US 20060192667A1

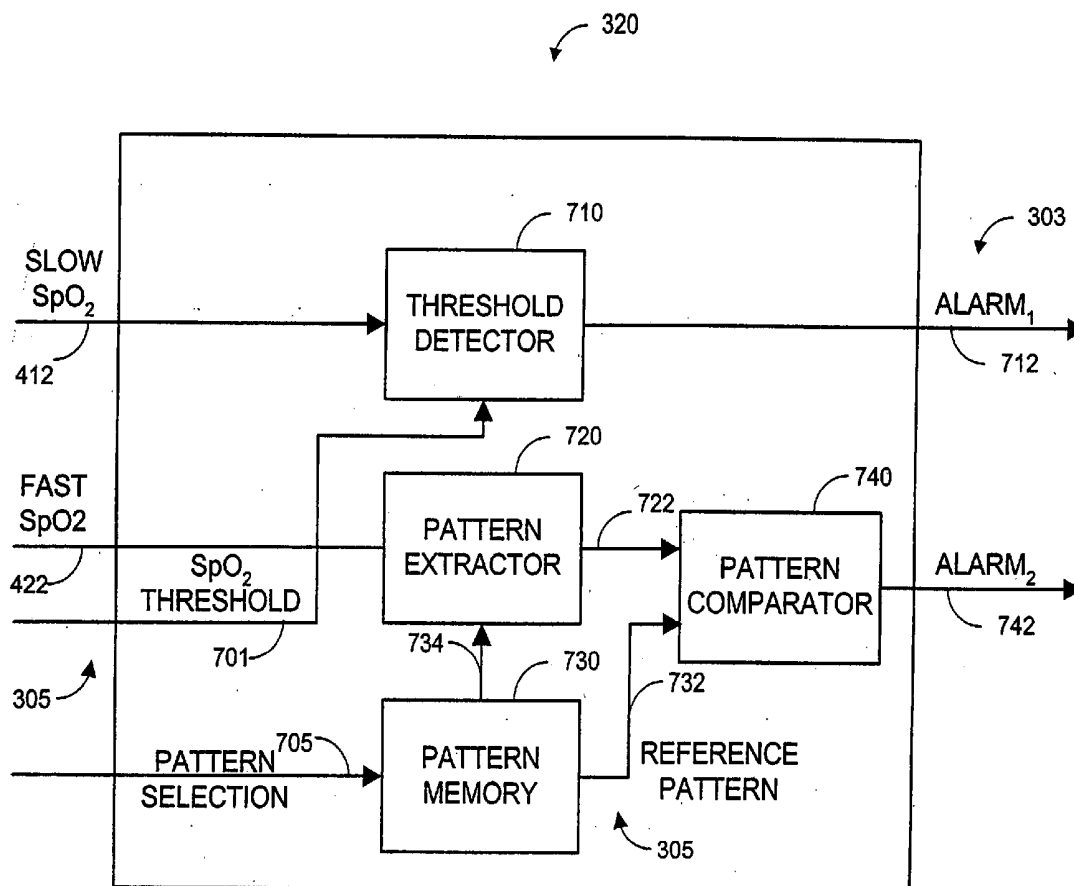(54) ARRHYTHMIA ALARM PROCESSOR

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(57) ABSTRACT

An arrhythmia alarm processor has a pattern extractor and a predetermined reference pattern. The pattern extractor has an output responsive to short duration, intermittent oxygen desaturations of a patient as determined by a fast blood oxygen saturation processor incorporated within a pulse oximeter. The reference pattern is indicative of a series of oxygen desaturations resulting from an irregular heartbeat. An alarm is triggered when the pattern extractor output matches the predetermined reference pattern.
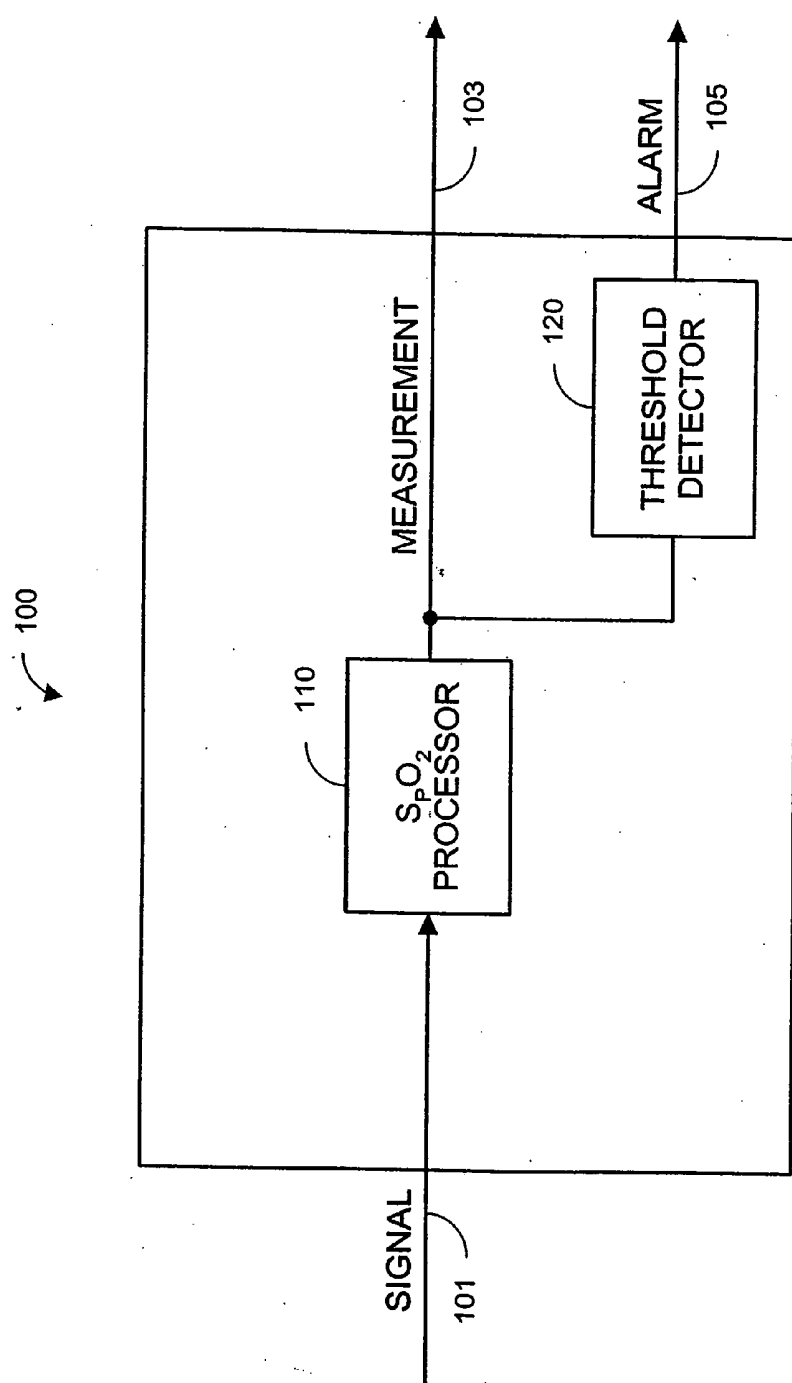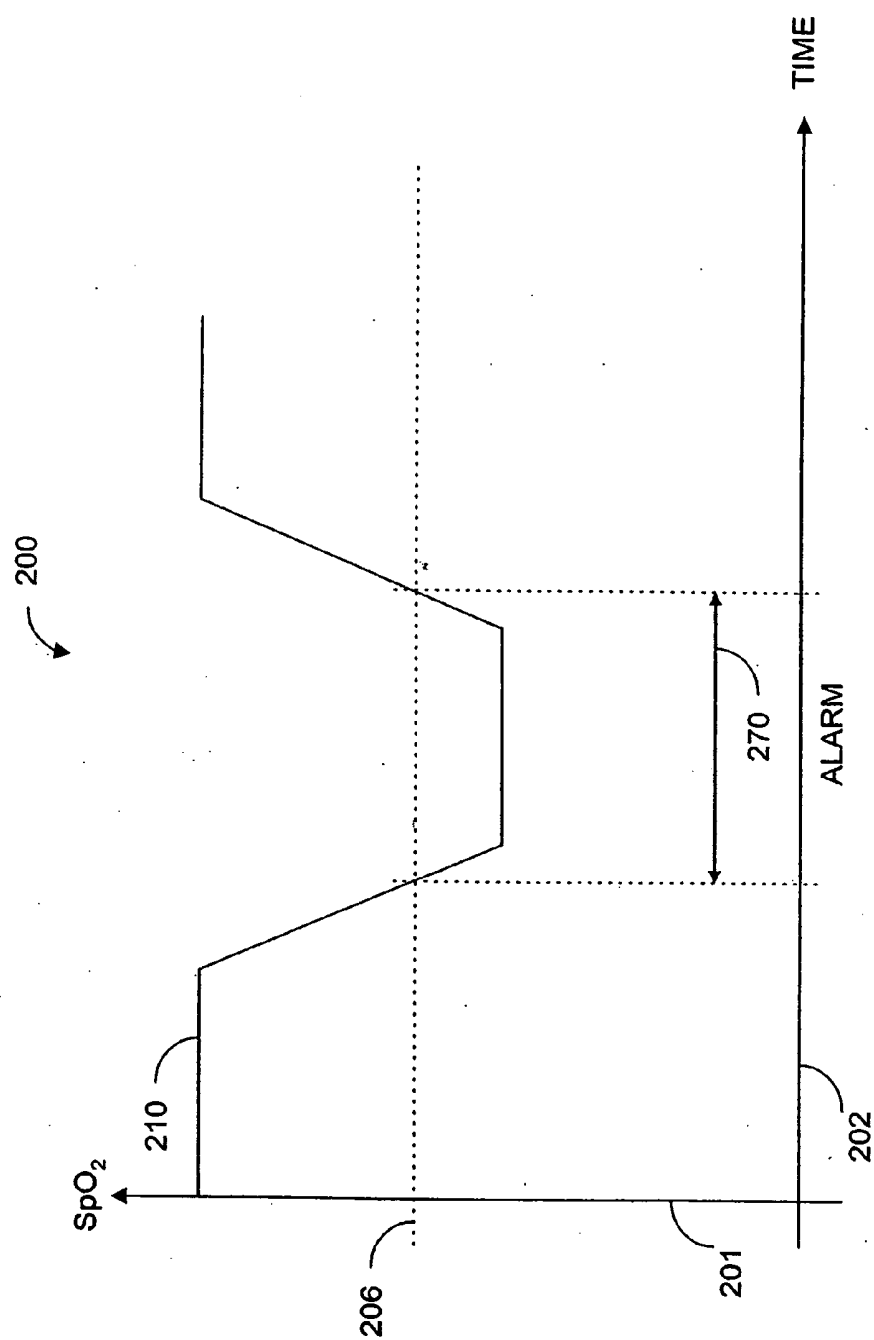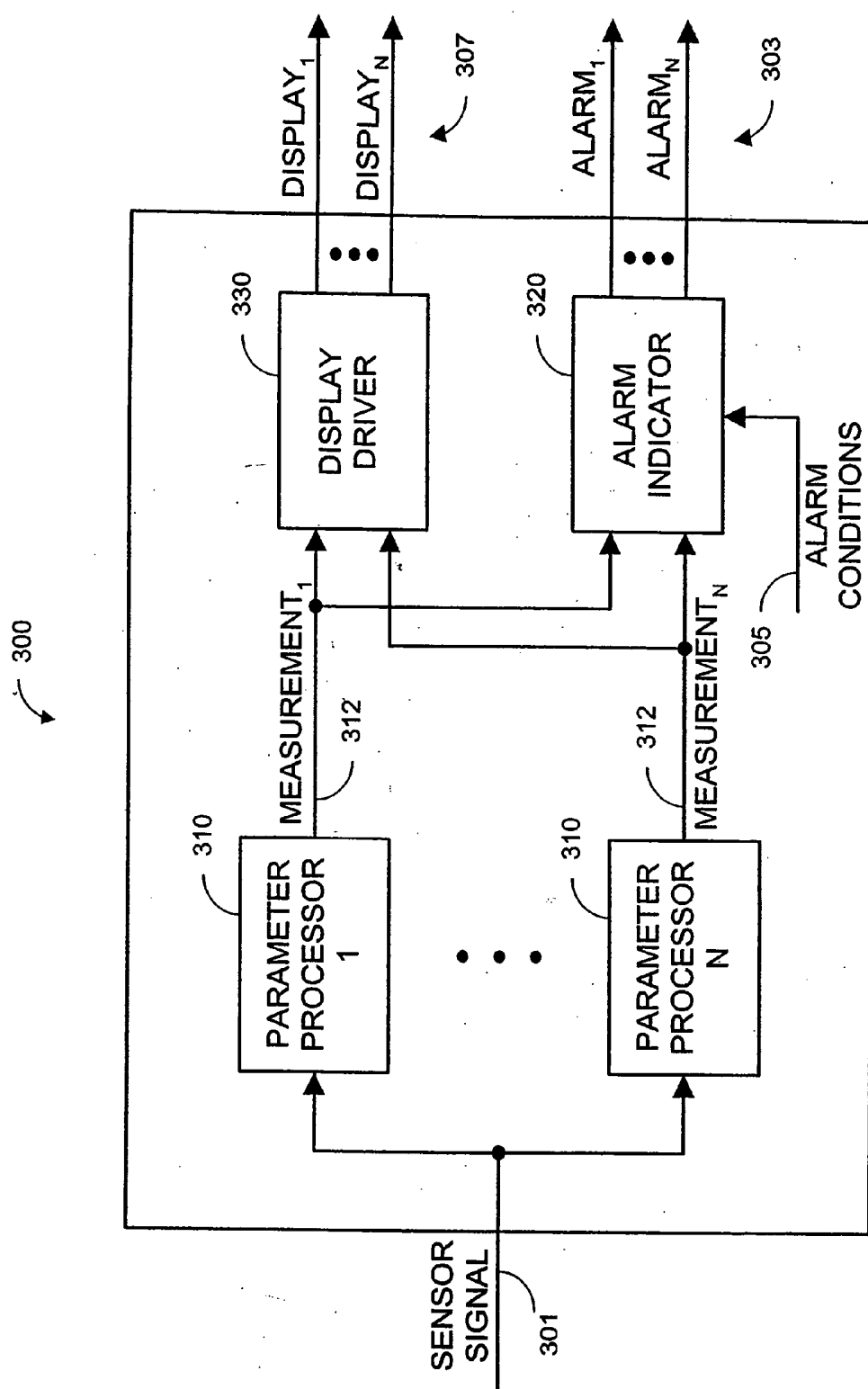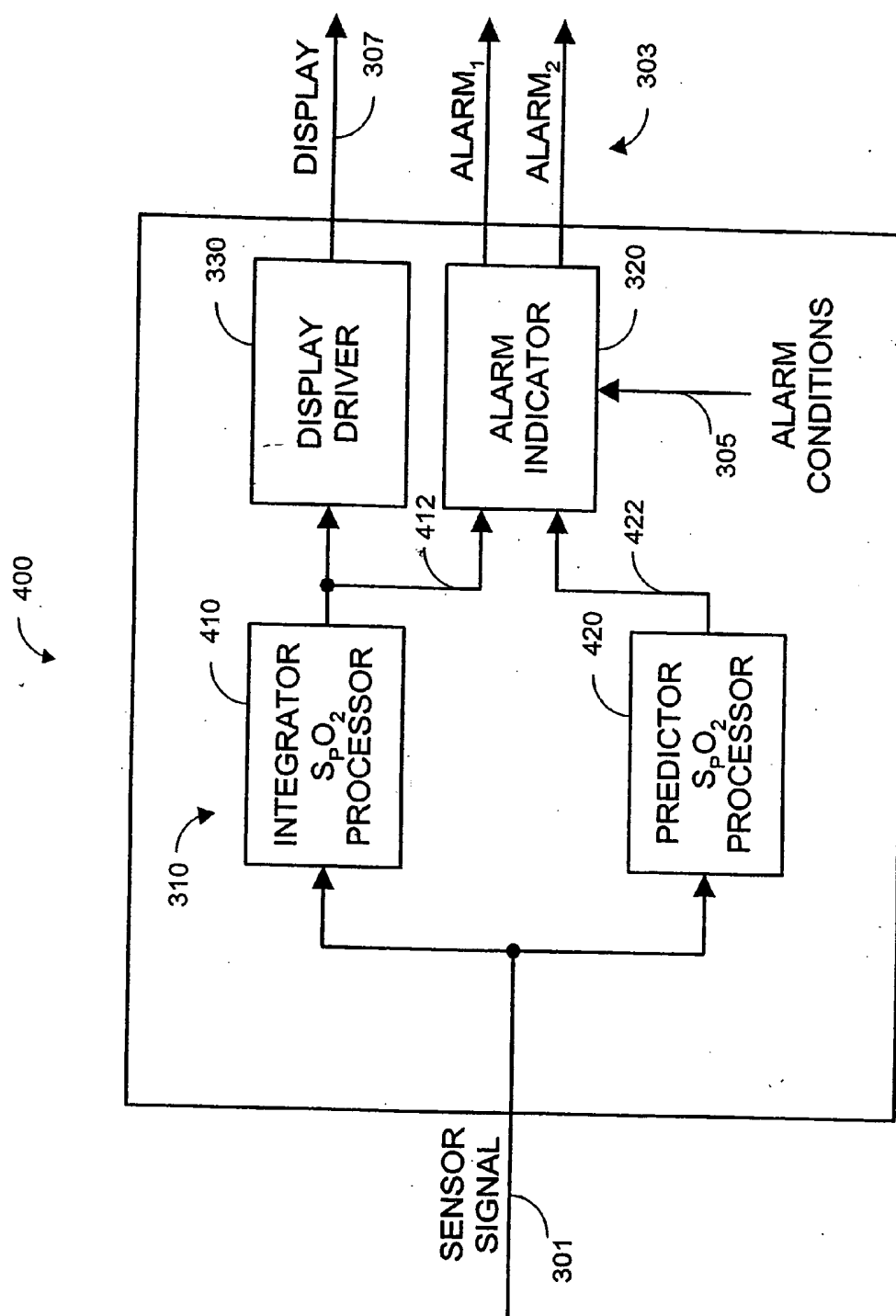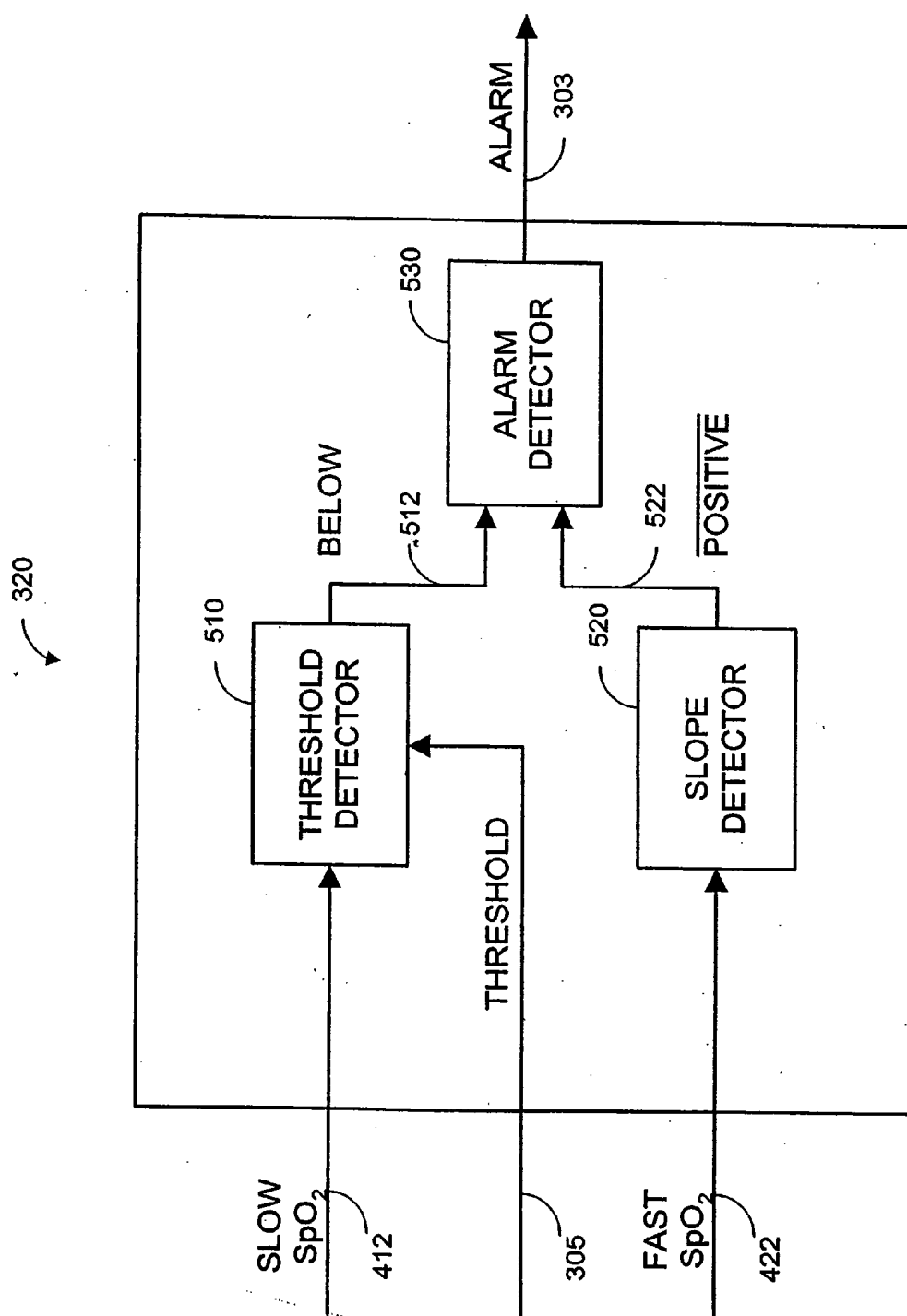
320
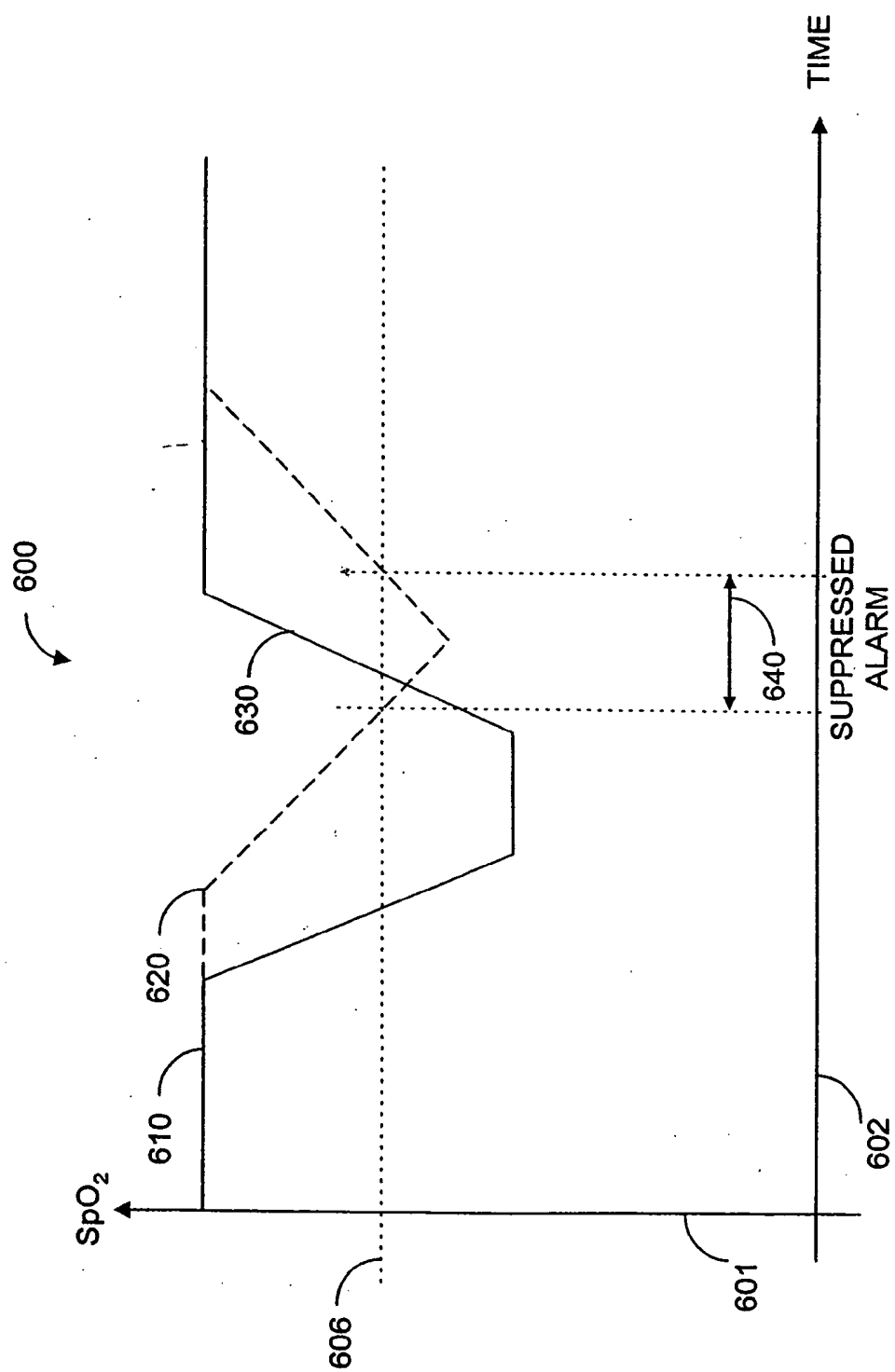
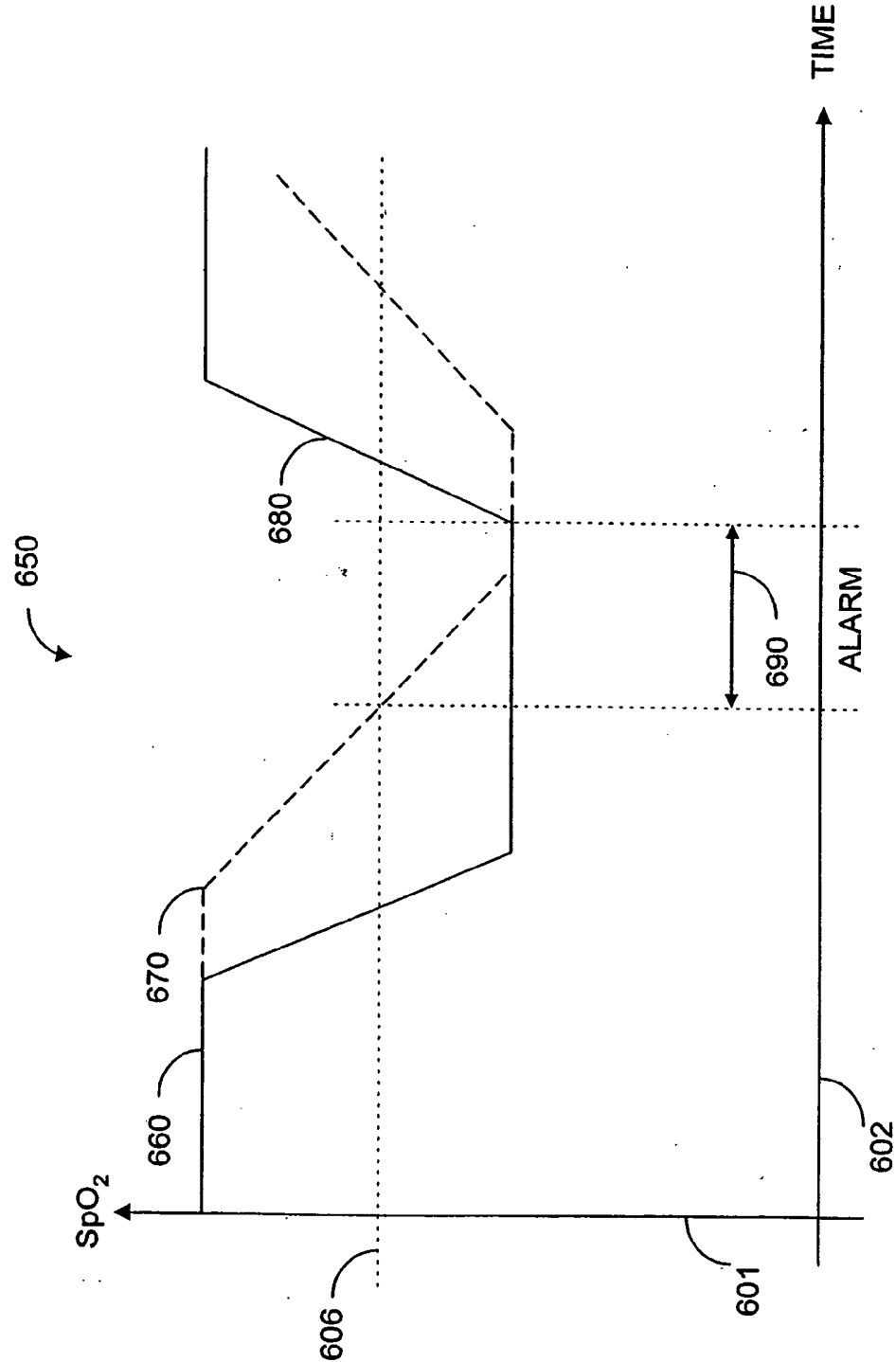FIG. 1 (Prior Art)
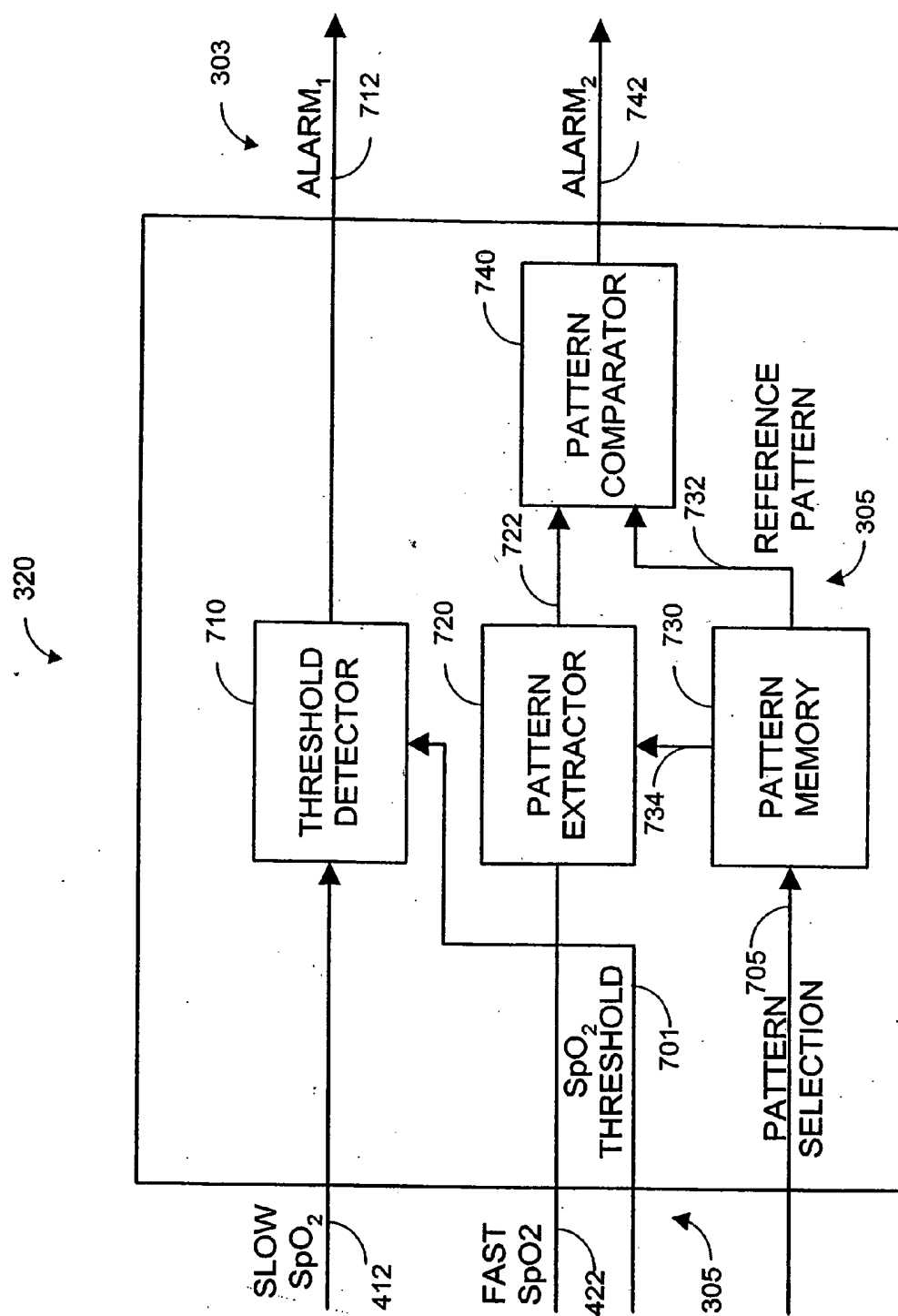
FIG. 2

FIG. 3

FIG. 4

FIG. 5

FIG. 6A

FIG. 6B

FIG. 7
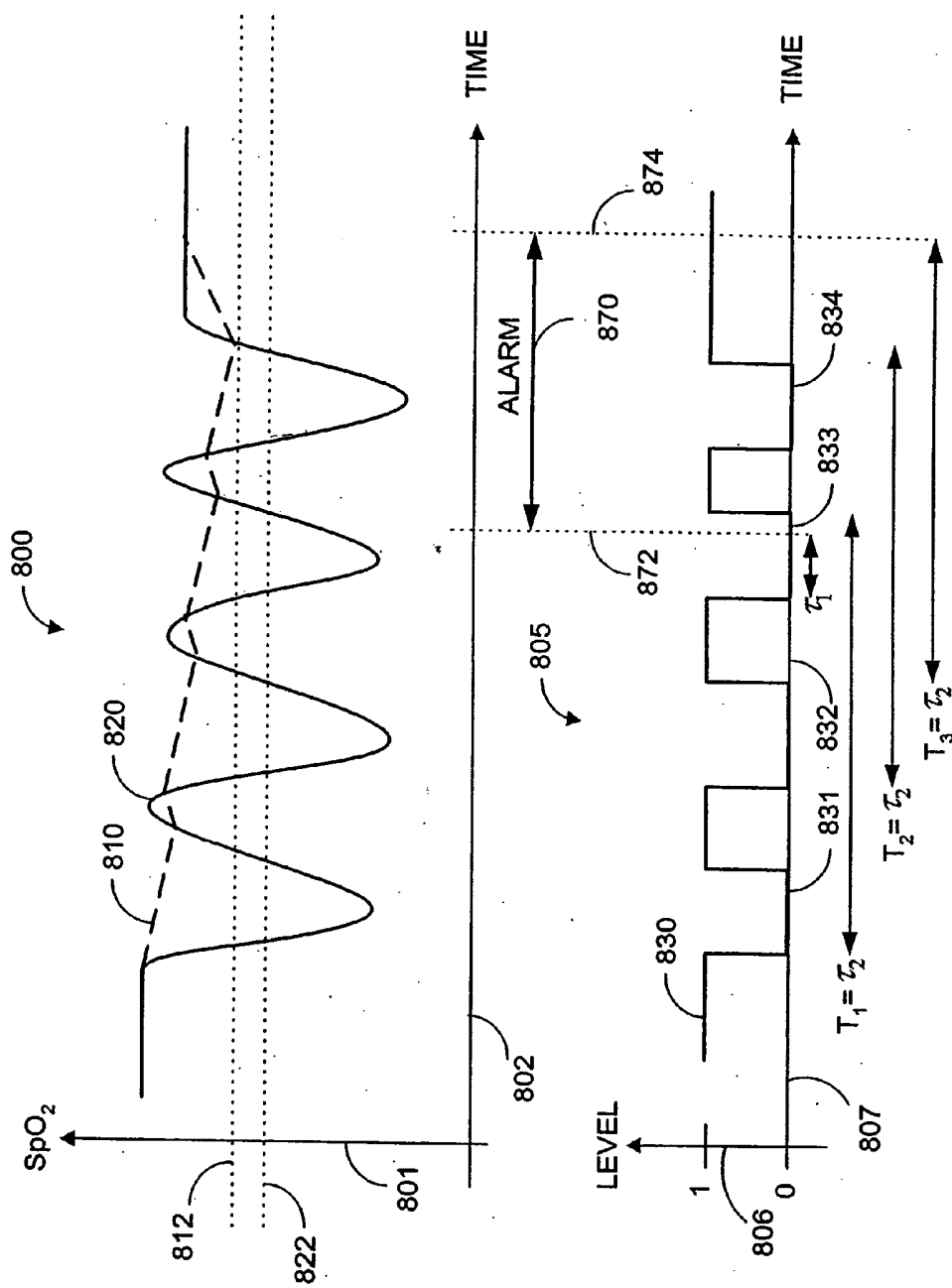
FIG. 8

ARRHYTHMIA ALARM PROCESSOR

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] The present application claims priority benefit under 35 U.S.C. § 120 to, and is a continuation of, U.S. patent application Ser. No. 10/975,860, filed Oct. 28, 2004 entitled "Parallel Measurement Alarm Processor," which is a continuation of U.S. patent application Ser. No. 10/351,735, filed Jan. 24, 2003, now U.S. Pat. No. 6,822,564, entitled "Parallel Measurement Alarm Processor," which claims priority benefit under 35 U.S.C. § 119(e) from U.S. Provisional Application No. 60/351,510, filed Jan. 24, 2002, entitled "Parallel Measurement Alarm Processor." The present application also incorporates the foregoing utility disclosures herein by reference.

BACKGROUND OF THE INVENTION

[0002] Physiological measurement instruments employed in healthcare environments often feature visual and audible alarm mechanisms that alert a caregiver when a patient's vital signs are outside of predetermined limits. One example is a pulse oximeter, which measures the oxygen saturation level of arterial blood, an indicator of oxygen supply. A typical pulse oximeter displays a numerical readout of the patient's oxygen saturation, a numerical readout of pulse rate, and a plethysmograph, which is indicative of a patient's pulse. In addition, a pulse oximeter provides an alarm that warns of a potential desaturation event.

[0003] FIG. 1 illustrates a prior art pulse oximeter portion 100 having a signal input 101 and generating an oxygen saturation measurement output 103 and an alarm output 105. The pulse oximeter portion 100 has an oxygen saturation (SpO_2) processor 110 and an associated threshold detector 120. The SpO_2 processor 110 derives an oxygen saturation measurement from the signal input 101. The signal input 101 is typically an amplified, filtered, digitized and demodulated sensor signal. A sensor emits both red and infrared (IR) wavelength light, which is transmitted through a patient's tissue, detected and input to the pulse oximeter. The pulse oximeter calculates a normalized ratio (AC/DC) of the detected red and infrared intensities, and an arterial oxygen saturation value is empirically determined based on a ratio of these normalized ratios, as is well-known in the art. The oxygen saturation measurement output 103 is typically a digital signal that is then communicated to a display.

[0004] FIG. 2 illustrates the operation of a conventional threshold detector 120 (FIG. 1) utilizing a graph 200 of oxygen saturation 201 versus time 202. The graph 200 displays a particular oxygen saturation measurement 210 corresponding to the measurement output 103 (FIG. 1) and a predetermined alarm threshold 206. During an alarm time period 270 when the measured oxygen saturation 210 is below the threshold 206, an alarm output 105 (FIG. 1) is generated, which triggers a caregiver alert. Adjusting the threshold 206 to a lower value of oxygen saturation 201 reduces the probability of an alarm, i.e. reduces the probability of a false alarm and increases the probability of a missed event. Likewise, adjusting the threshold 206 to a higher value of oxygen saturation 201 increases the probability of an alarm, i.e. increases the probability of a false alarm and decreases the probability of a missed event.

SUMMARY OF THE INVENTION

[0005] One performance measure for a physiological measurement instrument is the probability of a false alarm compared with the probability of a missed event. Missed events, such as an oxygen desaturation when measuring oxygen saturation, may detrimentally effect patient health. False alarms waste caregiver resources and may also result in a true alarm being ignored. It is desirable, therefore, to provide an alarm mechanism to reduce the probability of false alarms without significantly increasing the probability of missed events, and, similarly, to reduce the probability of missed events without significantly increasing the probability of false alarms.

[0006] An alarm processor has a signal input responsive to a physiological parameter and a plurality of parameter processors responsive to the signal input so as to provide a plurality of measurements of the parameter having differing characteristics. In addition, the alarm processor has an alarm condition applicable to at least one of the measurements so as to define a limit for the parameter. Further, the alarm processor has an alarm indicator operating on the measurements and the alarm condition so as to provide an alarm output that changes state to indicate that the parameter may have exceeded the limit.

[0007] One aspect of an arrhythmia alarm processor is a pattern extractor and a predetermined reference pattern. The pattern extractor has an output responsive to short duration, intermittent oxygen desaturations of a patient as determined by a fast blood oxygen saturation processor incorporated within a pulse oximeter. The reference pattern is indicative of a series of oxygen desaturations resulting from an irregular heartbeat. An alarm is triggered when the pattern extractor output matches the predetermined reference pattern.

[0008] In another aspect of an arrhythmia alarm processor, a patient monitor is configured to receive a sensor signal responsive to multiple wavelengths of light emitted into a tissue site. The patient monitor has a blood oxygen saturation processor, a pattern processor and a blood oxygen saturation processor. The blood oxygen saturation processor is capable of providing a predictor measurement of blood oxygen saturation derived from a tissue site in response to a sensor signal and is responsive to short duration, intermittent oxygen desaturations of a patient. The pattern processor is responsive to the predictor measurement of blood oxygen saturation so as to detect a pattern in a series of oxygen desaturations indicative of an irregular heartbeat of a patient. An alarm is responsive to the pattern processor so as to indicate the occurrence of irregular heartbeats.

[0009] A further aspect of an arrhythmia alarm processor comprises transmitting light having multiple wavelengths into a patient tissue site and detecting the light after absorption by arterial blood within the tissue site so as to generate a sensor signal. A predictor blood oxygen saturation measurement responsive to the sensor signal and to short duration, intermittent oxygen desaturations of the patient is generated. A pattern in the blood oxygen saturation measurement indicative of an irregular heartbeat event is recognized. An alarm is triggered in response to the recognized pattern.

[0010] In yet another aspect of an arrhythmia alarm processor, a patient monitor has a processor means, a pattern

recognition means, a reference means and an alarm means. The processor means is for deriving a plurality of oxygen saturation measurements. The pattern recognition means is for extracting a desaturation pattern of short duration, intermittent oxygen desaturations. The reference means is for comparing the extracted desaturation pattern with a stored pattern indicative of irregular heartbeats. The alarm means is for indicating a match between the extracted desaturation pattern and the stored pattern.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] FIG. 1 is a block diagram of a prior art pulse oximeter portion;

[0012] FIG. 2 is a graph of oxygen saturation versus time illustrating a conventional threshold detector alarm;

[0013] FIG. 3 is a block diagram of an alarm processor utilizing parallel measurements of a physiological parameter;

[0014] FIG. 4 is a block diagram of a pulse oximeter processor utilizing dual oxygen saturation measurements;

[0015] FIG. 5 is a block diagram of a predictive alarm indicator utilizing a threshold detector with a slow oxygen saturation measurement input and a slope detector with a fast oxygen saturation measurement input;

[0016] FIGS. 6A-B are graphs of oxygen saturation versus time illustrating operation of the alarm indicator according to FIG. 5;

[0017] FIG. 7 is a block diagram of a pattern recognition alarm indicator utilizing a threshold detector with a slow oxygen saturation measurement input and a pattern extractor with a fast oxygen saturation measurement input; and

[0018] FIG. 8 is a graph of oxygen saturation versus time illustrating the pattern recognition alarm indicator according to FIG. 7.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0019] FIG. 3 illustrates a parallel measurement alarm processor 300. The alarm processor 300 has a sensor signal input 301 responsive to a physiological parameter and provides one or more alarm outputs 303 to indicate that the physiological parameter may have exceeded particular limits. The alarm processor 300 also has multiple parameter processors 310, which do not necessarily have the same or similar internal configurations. The multiple parameter processors 310 input the sensor signal 301 and provide parallel measurements 312 of the physiological parameter, each measurement having differing characteristics, such as response time or bandwidth to name a few. The alarm processor 300 further has an alarm indicator 320 that inputs the parallel parameter measurements 312 and generates the alarm outputs 303 based upon alarm conditions 305. The alarm outputs 303 change state to indicate that the parameter may have exceed one or more limits and to trigger an alarm accordingly. The alarm conditions 305 define particular limits with respect to one or more of the measurements 312. The alarm conditions 305 may be predefined, such as by user input, or determined by a separate process, such as a measurement of sensor signal quality or data confidence as described in U.S. patent application Ser. No. 09/858,114

entitled "Pulse Oximetry Data Confidence Indicator," assigned to Masimo Corporation, Irvine, Calif. and incorporated by reference herein. The alarm processor 300 may also have a display driver 330 that processes one or more of the parameter measurements 312 and provides one or more display outputs 307.

[0020] FIG. 4 illustrates a pulse oximeter embodiment 400 of the alarm processor 300 (FIG. 3) described above. A pulse oximeter sensor (not shown) provides a signal input 301 responsive to arterial oxygen saturation, as described with respect to FIG. 1, above. The alarm processor 400 has dual oxygen saturation processors 310. An integrator oxygen saturation (SpO_2) processor 410 outputs a slow SpO_2 measurement 412, i.e. a measurement having a slow response time to changes in the SpO_2 parameter. A predictor SpO_2 processor 420 outputs a fast SpO_2 measurement 422, i.e. a measurement having a fast response time that tracks changes in the SpO_2 parameter. The slow SpO_2 measurement 412 is input to a display driver 330, which provides an oxygen saturation display output 307. For example, the display output 307 may be input to a digital display that provides a numerical readout of oxygen saturation to a caregiver. Both the slow SpO_2 measurement 412 and the fast SpO_2 measurement 422 are input to an alarm indicator 320 that generates at least one alarm output 303 based upon alarm conditions 305, as described in further detail with respect to FIGS. 5-8, below.

[0021] The integrator SpO_2 processor 410, advantageously, provides a smoothed measurement of oxygen saturation suitable for threshold detection. The predictor SpO_2 processor 420, advantageously, provides a curve-fitting or a predictive measurement of oxygen saturation that detects trends in oxygen saturation, as described in further detail with respect to FIG. 5 and FIGS. 6A-B, below. Further, the predictor SpO_2 processor 420 advantageously tracks oxygen saturation details that may signal a critical physiological event, as described in further detail with respect to FIGS. 7-8, below. The integrator SpO_2 processor 410 and predictor SpO_2 processor 420 may be a pulse oximeter as described in U.S. patent application Ser. No. 09/586,845 entitled "Variable Mode Averager," assigned to Masimo Corporation, Irvine, Calif. and incorporated by reference herein.

[0022] FIG. 5 illustrates a trend embodiment of an alarm indicator 320, which has a threshold detector 510, a slope detector 520 and alarm detector 530. The threshold detector 510 has a slow SpO_2 measurement 412 and a threshold alarm condition 305 as inputs and a logic output BELOW 512. The slope detector 520 has a fast SpO_2 measurement 422 input and a logic output POSITIVE/522. The alarm detector 530 has BELOW 512 and POSITIVE/522 logic inputs and generates an alarm output 303. The threshold detector 510 is a comparator that asserts BELOW 512 while the slow SpO_2 measurement 412 is less in value than the value of the threshold 305. The slope detector 520 is a differentiator and comparator that asserts POSITIVE/522 while the slope of the fast SpO_2 measurement 422 is non-positive, i.e. while the derivative of the fast SpO_2 measurement 422 is zero or less than zero. The alarm detector 530 performs a logical AND function, asserting the alarm output 303 and indicating an alarm when BELOW 512 and POSITIVE/522 are both asserted. In this manner, an alarm output 303 only changes state when the slow SpO_2 measurement 412 is below a threshold 305 and the fast SpO_2 measurement 422 has not

begun to increase in value. Advantageously, the trend recognition alarm indicator **320** reduces false alarms by suppressing a threshold-based alarm on the slow SpO_2 measurement **412** when the fast SpO_2 measurement **422** determines that a patient's oxygen saturation is in recovery, as described in further detail with respect to FIGS. **6A-B**, below.

[0023] FIGS. **6A-B** illustrate operation of the trend recognition alarm indicator **320** (**FIG. 5**). In **FIG. 6A**, a graph **600** has an SpO_2 axis **601** and a time axis **602**. Shown along the SpO_2 axis **601** is a constant SpO_2 value **606** corresponding to a threshold **305** (**FIG. 5**). The graph **600** shows a first plot of SpO_2 versus time **610** corresponding to a fast SpO_2 measurement **422** (**FIG. 5**). The graph **600** also shows a second plot of SpO_2 versus time **620** corresponding to a slow SpO_2 measurement **412** (**FIG. 5**). A suppressed alarm interval **640** along the time axis **602** corresponds to an alarm that would be indicated by the threshold detector **510** (**FIG. 5**) but is suppressed as occurring during a positive slope portion **630** of a fast SpO_2 measurement **610**. The alarm detector **530** (**FIG. 5**) would not assert an alarm output **303** (**FIG. 5**) during this interval.

[0024] In **FIG. 6B**, a graph **650** shows a first plot of SpO_2 versus time **660** corresponding to a fast SpO_2 measurement **422** (**FIG. 5**). The graph **650** also shows a second plot of SpO_2 versus time **670** corresponding to a slow SpO_2 measurement **412** (**FIG. 5**). An alarm interval **690** along the time axis **602** corresponds to an alarm period triggered by the alarm output **303** (**FIG. 5**). This alarm interval **640** occurs while a slow SpO_2 measurement **670** is below the threshold **606** and before a positive slope portion **680** of a fast SpO_2 measurement **660**.

[0025] **FIG. 7** illustrates a pattern recognition embodiment of an alarm indicator **320**, having a threshold detector **710**, a pattern extractor **720**, a pattern memory **730** and a pattern comparator **740**. Further, the alarm indicator **320** has slow SpO_2 **412** and fast SpO_2 **422** measurement inputs in addition to threshold **701** and reference pattern **732** alarm condition inputs **305**. The threshold detector **710** has a slow SpO_2 measurement **412** and a SpO_2 threshold **701** as inputs and a first alarm output **712**. The threshold detector **710** changes the state of the first alarm output **712** when the value of the slow SpO_2 measurement **412** crosses the SpO_2 threshold **701**. For example, the first alarm output **712** changes state to trigger an alarm when the slow SpO_2 measurement **412** becomes less than the SpO_2 threshold **701**.

[0026] As shown in **FIG. 7**, the pattern extractor **720** has a fast SpO_2 measurement **422** and a pattern threshold **734** as inputs and an extracted pattern output **722**. The pattern extractor **720** identifies features of the fast SpO_2 measurement **422** that may be used for pattern matching. Features may be, for example, the number of times the fast SpO_2 measurement **422** crosses the pattern threshold **734** within a certain time period, or the duration of each time period that the fast SpO_2 measurement **422** is less than the pattern threshold **734**, to name a few. The pattern memory **730** has a pattern selection input **705** and a reference pattern output **732**. The pattern memory **730** stores values for particular features that are identified by the pattern extractor **720**. The reference pattern output **732** transfers these stored values to the pattern comparator **740**. The pattern memory **730** may be nonvolatile and one or more patterns may be stored at the

time of manufacture or downloaded subsequently via a data input (not shown). One of multiple patterns may be determined via the pattern selection input **705**, by a user or by a separate process, for example. The pattern threshold **734** may be generated in response to the pattern selection input **705** or in conjunction with a selected reference pattern **732**.

[0027] Also shown in **FIG. 7**, the pattern comparator **740** has the extracted pattern **722** and the reference pattern **732** as inputs and generates a second alarm output **742**. That is, the pattern comparator **740** matches extracted measurement features provided by the pattern extractor **720** with selected features retrieved from pattern memory **730**, changing the state of the second alarm output **742** accordingly. For example, the second alarm output **742** changes state to trigger an alarm when features of the fast SpO_2 measurement **422** match the reference pattern output **732**. Advantageously, the pattern recognition alarm indicator **320** reduces missed events by supplementing the threshold-based first alarm output **712** responsive to the slow SpO_2 measurement **412** with a pattern-based second alarm output **742** responsive to detail in the fast SpO_2 measurement **422**. In this manner, if a patient's oxygen saturation is, for example, irregular or intermittent, the second alarm output **742** may trigger a caregiver alert when the first alarm output **712** does not, as described in further detail with respect to **FIG. 8**, below.

[0028] **FIG. 8** illustrates operation of a pattern recognition alarm indicator **320** (**FIG. 7**), as described above. A graph **800** has an SpO_2 axis **801** and a time axis **802**. The graph **800** shows a SpO_2 plot versus time **810** corresponding to the slow SpO_2 measurement **412** (**FIG. 7**). Shown along the time axis **802** is a constant SpO_2 value **812** corresponding to the SpO_2 threshold **701** (**FIG. 7**). Due to the short duration of irregular and intermittent drops in SpO_2, the slow SpO_2 measurement **810** does not fall below the SpO_2 threshold **812**. Thus, the first alarm output **712** (**FIG. 7**) does not trigger an alarm in this example.

[0029] Also shown in **FIG. 8**, the graph **800** shows a SpO_2 plot versus time **820** corresponding to the fast SpO_2 measurement **422** (**FIG. 7**). Shown along the time axis **802** is a constant SpO_2 value **822** corresponding to the pattern threshold **734** (**FIG. 7**). A corresponding graph **805** has a logic level axis **806** and a time axis **807**. The graph **805** shows a logic level plot versus time **830** corresponding to the extracted pattern output **722** (**FIG. 7**). The logic level plot **830** has a "1" level when the fast SpO_2 plot **820** is above the pattern threshold **822** and a "0" level when the fast SpO_2 plot **820** is below the pattern threshold **822**. In this manner, the logic level plot **830** indicates the number and duration of times the fast SpO_2 plot **820** falls below a threshold value **822**.

[0030] Further shown in **FIG. 8**, an alarm interval **870** along the time axis **802** corresponds to an alarm period indicated by the pattern comparator **740** (**FIG. 7**). This alarm interval **870** occurs after a reference pattern **732** (**FIG. 7**) is detected as matching an extracted pattern **722** (**FIG. 7**) and ends, correspondingly, when there is no longer a match. For example, assume that the reference pattern output **732** (**FIG. 7**) has the alarm criteria that at least three below threshold periods of minimum duration T_1 must occur during a maximum period T_2, where the value of T_1 and T_2 are illustrated along the time axis **807**. The below threshold time periods **831-834** are each greater in duration than T_2 and a first set

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of three, below-threshold time periods **831-833** occurs within a time period $T_1 = T_2$, as illustrated. Thus, the alarm interval beginning **872** is triggered by the second alarm output **742** (**FIG. 7**). A second set of three, below-threshold time periods **832-834** also occurs within a time period $T_2 = T_2$, as illustrated. Thus, the alarm interval **870** continues. There is no third set of three, below-threshold time periods. Thus, after the end of the time interval $T_3 = T_2$, the alarm interval end **874** is triggered. This example illustrates how the pattern recognition alarm indicator **320** (**FIG. 7**) can trigger an alarm on an event, such as a period of irregular heartbeats, that might be missed by a threshold-based alarm responsive to the slow SpO_2 measurement **412**.

[0031] Although some alarm processor embodiments were described above in terms of pulse oximetry and oxygen saturation measurements, one of ordinary skill in the art will recognize that an alarm processor as disclosed herein is also applicable to the measurement and monitoring of other blood constituents, for example blood glucose and total hemoglobin concentration to name a few, and other physiological parameters such as blood pressure, pulse rate, respiration rate, and EKG to name a few.

[0032] An arrhythmia alarm processor has been disclosed in detail in connection with various embodiments. These embodiments are disclosed by way of examples only and are not to limit the scope of the claims that follow. One of ordinary skill in the art will appreciate many variations and modifications.

What is claimed is:

1. An arrhythmia alarm processor comprising:

a pattern extractor having an output responsive to short duration, intermittent oxygen desaturations of a patient as determined by a fast blood oxygen saturation processor incorporated within a pulse oximeter;

a predetermined reference pattern indicative of a series of oxygen desaturations resulting from an irregular heartbeat; and

an alarm triggered when the pattern extractor output matches the predetermined reference pattern.

2. A patient monitor configured to receive a sensor signal responsive to multiple wavelengths of light emitted into a tissue site, the patient monitor comprising:

a blood oxygen saturation processor capable of providing a predictor measurement of blood oxygen saturation derived from a tissue site in response to a sensor signal, wherein the blood oxygen saturation processor is responsive to short duration, intermittent oxygen desaturations of a patient;

a pattern processor responsive to the predictor measurement of blood oxygen saturation so as to detect a pattern in a series of oxygen desaturations indicative of an irregular heartbeat of a patient; and

an alarm responsive to the pattern processor so as to indicate the occurrence of irregular heartbeats.

3. An arrhythmia alarm method comprising the steps of:

transmitting light having multiple wavelengths into a patient tissue site;

detecting the light after absorption by arterial blood within the tissue site so as to generate a sensor signal;

generating a predictor blood oxygen saturation measurement responsive to the sensor signal and to short duration, intermittent oxygen desaturations of the patient;

recognizing a pattern in the blood oxygen saturation measurement indicative of an irregular heartbeat event; and

triggering an alarm in response to the recognized pattern.

4. A patient monitor comprising:

a processor means for deriving a plurality of oxygen saturation measurements;

a pattern recognition means for extracting a desaturation pattern of short duration, intermittent oxygen desaturations;

a reference means for comparing the extracted desaturation pattern with a stored pattern indicative of irregular heartbeats; and

an alarm means for indicating a match between the extracted desaturation pattern and the stored pattern.

* * * * *

专利名称(译)	心律失常报警处理器		
公开(公告)号	US20060192667A1	公开(公告)日	2006-08-31
申请号	US11/405815	申请日	2006-04-18
[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)	摩根大通银行，NATIONAL ASSOCIATION		
[标]发明人	AL ALI AMMAR		
发明人	AL-ALI, AMMAR		
IPC分类号	G08B29/00 A61B5/00 G08B1/08 G08B23/00		
CPC分类号	A61B5/14551 A61B5/746		
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其他公开文献	US7190261		
外部链接	Espacenet USPTO		

摘要(译)

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