}}(t^{MAX} - t^{WA}) + v^{WA} \qquad (20)$$

where:

$$t^{MAX} = \max\{t_1, t_2, \cdots, t_n\} \qquad (21)$$

[0023] As illustrated by FIG. **3,** unlike the constant mode averager, the linear mode averager is sensitive to the input signal trend. That is, the constant mode averager provides a constant fit to the input values, whereas the linear mode averager provides a linear fit to the input values that corresponds to the input value trend. As a result, the output of the linear mode averager output responds faster to changes in the input signal than does the output of the constant mode averager. The time lag or delay between the output of the constant mode averager and the output of the linear mode averager can be visualized by comparing the time difference **360** between the constant mode averager output value **340** and the linear mode averager output value **350.**

[0024] FIGS. **4-6** illustrate further comparisons between the constant mode averager and the linear mode averager. FIG. **4** depicts a noise-corrupted input signal **410,** which increases in frequency with time. FIGS. **5-6** depict the corresponding noise-free signal **400.** FIG. 5 also depicts the constant mode averager output 500 in response to the input signal **410,** with the noise-free signal **400** shown for reference. FIG. **6** depicts the linear mode averager output **600** in response to the input signal **410,** with the noise-free signal **400** also shown for reference. As shown in FIG. 5, the constant mode averager output **500** suppresses noise from the input signal **410** (FIG. **4**) but displays increasing time lag and amplitude deviation from the input signal **400** as frequency increases. As shown in FIG. **6,** the linear mode averager output **600** tends to track the input signal **400** but also tracks a portion of the noise on the input signal **410.**

[0025] FIGS. **4-6** suggest that it would be advantageous to have an averager that has variable characteristics between those of the linear mode averager and those of the constant mode averager, depending on signal confidence. Specifically, it would be advantageous to have a variable mode averager that can be adjusted to track input signal features with a minimal output time lag when signal confidence is high and yet adjusted to smooth an input signal when signal confidence is low. Further, it would be advantageous to have a variable mode averager that can be adjusted so as not to track superfluous input signal features regardless of signal confidence.

[0026] One aspect of the present invention is a variable mode averager having a buffer that stores weighted input values. A mode input specifies a time value relative to the input values. A processor is coupled to the buffer, and the processor is configured to provide an estimate of the input values that corresponds to the time value. In a particular embodiment, the mode input is adjustable so that the estimate varies between that of a smoother and that of a forward predictor of the input values. In another embodiment, the mode input is adjustable so that the estimate varies between that of a smoother and that of a filter of the input values. In yet another embodiment, the mode input is adjustable so that the estimate varies between that of an average of the input values and that of a filter of the input values. The mode input may be adjustable based upon a characteristic associated with the input values, such as a confidence level. In one variation of that embodiment, the estimate can be that of a smoother when the confidence level is low and that of a filter when the confidence level is high. The estimate may occur along a curve-fit of the input values at the time value. In one embodiment, the curve-fit is a linear LMS fit to the input values.

[0027] Another aspect of the present invention is a signal averaging method. The method includes identifying signal values and determining weights corresponding to the signal values. The method also includes computing a trend of the signal values adjusted by the weights. Further, the method includes specifying a time value relative to the signal values based upon a characteristic associated with the signal values and estimating the signal values based upon the trend evaluated at the time value. The method may also incorporate the steps of determining a confidence level associated with the signal values and specifying the time value based upon the confidence level. In one embodiment, the trend is a linear LMS fit to the signal values adjusted by the weights. In that case, the time value may generally correspond to the maximum time of the signal values when the confidence level is high and generally correspond to the weighted average time of the signal values when the confidence level is low.

[0028] Yet another aspect of the present invention is a signal averaging method having the steps of providing an input signal, setting a mode between a first mode value and a second mode value and generating an output signal from an estimate of the input signal as a function of said mode. The output signal generally smoothes the input signal when the mode is proximate the first mode value, and the output signal generally tracks the input signal when the mode is proximate the second mode value. The method may also include determining a characteristic of the input signal, where the setting step is a function of the characteristic. In one embodiment, the characteristic is a confidence level relating to the input signal. In another embodiment, the setting step incorporates the substeps of setting the mode proximate the first mode value when the confidence level is low and setting the mode proximate the second mode value when the confidence level is high. In another embodiment, the input signal is a physiological measurement and the setting step comprises setting the mode proximate the first mode value when the measurement is corrupted with noise or signal artifacts and otherwise setting the mode proximate the second mode value so that the output signal has a fast response to physiological events.

[0029] A further aspect of the present invention is a signal averager having an input means for storing signal values, an adjustment means for modifying the signal values with corresponding weights, a curve fitting means for determining a trend of the signal values, and an estimate means for generating an output value along the trend. The signal averager may further have a mode means coupled to the estimate means for variably determining a time value at which to generate the output value.

Brief Description of the Drawings

[0030]

FIG.1 **is** a time graph depicting the output of conventional smoother, filter and predictor signal processors;

FIG. **2A** is an amplitude versus time graph depicting the output of a conventional constant mode averager;

FIG. **2B** is an amplitude versus time graph depicting the output of a conventional linear mode averager;

FIG. **3** is an amplitude versus time graph comparing the outputs of a constant mode averager and a linear mode averager;

FIG. **4** is an amplitude versus time graph depicting a noisy input signal;

FIG. **5** is an amplitude versus time graph depicting a constant mode averager output signal corresponding to the input signal of FIG. **4;**

FIG. **6** is an amplitude versus time graph depicting a linear mode averager output signal corresponding to the input signal of FIG. **4;**

FIG. **7** is an amplitude versus time graph illustrating the characteristics of one embodiment of the variable mode averager;

FIG. **8** is a flow chart of a variable mode averager embodiment;

FIG. **9** is a block diagram illustrating a variable mode averager applied to a pulse oximeter, and

FIG.**10** is an oxygen saturation output versus time graph for a pulse oximeter utilizing a variable mode averager.

Detailed Description of the Preferred Embodiments

[0031] FIG. 7 illustrates the output characteristics of a variable mode averager according to the present invention. The output of the variable mode averager is a mode-dependent weighted linear average (MWLA) defined as

$$v^{MWLA} = mode \cdot \frac{\sigma_{vt}^{\ 2}}{\sigma_{tt}^{\ 2}} (t^{MAX} - t^{WA}) + v^{WA} \qquad (22)$$

Equation (22) is a modified form of equation (20), which is motivated by equations (2) and (19) along with recognition of the relationships in Table **1.**

TABLE 1: VARIABLE MODE AVERAGER OUTPUT

	mode = 0	mode = 1	any mode ∃ 0
Processing Function	Constant Mode Averager	Linear Mode Averager	Variable Mode Averager
Output	v^{WA}	v^{WLA}	v^{MWLA}
Defining Formula	Equation (2)	Equation (20)	Equation (22)
Processing Method	Weighted Average	LMS Linear Fit	Figure 8

As shown in Table **1,** the Variable Mode Averager in accordance with the present invention includes the constant mode averager processing function and the linear mode averager processing function, which are known processing functions. As further shown in Table **1,** the Variable Mode Averager of the present invention also includes a variable mode averager processing function, which will be described below.

[0032] As shown in Table 1, if *mode* = 0, the variable mode averager output is v^{WA}, the output of the constant mode averager function, which utilizes a weighted average of the input signal values. If *mode* = 1, the variable mode averager output is v^{WLA}, the output of the linear mode averager function, which utilizes a LMS linear fit to the input signal values. If 0 < *mode* < 1, then the variable mode averager output is v^{MWLA} and has output characteristics that are between that of the constant mode averager and the linear mode averager. In addition, if *mode* > 1, then the variable mode averager behaves as a forward predictor.

[0033] As shown in FIG. 7, the variable mode averager output **720** is an estimate of the input values at a selected time along the linear fit **710,** which indicates a trend of the input values. Assuming 0 < *mode* < 1, the *mode* variable determines the equivalent time **730** between t^{WA} and t^{MAX} for which the estimate is evaluated, yielding an output value **740** between v^{WA} and v^{WLA}. Thus, the *mode* variable acts to parametrically vary the time delay between the input and output signals of the variable mode averager, along with associated output characteristics. If *mode* = 0, the time delay **360** (FIG. **3)** is that of the constant mode averager. If *mode* = 1, there is no time delay. If *mode* > 1, the variable mode averager is predicting a future input value based on n past values. In this manner, the variable mode averager can be used to advantageously adjust between the smoothing characteristics of the constant mode averager and the tracking characteristics of the linear mode averager, as described above with respect to FIGS **4-6.** The variable mode control determines how much of each particular characteristic to use for a particular input signal and application. For example, for time periods when the input signal has low confidence, mode can be set further towards zero, although with a time lag penalty. For time periods when the input signal has high confidence or when minimum time lag is required, mode can be set further towards one, or even to a value greater than one.

[0034] The variable mode averager has been described in terms of weighted input values. One of ordinary skill, however, will recognize that the present invention includes the case where all of the weights are the same, i.e., where the input values are equally weighted or unweighted. Further, although the variable mode averager has been described in terms of a linear mode averager, one of ordinary skill in the art will recognize that a variable mode averager could also be based on non-linear curve fits, such as exponential or quadratic curves indicating a non-linear trend of the input signal. In addition, one of ordinary skill will understand that the variable mode averager can be implemented to operate on continuous data as well as infinitely long data. Also, a variable mode averager based upon a linear fit by some criteria other than LMS; a variable mode averager using any mode value, including negative values, and a variable mode averager based upon a linear fit where $t^{min} = \min\{t_1, t_2, ..., t_n\}$ is substituted for t^{MAX} in equation (22) are all contemplated as within the scope of the present invention.

[0035] FIG. **8** illustrates one embodiment **800** of a variable mode signal averager. After an entry point **802,** variables are initialized to zero in a block **808.** Next, in a block **812,** the sums of various parameters are calculated by summing the products of corresponding values in each of three buffers: an input data buffer, *value*[*i*]; a weight buffer, *weight*[*i*] and a time value buffer, *time*[*i*]. In addition, the *weight*[*i*] values are summed. These sums are calculated over the entire length of each buffer, representing a single time window of *n* values. The calculations are performed by incrementing a loop counter *i* in a block **810** and reentering the block **812.** The loop counter *i* specifies a particular value in each buffer.

Each time through the block **812,** the variable mode signal averager generates products of buffer values and adds the results to partial sums. After completing the partial sums, the variable mode signal averager then determines if the ends of the buffers have been reached in a decision block **814** by comparing the incremented value of *i* to the size of the buffer. If the ends of the buffers have not been reached, the variable mode averager increments the loop counter *i* and reenters the block **812;** otherwise, the variable mode averager continues to a decision block **816.**

[0036] In the decision block **816,** a check is made whether the sum of the weights, *sumw,* is greater than zero. If so, each of the sums of the products from the block **812** is divided by *sumw* in a block **820.** In the block **820,** the parameters computed are:

sumwv, the weighted average value of equation (2);
sumwt, the weighted average time of equation (10);
sumwvt, the weighted average product of value and time; and
sumwt2, the weighted average product of time squared.

The *sumwt2* parameter from the block **820** is then used in a block **822** to calculate an autovariance *sigma**2tt*** in accordance with equation (18b). If, in a decision block **824,** a determination is made that the autovariance is not greater than zero, then in a decision block **825,** a determination is made whether the sum of the weights is greater than zero. If, in the decision block **825,** the sum of the weights is not greater than zero, then an output value, *out,* which was initialized to zero in the block **808,** is returned as a zero value at a termination point **804.** Otherwise, if, in the decision block **825,** a determination is made that the sum of the weights is greater than zero, then in a block **826,** the value of the sum of the weights is assigned to the output value, *out,* and the output value is then returned at the termination point **804.**

[0037] If, in the decision block **824,** the autovariance is determined to be greater than zero, then in a block **827,** the *sumwvt* parameter from the block **820** is used to calculate a crossvariance signal *sigma2vt* in accordance with equation (18a). Thereafter, the maximum time, t^{MAX}, as defined in equation (21), is determined by finding the largest time value in the time buffer, *time*[*i*]. In particular, in a block **829,** the loop counter, *i*, is reinitialized to zero and the value of t^{MAX} is initialized to zero. Next, in a decision block **832,** the current value of t^{MAX} is compared to the current value of the time buffer indexed by the loop counter, *i*. If the current value of t^{MAX} is not less than the current value of the time buffer or if the current *weight* value indexed by *i* is not greater than zero, then t^{MAX} is not changed and a block **834** is bypassed. On the other hand, if the current value of t^{MAX} is less than the current time value and if the current *weight* value is greater than zero, then the block **834** is entered, and the value of t^{MAX} is replaced with the current time value *time* [*i*]. In either case, in a decision block **838,** the loop counter, *i*, is compared to the buffer size, and, if the loop counter, *i*, is less than the buffer size, the loop counter, *i*, is incremented in a block **830,** and the comparisons are again made in the decision block **832.**

[0038] When, in the decision block **838,** it is determined that the loop counter, *i*, has reached the buffer size, the variable mode averager proceeds to a block **840** with the largest value of *time*[*i*] saved as the value of t^{MAX}. In the block **840,** a single output value, *out,* is computed in accordance with equation (22). Thereafter, the output value, *out,* is limited to the range of values in the input data buffer, *value*[*i*]. This is accomplished by comparing *out* to the maximum and minimum values in the data buffer. First, in a block **850,** the maximum of the value buffer is determined. Then, in a decision block **852,** the maximum of the value buffer is compared to *out*. If *out* is bigger than the maximum of the value buffer, then, in a block **854,** *out* is limited to the maximum value in the buffer. Otherwise, the block **854** is bypassed, and *out* remains as previously calculated in the block **840.** Thereafter, in a block **860,** the minimum of the value buffer is determined. The minimum of the value buffer is compared to *out* in a decision block **862.** If *out* is smaller than the minimum of the value buffer, then, in a block **864,** *out* is set to the minimum value in the buffer. Otherwise, the block **864** is bypassed, and *out* is not changed. The value of *out* determined by the block **840,** the block **852** or the block **864** is then returned from the routine via the termination point **804.**

[0039] In one embodiment, the process described with respect to FIG. **8** is implemented as firmware executing on a digital signal processor. One of ordinary skill in the art will recognize that the variable mode averager can also be implemented as a digital circuit. Further, a variable mode averager implemented as an analog circuit with analog inputs and outputs is also contemplated to be within the scope of the present invention.

[0040] Pulse oximetry is one application that can effectively use signal processing techniques to provide caregivers with improved physiological measurements. Pulse oximetry is a widely accepted noninvasive procedure for measuring the oxygen saturation level of arterial blood, an indicator of oxygen supply. Early detection of low blood oxygen is critical in the medical field, for example in critical care and surgical applications, because an insufficient supply of oxygen can result in brain damage and death in a matter of minutes. Pulse oximeter systems are described in detail in U.S. Patent No. 5,632,272, U.S. Patent No. 5,769,785, and U.S. Patent No. 6,002,952, which are assigned to the assignee of the present invention and which are incorporated by reference herein.

[0041] FIG. **9** depicts a general block diagram of a pulse oximetry system **900** utilizing a variable mode averager **960.** A pulse oximetry system **900** consists of a sensor **902** attached to a patient and a monitor **904** that outputs desired parameters **982** to a display **980,** including blood oxygen saturation, heart rate and a plethysmographic waveform. Conventionally, a pulse oximetry sensor **902** has both red (RED) and infrared (IR) light-emitting diode (LED) emitters (not shown) and a photodiode detector (not shown). The sensor **902** is typically attached to a patient's finger or toe, or to a very young patient's foot. For a finger, the sensor **902** is configured so that the emitters project light through the fingernail and into the blood vessels and capillaries underneath. The photodiode is positioned at the fingertip opposite the fingernail so as to detect the LED transmitted light as it emerges from the finger tissues, producing a sensor output **922** that indicates arterial blood absorption of the red and infrared LED wavelengths.

[0042] As shown in FIG. **9,** the sensor output **922** is coupled to analog signal conditioning and an analog-to-digital conversion (ADC) circuit **920.** The signal conditioning filters and amplifies the analog sensor output **922,** and the ADC provides discrete signal values to the digital signal processor **950.** The signal processor **950** provides a gain control **952** to amplifiers in the signal conditioning circuit **920.** The signal processor **950** also provides an emitter control **954** to a digital-to-analog conversion (DAC) circuit **930.** The DAC **930** provides control signals for the emitter current drivers **940.** The emitter drivers **940** couple to the red and infrared LEDs in the sensor **902.** In this manner, the signal processor **950** can alternately activate the sensor LED emitters and read the resulting output **922** generated by the photodiode detector.

[0043] The digital signal processor **950** determines oxygen saturation by computing the differential absorption by arterial blood of the red and infrared wavelengths emitted by the sensor **902.** Specifically, the ADC **920** provides the processor **950** with a digitized input **924** derived from the sensor output **922.** Based on this input **924,** the processor **950** calculates ratios of detected red and infrared intensities. Oxygen saturation values, v_i, are empirically determined based on the calculated red and infrared ratios. These values are an input signal **962** to the variable mode averager **960.** Each of the input values, v_i, are associated with weights, w_i, which form a second input **964** to the averager **960.** The individual weights, w_i, are indicative of the confidence in particular ones of the corresponding saturation values, v_i. A third input **974** sets the mode of the averager **960.** The variable mode averager **960** processes the values, v_i, weights, w_i, and *mode* as described above with respect to FIGS. **7-8** to generate values, z_i. The values z_i are the averager output 968, from which is derived the saturation output **982** to the display **980.**

[0044] The *mode* signal may be generated by an external source (not shown) or it may be generated by another function within the digital signal processor. For example, *mode* may be generated from the confidence level of the input signal as illustrated in FIG. **9.** FIG. **9** illustrates a signal confidence input **972** to a mode control process **970.** The mode control process **970** maps the signal confidence input **972** to the mode input **974** of the variable mode averager **960.** When the signal confidence is low, the mode control **970** sets *mode* to a relatively small value. Depending on the application, *mode* may be set close to zero. When the signal confidence is high, the mode control **970** sets *mode* to a relatively large value. Some applications may prefer a *mode* of one for a high signal confidence, but this is not a requirement. When the signal confidence is neither high nor low, *mode* is set to an intermediate value (in some applications, *mode* may be set to a value between zero and one) empirically to achieve a reasonable tradeoff between a fast saturation output response and saturation accuracy.

[0045] The signal quality of pulse oximetry measurements is adversely affected by patients with low perfusion of blood, causing a relatively small detected signal, ambient noise, and artifacts caused by patient motion. The signal confidence input **972** is an indication of the useful range of the pulse oximetry algorithms used by the digital signal processor **950** as a function of signal quality. This useful range is extended by signal extraction techniques that reduce the effects of patient motion, as described in U.S. Patent No. 5,632,272, U.S. Patent No. No. 5,769,785, and U.S. Patent No. No. 6,002,952, referenced above. Signal confidence is a function of how well the sensor signal matches pulse oximetry algorithm signal models. For example, the red and infrared signals should be highly correlated and the pulse shapes in the pulsatile red and infrared signals should conform to the shape of physiological pulses, as described in U.S. Patent Application No. 09/471,510 filed December 23, 1999, entitled *Plethysmograph Pulse Recognition Processor,* which is assigned to the assignee of the present invention and which is incorporated by reference herein. As a particular example, signal confidence can be determined by measuring pulse rate and signal strength. If the measured signal strength is within an expected range for the measured pulse rate, then the confidence level will be high. On the other hand, if the measured signal strength is outside the expected range (e.g., too high for the measured pulse rate), then the confidence level will be low. Other measured or calculated parameters can be advantageously used to set the confidence level.

[0046] FIG. 10 illustrates the oxygen saturation output of a pulse oximeter utilizing a variable mode averager, as described above with respect to FIG. **9.** A first output **1010** illustrates oxygen saturation versus time for input oxygen saturation values processed by a conventional weighted averager or, equivalently, by a variable mode averager **960** with *mode* $\approx$ 0. A second output **1020** illustrates oxygen saturation versus time for the variable mode averager **960** with *mode* $\approx$ 1. Each output **1010**, **1020** indicates exemplary desaturation events occurring around a first time **1030** and a second time 1040. The desaturation events correspond to a patient experiencing a potentially critical oxygen supply shortage due to a myriad of possible physiological problems. With *mode* $\approx$ 1, the variable mode averager responds to the onset of the desaturation events with less lag time **1050** than that of the conventional weighted average. Further, the variable mode averager responds to the full extent of the desaturations **1060** whereas the conventional weighted average does not. When signal confidence is low, the variable mode averager is adjusted to provide similar smoothing features to those of a conventional weighted average. When signal confidence is high, however, the variable mode averager is advantageously adjusted to respond faster and more accurately to a critical physiological event. The fast response advantage of the variable mode averager has other physiological measurement applications, such as blood-pressure monitoring and ECG.

[0047] The variable mode averager has been disclosed in detail in connection with various embodiments of the present invention. These embodiments are disclosed by way of examples only and are not to limit the scope of the present invention, which is defined by the claims that follow. One of ordinary skill in the art will appreciate many variations and modifications within the scope of this invention.

Claims

1. A pulse oximeter (900) adapted to determine an output oxygen saturation value (SpO_2) (982) for a set of input SpO_2 values (962) using a variable mode averager, the pulse oximeter comprising:

   a signal confidence indicator (972); and
   a variable mode averager, said variable mode averager comprising:

      a buffer adapted to store input SpO_2 values in a time window determined from detected light signals attenuated through tissue of a patient; and
      a processor (950) adapted to receive the signal confidence indicator (972) and to access the buffer to receive the input SpO_2 values (962), wherein the processor is configured to determine an output SpO_2 value (982) for the window of input SpO_2 values,

   characterized in that a processing function used by the processor to determine the output SpO_2 value (982) is adjusted between the smoothing characteristics of a constant mode average and the tracking characteristics of a linear or non-linear mode averager which indicates a trend of the input SpO_2 values, wherein the adjustment is based on the signal confidence indicator (972) which is a function of signal quality.

2. The signal processor of Claim 1, wherein the processor is adapted to reduce the imput SpO_2 values using one or more of a smoother, a filter, a forward predictor, and a backward predictor.

3. The signal processor of Claim 1, wherein the signal confidence indicator corresponds to a level of confidence that one or more of the input SpO_2 values represent a value of a desired signal.

4. The signal processor of Claim 1, wherein the signal confidence indicator is adjustable based on a characteristic associated with the input SpO_2 values.

5. The signal processor of Claim 4, wherein the output SpO_2 value approximates a smoother when the signal confidence indicator is low.

6. The signal processor of Claim 4, wherein the output SpO_2 value approximates a filter when the signal confidence indicator is high.

7. The signal processor of Claim 6, wherein the output SpO_2 value includes a faster response to the input SpO_2 values when the signal confidence indicator is high,

8. The signal processor of Claim 6, wherein the output SpO_2 value includes a more accurate response to the input SpO_2 values when the signal confidence indicator is high.

9. The signal processor of Claim 1, wherein the signal includes a desired signal portion indicative of SpO_2 and can include other signal artifacts.

10. A method of generating an output oxygen saturation (SpO_2) value**(982)** representative of a desired signal from a set of input (SpO_2) values (962), the method comprising the steps:

   providing a set of input (SpO_2) values of a signal wherein the signal includes a desired signal indicative of an accurate SpO_2 and may include other signal artifacts

providing a measure of signal confidence **(972);**
estimating values of the desired signal from the input (SpO_2) values (968)
and determining an output (SpO_2) value **(982)** based on the estimated values **(968)** and on a time associated with the measure of signal confidence.

11. The method of Claim 10, wherein the measurement of signal confidence is based on whether the input (SpO_2) values represent values of the desired signals,

12. The method of Claim 10, wherein the determining said output (SpO_2) value comprises applying one of a smoother, a filter, a forward predictor, and a backward predictor to the input (SpO_2) values,

Patentansprüche

1. Pulsoximeter (900), das geeignet ist, einen Ausgangssauerstoffsättigungswert (SpO_2) (982) für einen Satz von Eingangs-SpO_2-Werten (962) mittels eines Mittelwertrechners mit variabler Betriebsart zu bestimmen, wobei das Pulsoximeter aufweist:

eine Signalkonfidenzanzeige (972); und
einen Mittelwertrechner mit variabler Betriebsart, wobei der Mittelwertrechner mit variabler Betriebsart aufweist:

einen Puffer, der geeignet ist, Eingangs-SpO_2-Werte in einem Zeitfenster zu speichern, die aus detektierten Lichtsignalen bestimmt werden, die durch das Gewebe eines Patienten gedämpft werden; und
einen Prozessor (950), der geeignet ist, die Signalkonfidenzanzeige (972) zu empfangen und auf den Puffer zuzugreifen, um die Eingangs-SpO_2-Werte (962) zu empfangen, wobei der Prozessor konfiguriert ist, einen Ausgangs-SpO_2-Wert (982) für das Fenster der Eingangs-SpO_2-Werte zu bestimmen,

dadurch gekennzeichnet, dass eine durch den Prozessor verwendete Verarbeitungsfunktion zum Bestimmen des Ausgangs-SpO_2-Werts (982), zwischen der Glättungscharakteristik eines Mittelwertrechners mit konstanter Betriebsart und der Nachlaufcharakteristik eines Mittelwertrechners mit linearer oder nicht-linearer Betriebsart eingestellt wird, die einen Trend der Eingangs-SpO_2-Werte anzeigt, wobei die Einstellung auf der Signalkonfidenzanzeige (972) beruht, die eine Funktion der Signalqualität ist.

2. Signalprozessor nach Anspruch 1, wobei der Prozessor geeignet ist, die Eingangs-SpO_2-Werte mittels eines Glättungsglieds, eines Filters, eines Vorwärtsprädiktors und/oder eines Rückwärtsprädiktors zu reduzieren.

3. Signalprozessor nach Anspruch 1, wobei die Signalkonfidenzanzeige einem Konfidenzpegel entspricht, dass ein oder mehrere Eingangs-SpO_2-Werte einen Wert eines erwünschten Signals repräsentieren.

4. Signalprozessor nach Anspruch 1, wobei die Signalkonfidenzanzeige beruhend auf einer Charakteristik einstellbar ist, die mit den Eingangs-SpO_2-Werten verbunden ist.

5. Signalprozessor nach Anspruch 4, wobei der Ausgangs-SpO_2-Wert ein Glättungsglied annähert, wenn die Signalkonfidenzanzeige-niedrig ist.

6. Signalprozessor nach Anspruch 4, wobei der Ausgangs-SpO_2-Wert einen Filter annähert, wenn die Signalkonfidenzanzeige hoch ist.

7. Signalprozessor nach Anspruch 6, wobei der Ausgangs-SpO_2-Wert eine schnellere Antwort auf die Eingangs-SpO_2-Werte aufweist, wenn die Signalkonfidenzanzeige hoch ist.

8. Signalprozessor nach Anspruch 6, wobei der Ausgangs-SpO_2-Wert eine genauere Antwort auf die Eingangs-SpO_2-Werte aufweist, wenn die Signalkonfidenzanzeige hoch ist.

9. Signalprozessor nach Anspruch 1, wobei das Signal einen erwünschten Signalanteil aufweist, der die SpO_2 anzeigt, und andere Signalartefakte aufweisen kann.

10. Verfahren zum Erzeugen eines Ausgangssauerstoffsättigungs-(spO_2) Werts (982), der für ein erwünschtes Signal repräsentativ ist, aus einem Satz Eingangs- (SpO_2) Werte (962), wobei das Verfahren die Schritte aufweist:

Bereitstellen eines Satzes von Eingangs- (SpO_2) Werten eines Signals, wobei das Signal ein erwünschtes Signal aufweist, das eine genaue SpO_2 anzeigt, und andere Signalartefakte aufweisen kann;
Bereitstellen eines Signalkonfidenzmaßes (972);
Schätzen von Werten des erwünschten Signals aus den Eingangs- (SpO_2) Werten (968) , und
Bestimmen eines Ausgangs- (SpO_2) Werts (982) beruhend auf den geschätzten Werten (968) und auf einer mit dem Signalkonfidenzmaß verbundenen Zeit.

11. Verfahren nach Anspruch 10, wobei die Messung der Signalkonfidenz darauf beruht, ob die Eingangs- (SpO_2) Werte Werte des erwünschten Signals repräsentieren.

12. Verfahren nach Anspruch 10, wobei das Bestimmen des Ausgangs- (SpO_2) Werts das Anwenden eines Glättungsglieds, eines Filters, eines Vorwärtsprädiktors und/oder eines Rückwärtsprädiktors auf die Eingangs- (SpO_2) Werte umfasst.

Revendications

1. Sphygmo-oxymètre (900) adapté pour déterminer une valeur de saturation en oxygène de sortie (SpO_2) (982) pour un jeu de valeurs (SpO_2) d'entrée (962) à l'aide d'un calculateur de moyenne à mode variable, le sphygmo-oxymètre comprenant :

► un indicateur de confiance de signal (972) ; et
► un calculateur de moyenne à mode variable, ledit calculateur de moyenne à mode variable comprenant :

► une mémoire tampon adaptée pour stocker des valeurs SpO_2 dans une fenêtre temporelle déterminées à partir de signaux de lumière détectés atténués à travers le tissu d'un patient ; et
► un processeur (950) adapté pour recevoir l'indicateur de confiance de signal (972) et pour accéder à la mémoire tampon afin de recevoir les valeurs SpO_2 d'entrée (962), où le processeur est configuré pour déterminer une valeur SpO_2 de sortie (982) pour la fenêtre de valeurs SpO_2 d'entrée,

caractérisé en ce qu'une fonction de traitement utilisée par le processeur pour déterminer la valeur SpO_2 de sortie (982) est ajustée entre les caractéristiques de lissage d'une moyenne à mode constant et les caractéristiques de lecture d'un calculateur de moyenne à mode linéaire ou non linéaire qui indique une tendance des valeurs SpO_2 d'entrée, où l'ajustement est basé sur l'indicateur de confiance de signal (972) qui est fonction de la qualité de signal.

2. Processeur de-signal selon la revendication 1, dans lequel le processeur est adapté pour réduire les valeurs SpO_2 d'entrée en utilisant un ou plusieurs éléments parmi un lisseur, un filtre, un prédicteur avant et un prédicteur arrière.

3. Processeur de signal selon la revendication 1, dans lequel l'indicateur de confiance de signal correspond à un niveau de confiance concernant le fait qu'une ou plusieurs des valeurs SpO_2 d'entrée représentent une valeur d'un signal souhaité.

4. Processeur de signal selon la revendication 1, dans lequel l'indicateur de confiance de signal est réglable d'après une caractéristique associée aux valeurs SpO_2 d'entrée.

5. Processeur de signal selon la revendication 4, dans lequel la valeur SpO_2 de sortie tend vers un lisseur lorsque l'indicateur de confiance de signal est bas.

6. Processeur de signal selon la revendication 4, dans lequel la valeur SpO_2 de sortie tend vers un filtre lorsque l'indicateur de confiance de signal est haut.

7. Processeur de signal selon la revendication 6, dans lequel la valeur SpO_2 de sortie inclut une réponse plus rapide aux valeurs SpO_2 d'entrée lorsque l'indicateur de confiance de signal est haut.

8. Processeur de signal selon la revendication 6, dans lequel la valeur SpO_2 de sortie inclut une réponse plus précise aux valeurs SpO_2 d'entrée lorsque l'indicateur de confiance de signal est haut.

9. Processeur de signal selon la revendication 1, dans lequel le signal inclut une portion de signal souhaitée indiquant SpO_2 et peut inclure d'autres artéfacts de signal.

10. Méthode de génération d'une valeur de saturation en oxygène (SpO_2) de sortie (982) représentative d'un signal souhaité dans un jeu de valeurs SpO_2 d'entrée (962), la méthode comprenant les étapes consistant à :

► fournir un jeu de valeurs SpO_2 d'entrée d'un signal, où le signal inclut un signal souhaité indiquant une SpO_2 précise et peut inclure d'autres artéfacts de signal ;
► fournir une mesure de confiance de signal (972);
► estimer des valeurs du signal souhaité à partir des valeurs (SpO_2) d'entrée (968) ; et
► déterminer une valeur (SpO_2) de sortie (982) d'après les valeurs estimées (968) et sur une durée associée à la mesure de confiance de signal.

11. Méthode selon la revendication 10, dans laquelle la mesure de confiance de signal est basée sur le fait que les valeurs (SpO_2) d'entrée représentent ou non des valeurs du signal souhaité.

12. Méthode selon la revendication 10, dans laquelle la détermination de ladite valeur (SpO_2) de sortie comprend l'application d'un élément parmi un lisseur, un filtre, un prédicteur avant et un prédicteur arrière aux valeurs (SpO_2) d'entrée.

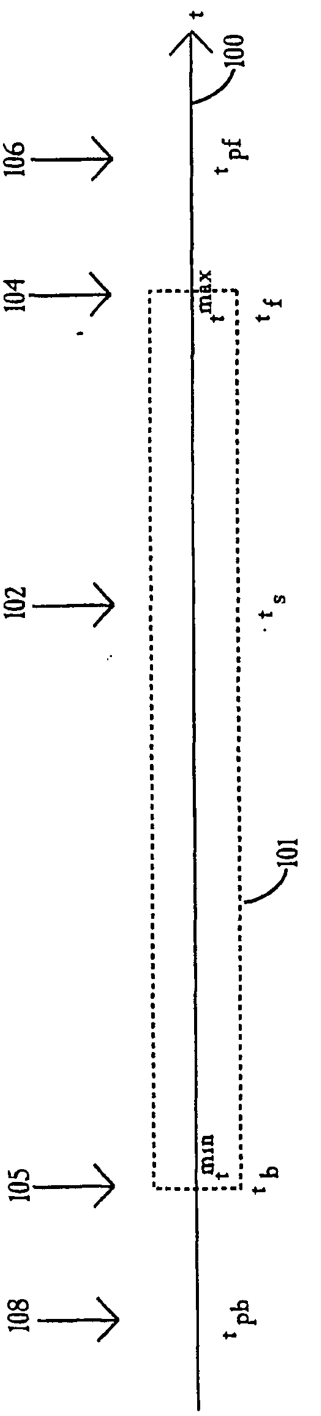

FIG. 1

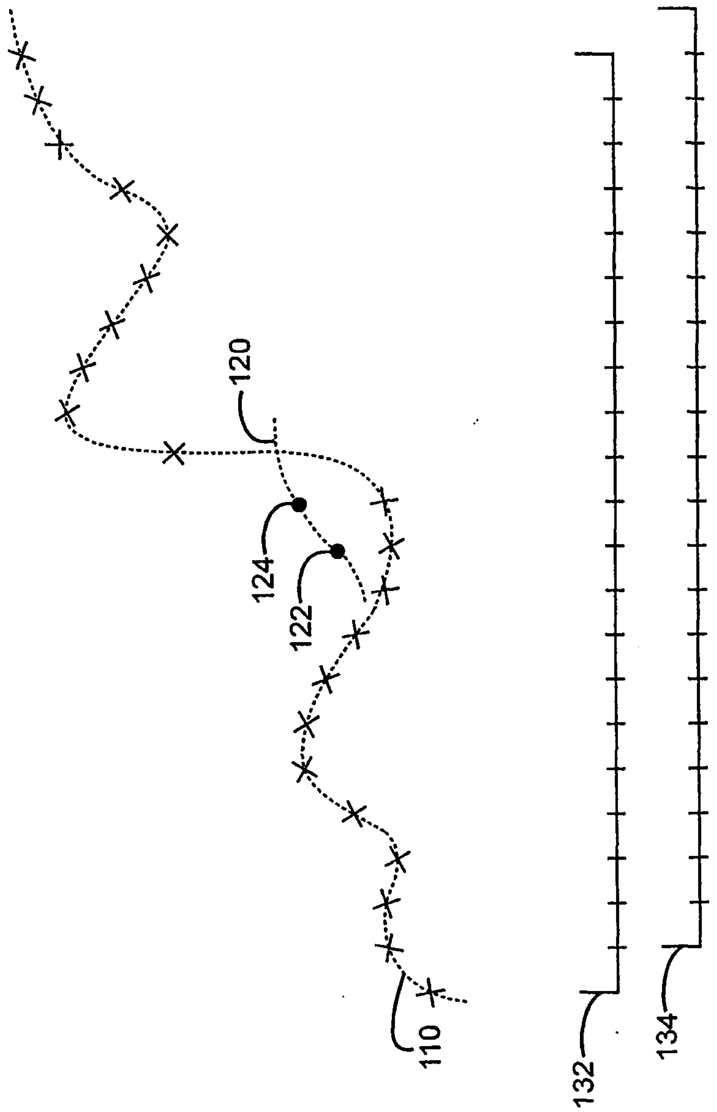

FIG. 2A

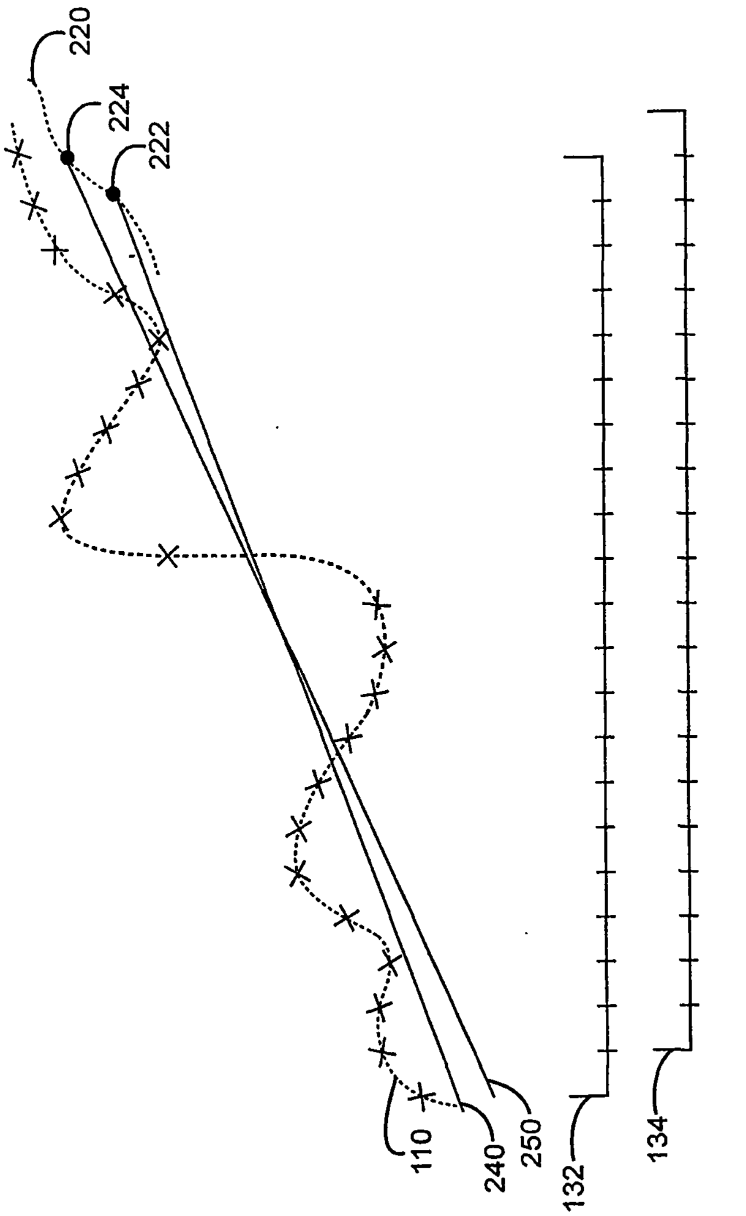

FIG. 2B

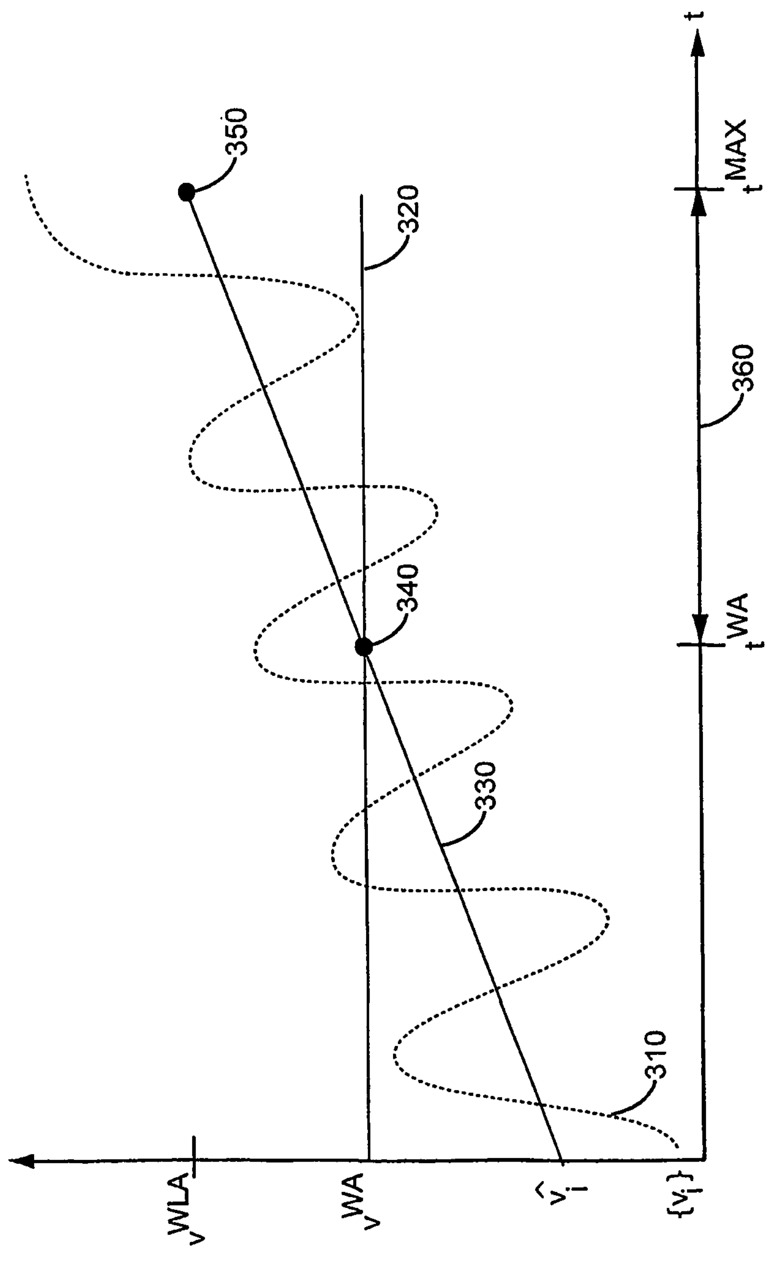

FIG. 3

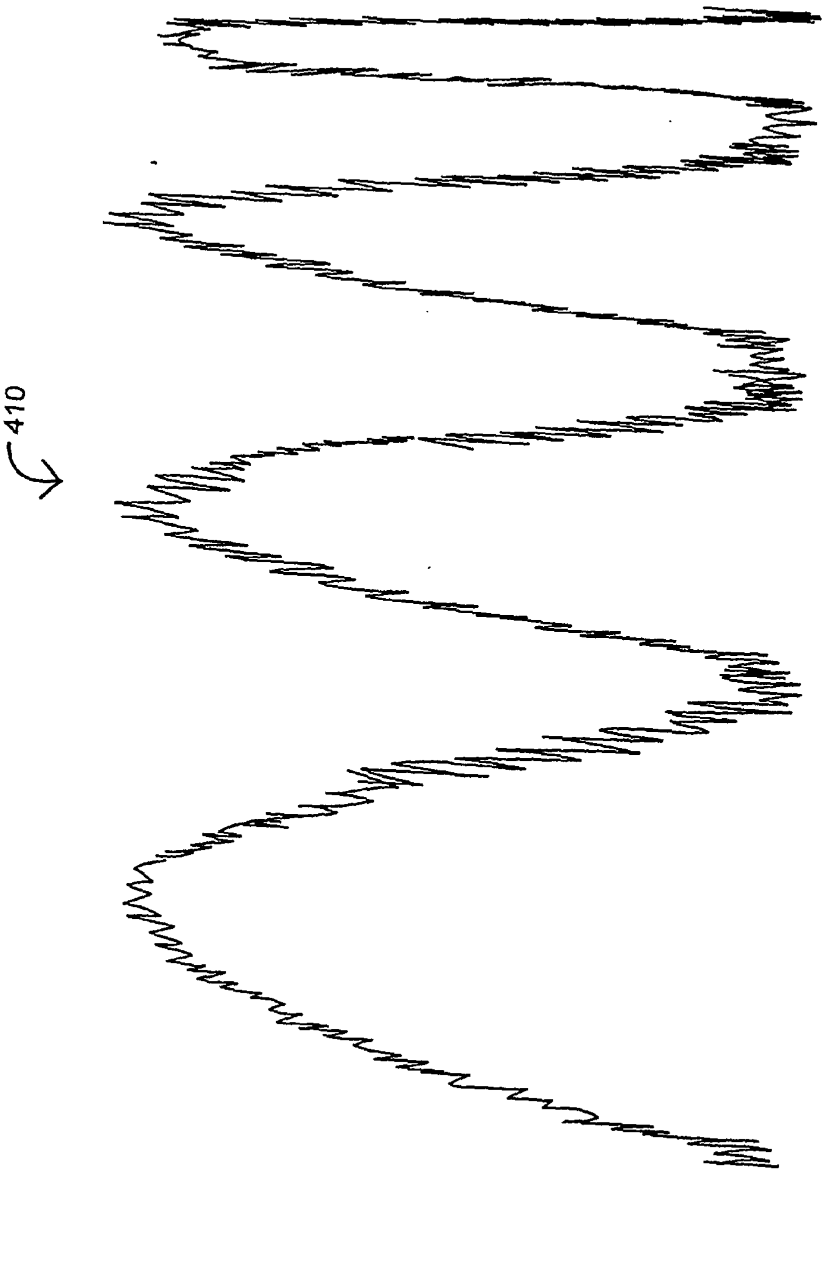

FIG. 4

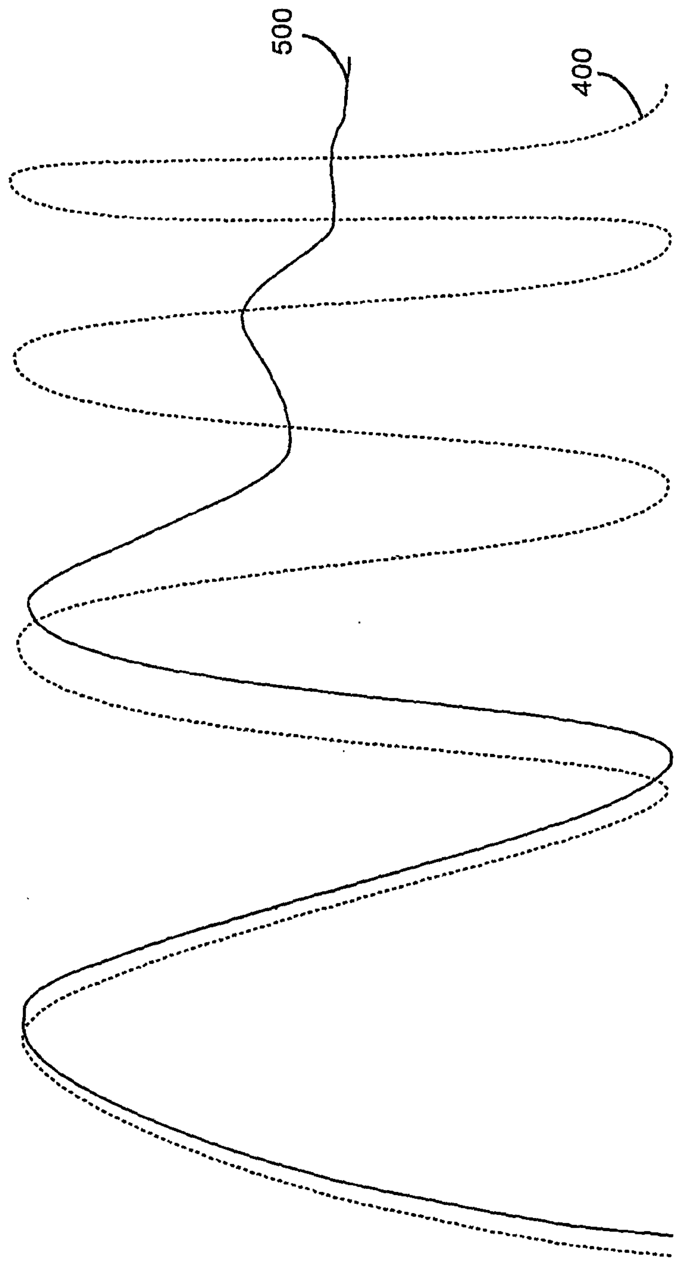

FIG. 5

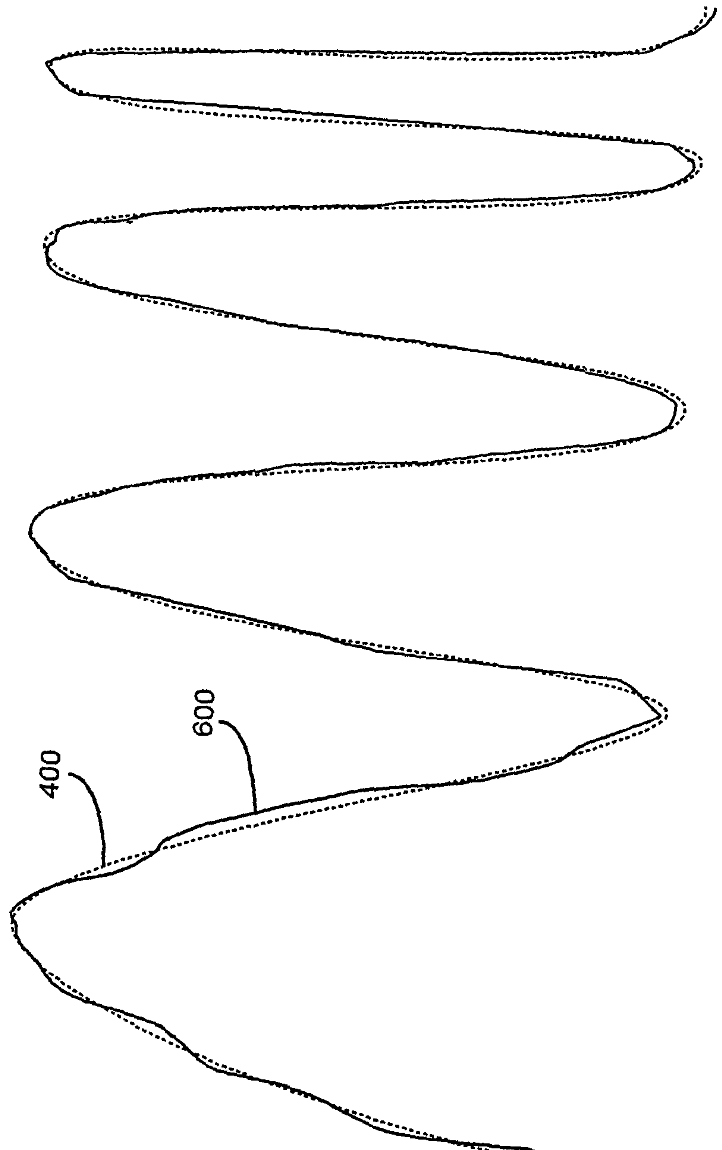

FIG. 6

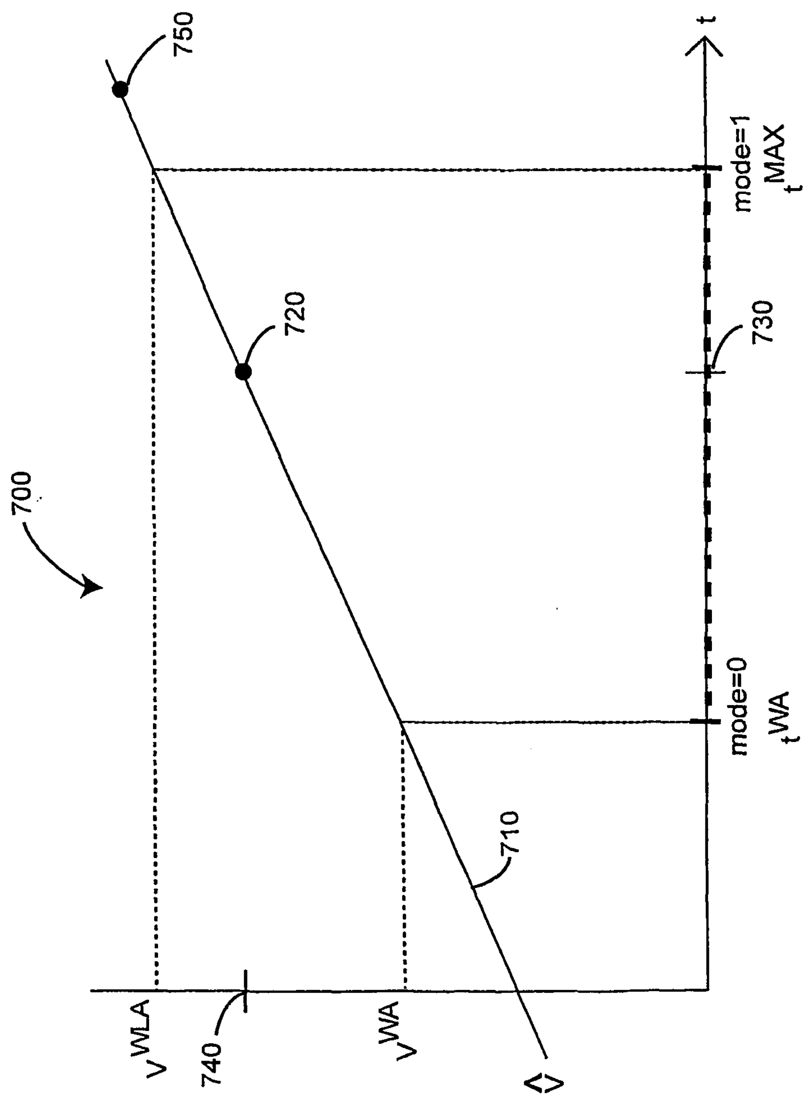

FIG. 7

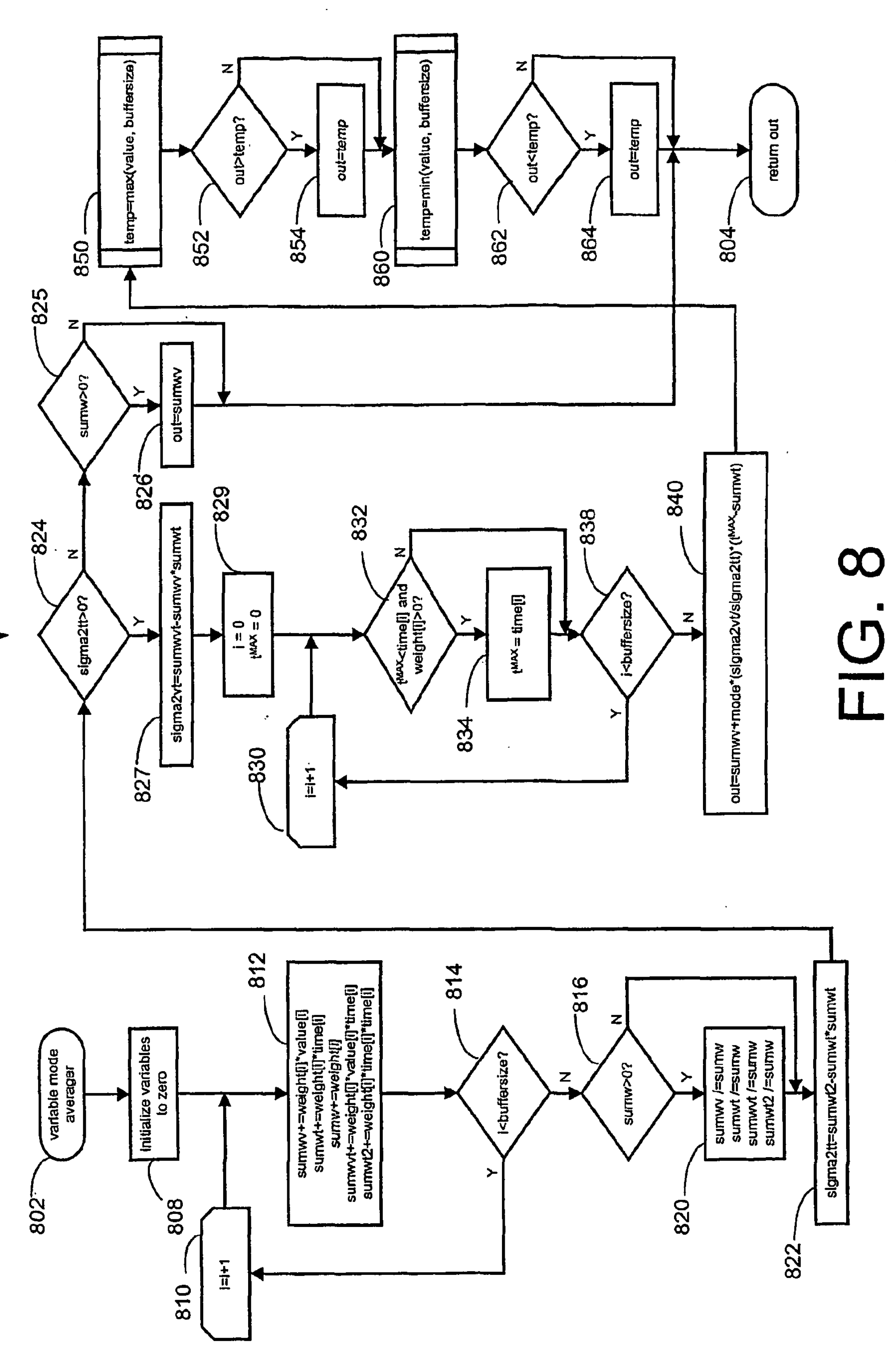
800
802
variable mode averager
808
initialize variables to zero
810
i=i+1
812
sumwv+=weight[i]*value[i]
sumwt+=weight[i]*time[i]
sumw+=weight[i]
sumwvt+=weight[i]*value[i]*time[i]
sumwt2+=weight[i]*time[i]*time[i]
814
i<buffersize?
816
sumw>0?
820
sumwv /=sumw
sumwt /=sumw
sumwvt /=sumw
sumwt2 /=sumw
822
sigma2tt=sumwt2-sumwt*sumwt
824
sigma2tt>0?
825
sumw>0?
826
out=sumwv
827
sigma2vt=sumwvt-sumwv*sumwt
829
i = 0
t^MAX = 0
830
i=i+1
832
t^MAX<time[i] and weight[i]>0?
834
t^MAX = time[i]
838
i<buffersize?
840
out=sumwv+mode*(sigma2vt/sigma2tt)*(t^MAX-sumwt)
850
temp=max(value, buffersize)
852
out>temp?
854
out=temp
860
temp=min(value, buffersize)
862
out<temp?
864
out=temp
804
return out
Y
N

FIG. 8

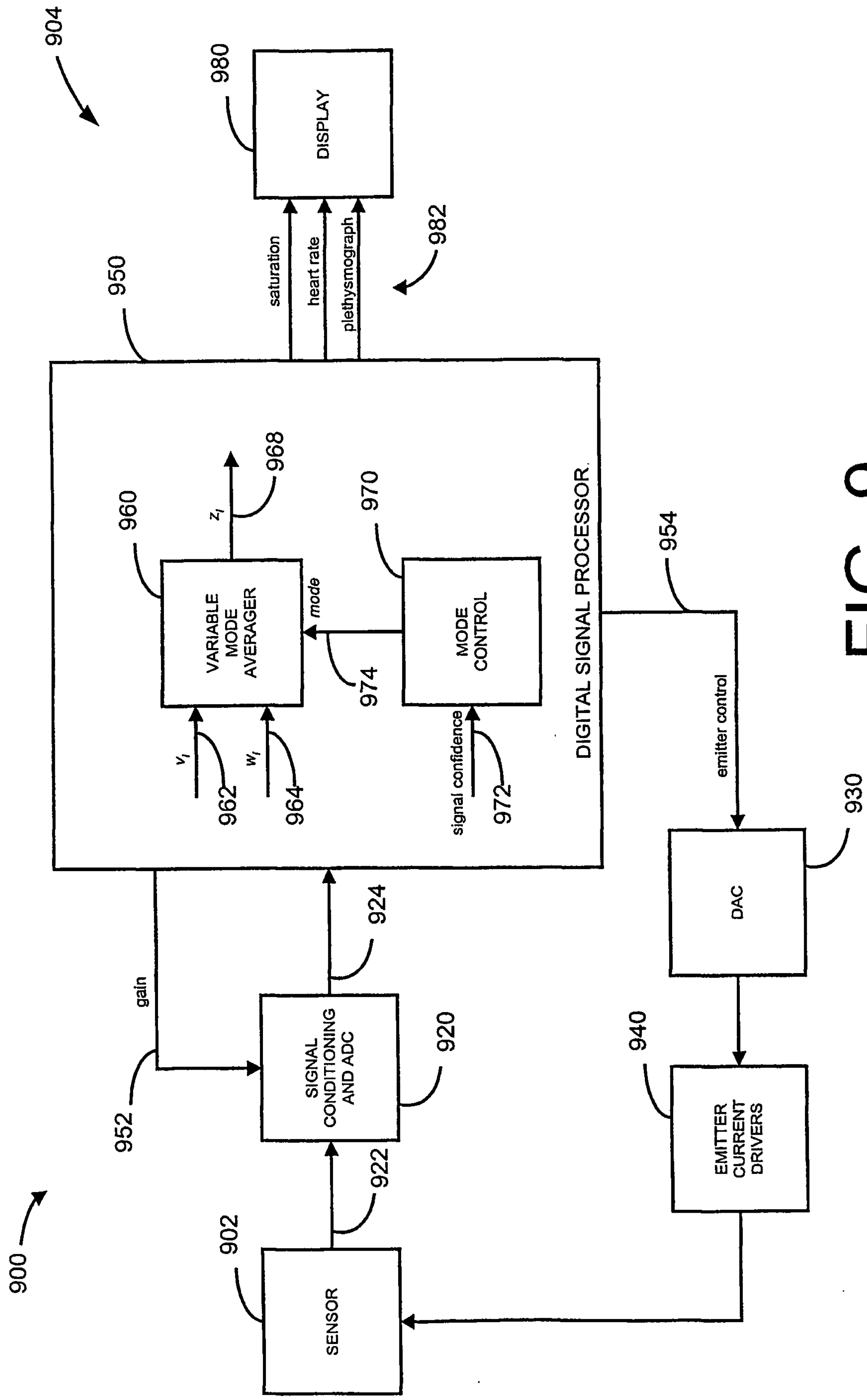
904
900
DISPLAY
980
saturation
heart rate
plethysmograph
982
950
DIGITAL SIGNAL PROCESSOR
VARIABLE MODE AVERAGER
960
968
z_i
v_i
w_i
962
964
MODE CONTROL
970
mode
974
signal confidence
972
954
emitter control
DAC
930
gain
952
SIGNAL CONDITIONING AND ADC
920
924
922
SENSOR
902
EMITTER CURRENT DRIVERS
940

FIG. 9

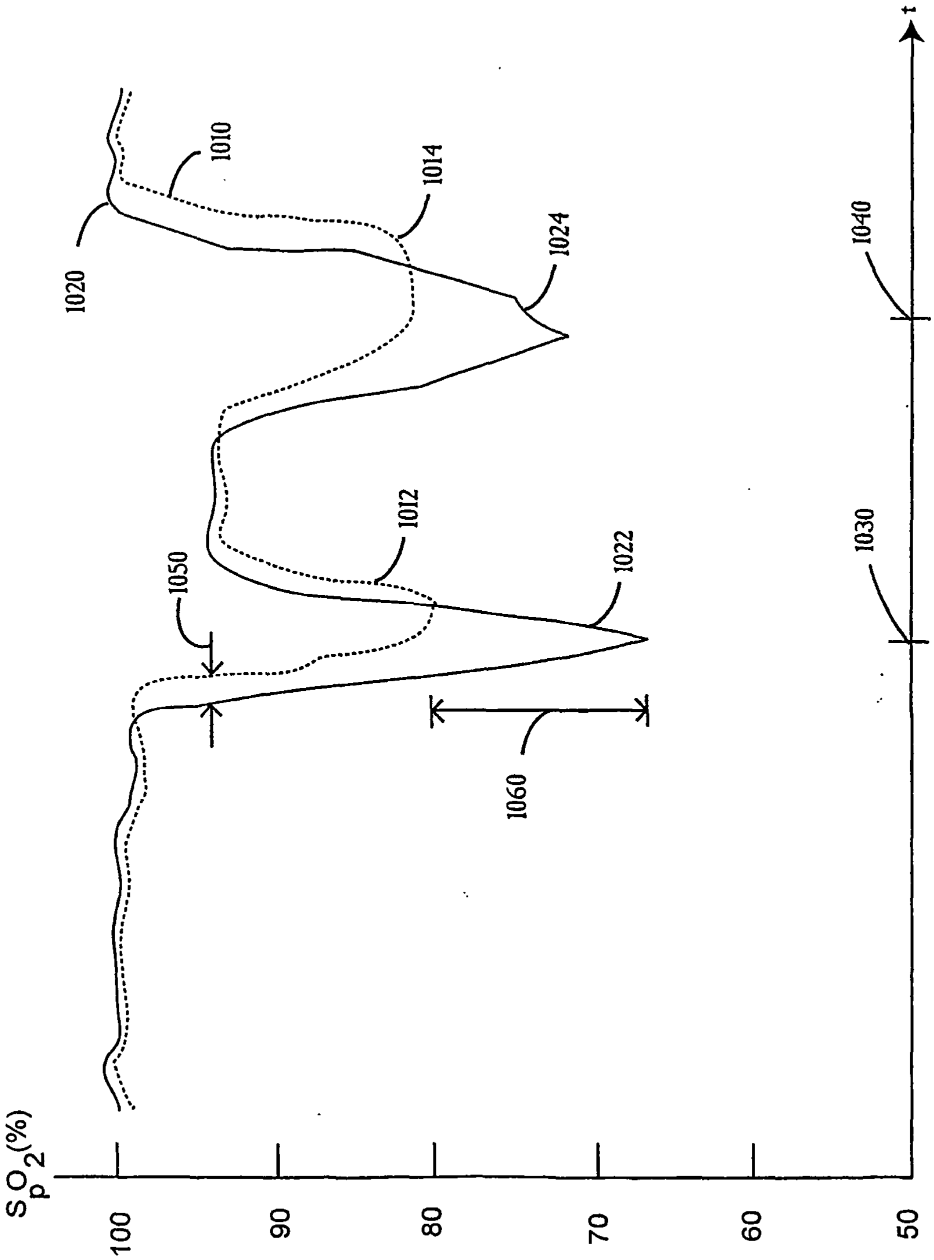
S_pO_2(%)
100
90
80
70
60
50
t
1010
1012
1014
1020
1022
1024
1030
1040
1050
1060

FIG. 10

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- WO 9612435 A **[0003]**
- WO 9502288 A **[0004]**
- US 5632272 A **[0040] [0045]**
- US 5769785 A **[0040] [0045]**
- US 6002952 A **[0040] [0045]**
- US 47151099 A **[0045]**

patsnap

专利名称(译)	可变模式平均值		
公开(公告)号	EP1286619B1	公开(公告)日	2011-04-20
申请号	EP2001946090	申请日	2001-06-05
[标]申请(专利权)人(译)	梅西莫股份有限公司		
申请(专利权)人(译)	Masimo公司		
当前申请(专利权)人(译)	Masimo公司		
[标]发明人	WEBER WALTER M AL ALI AMMAR		
发明人	WEBER, WALTER, M. AL-ALI, AMMAR		
IPC分类号	A61B5/00 H03H17/00 A61B5/145 A61B5/1455 G06F17/00 G06F17/18		
CPC分类号	A61B5/7271 A61B5/0002 A61B5/021 A61B5/1455 A61B5/14551 A61B5/6826 A61B5/6829 A61B5/6838 A61B5/72 A61B5/7207 A61B5/7239 G06K9/0051		
代理机构(译)	法思博事务所		
优先权	09/586845 2000-06-05 US		
其他公开文献	EP1286619A4 EP1286619A1		
外部链接	Espacenet		

摘要(译)

一种可变指示估计器，其确定表示一组输入数据的输出值。例如，估计器可以将输入数据减少到期望信号的估计，选择时间，并根据估计和时间确定输出值。在一个实施例中，使用一个或多个可调信号置信度参数来选择时间，确定沿估计的位置将计算输出值。通过改变参数，输出值的特征是可变的。例如，当输入信号置信度低时，调整参数使得输出值是输入信号的平滑表示。当输入信号置信度高时，调整参数以使输出值对输入信号具有更快和更准确的响应。