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Al-Ali

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(54) **PARALLEL MEASUREMENT ALARM PROCESSOR**

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(51) **Int. Cl.**[7] **G08B 29/00**

(52) **U.S. Cl.** **340/511**; 340/573.1; 340/521; 600/322; 600/300; 600/301

(58) **Field of Search** 340/573.1, 511, 340/521; 600/322–326, 300, 301; 700/10, 14, 79; 702/119

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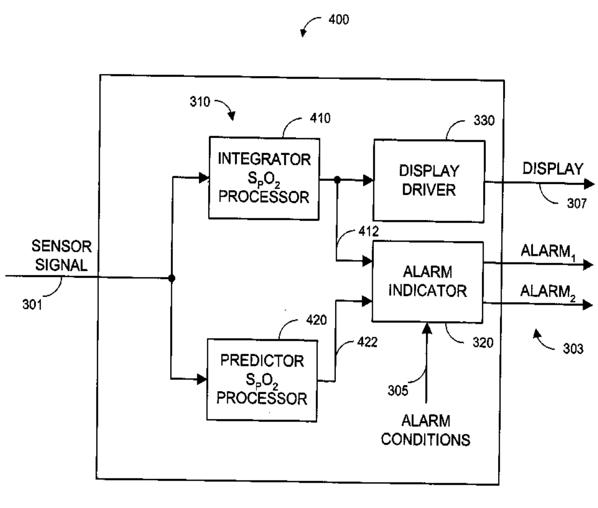
(57) **ABSTRACT**

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 different measurements of the parameter. 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.

27 Claims, 9 Drawing Sheets



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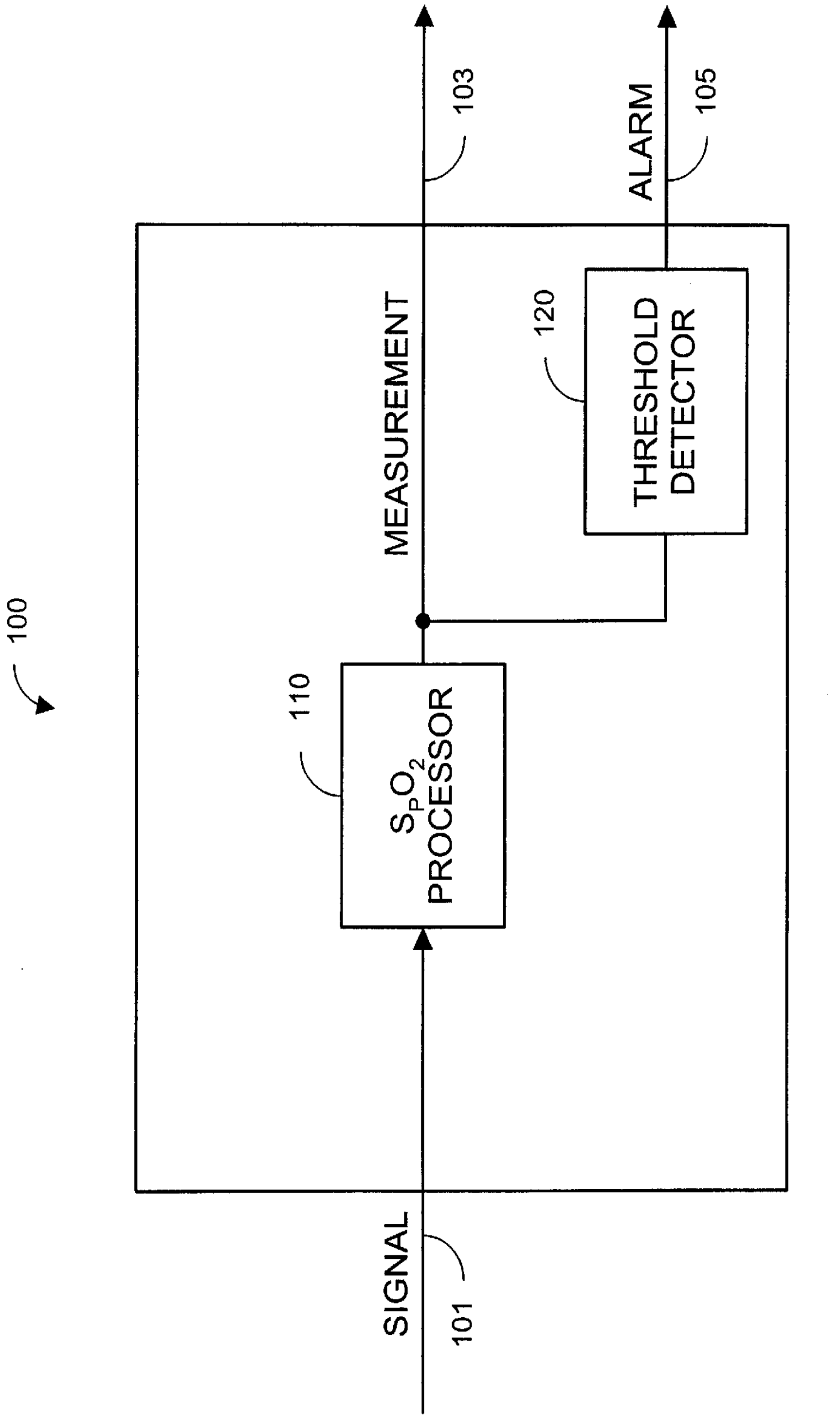


FIG. 1 (Prior Art)

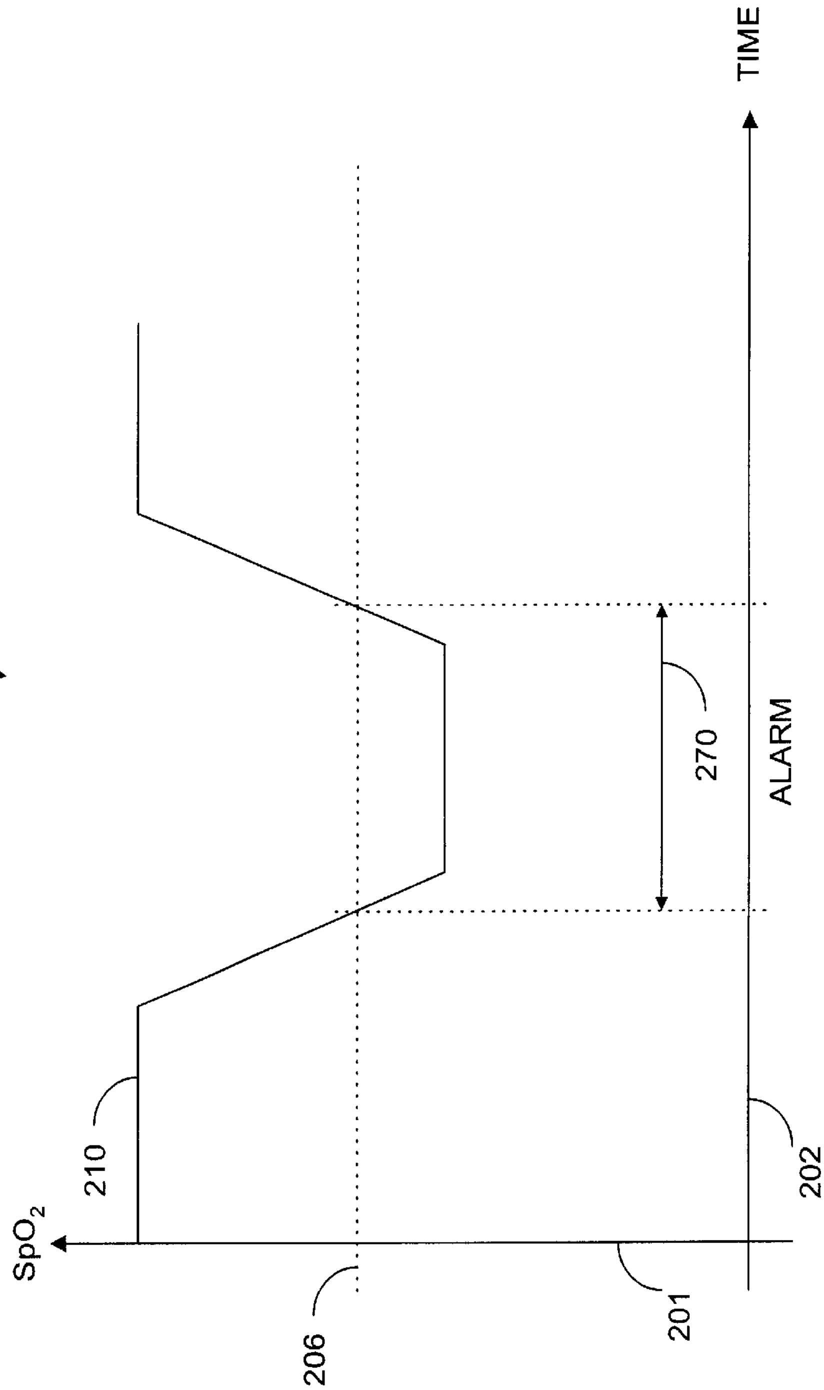


FIG. 2

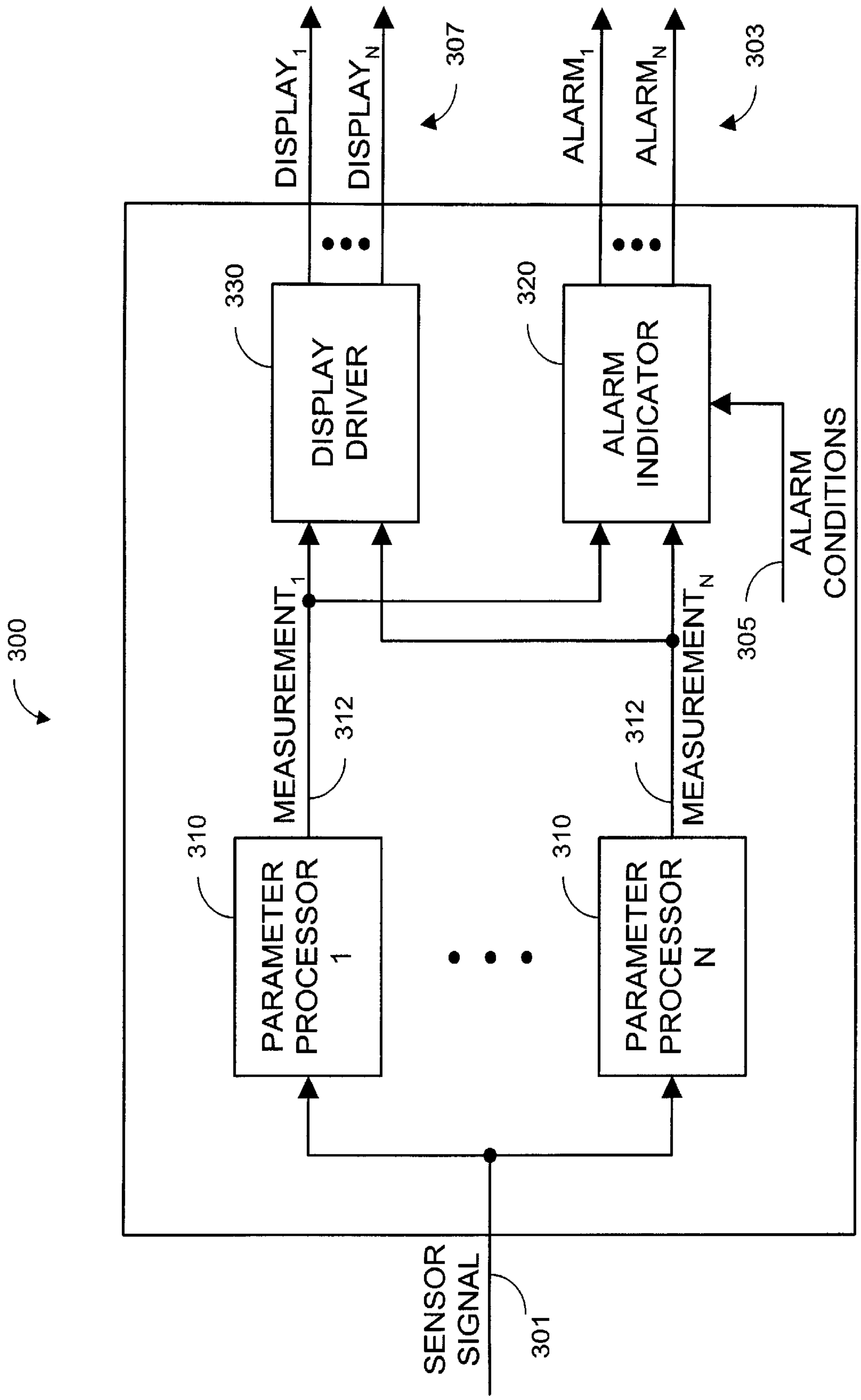

300
SENSOR SIGNAL
301
PARAMETER PROCESSOR 1
310
PARAMETER PROCESSOR N
310
MEASUREMENT$_1$
312
MEASUREMENT$_N$
312
DISPLAY DRIVER
330
ALARM INDICATOR
320
ALARM CONDITIONS
305
DISPLAY$_1$
DISPLAY$_N$
307
ALARM$_1$
ALARM$_N$
303

FIG. 3

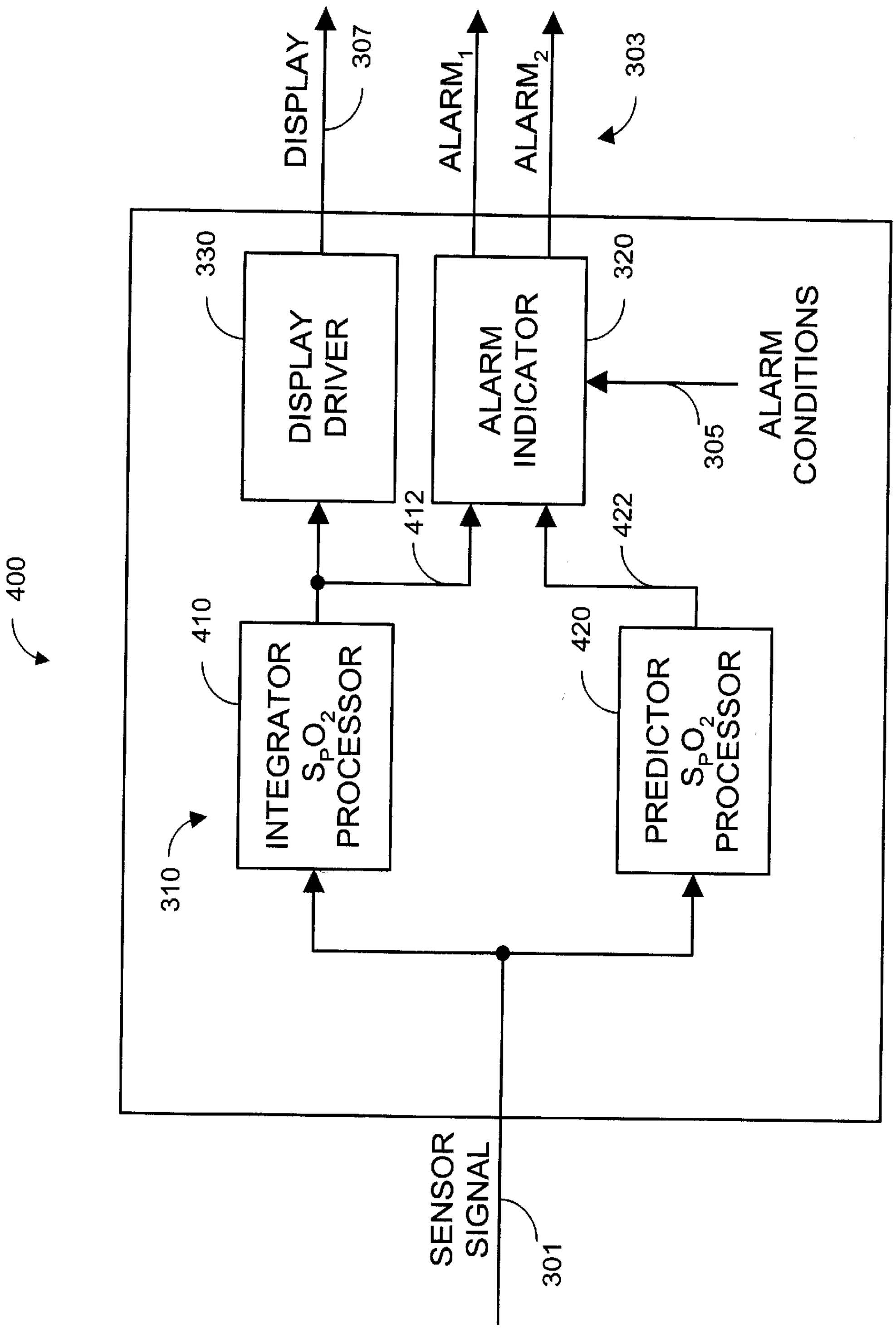
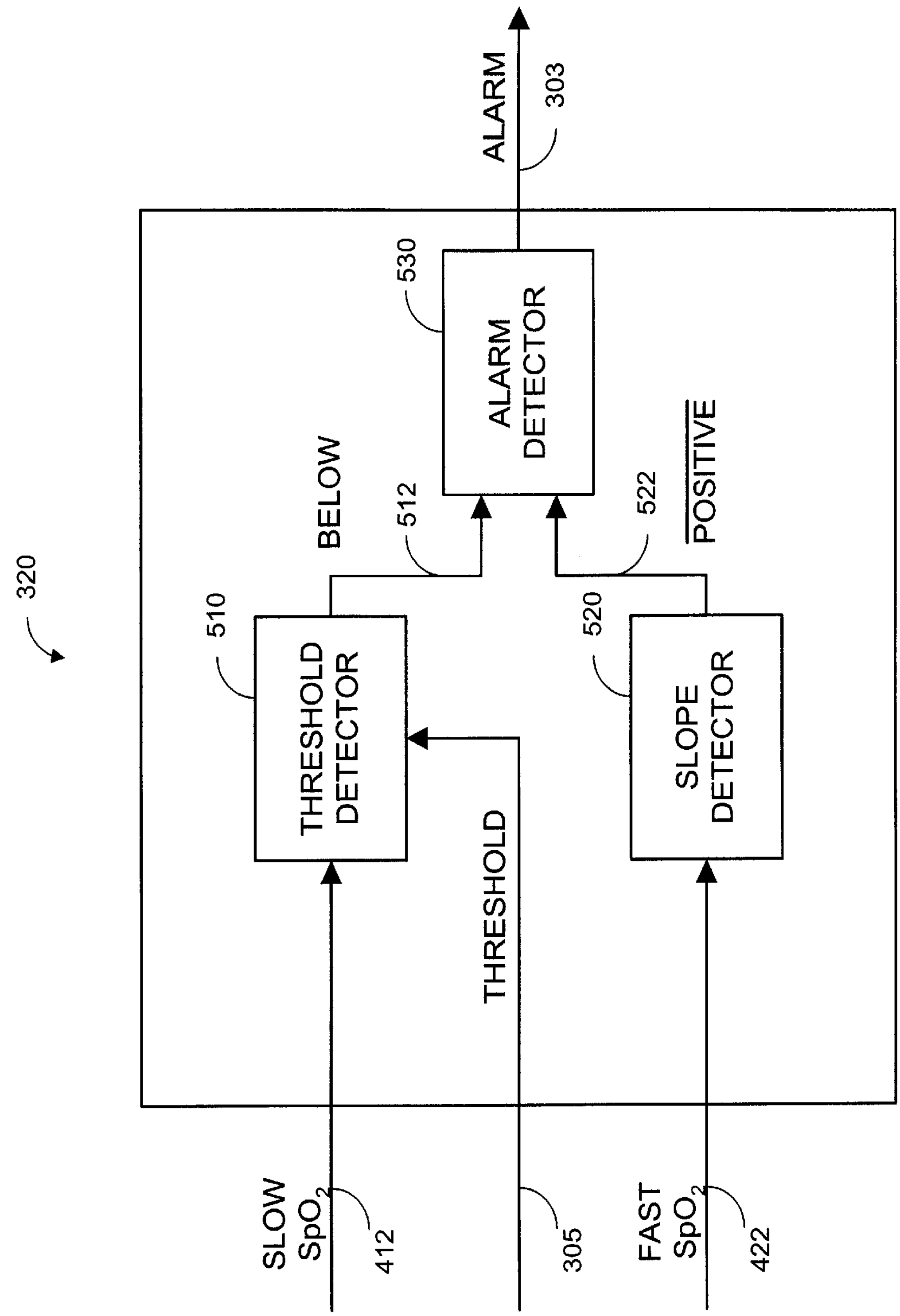

400
DISPLAY
307
$ALARM_1$
$ALARM_2$
303
330
DISPLAY DRIVER
320
ALARM INDICATOR
305
ALARM CONDITIONS
412
422
410
INTEGRATOR S_pO_2 PROCESSOR
420
PREDICTOR S_pO_2 PROCESSOR
310
SENSOR SIGNAL
301

FIG. 4



320
ALARM
303
530
ALARM DETECTOR
BELOW
512
522
POSITIVE
510
THRESHOLD DETECTOR
520
SLOPE DETECTOR
THRESHOLD
SLOW SpO2
412
305
FAST SpO2
422

FIG. 5

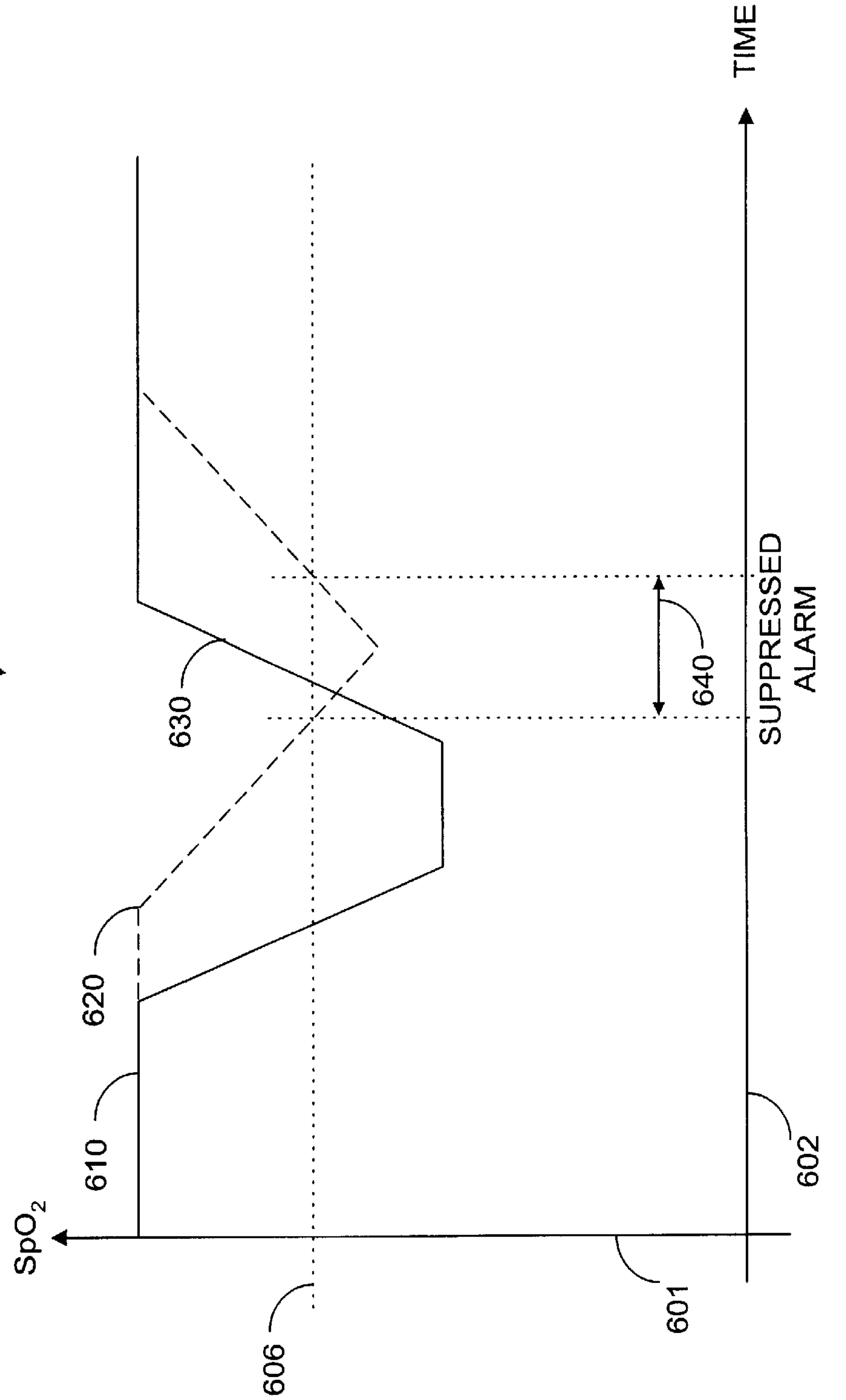


FIG. 6A

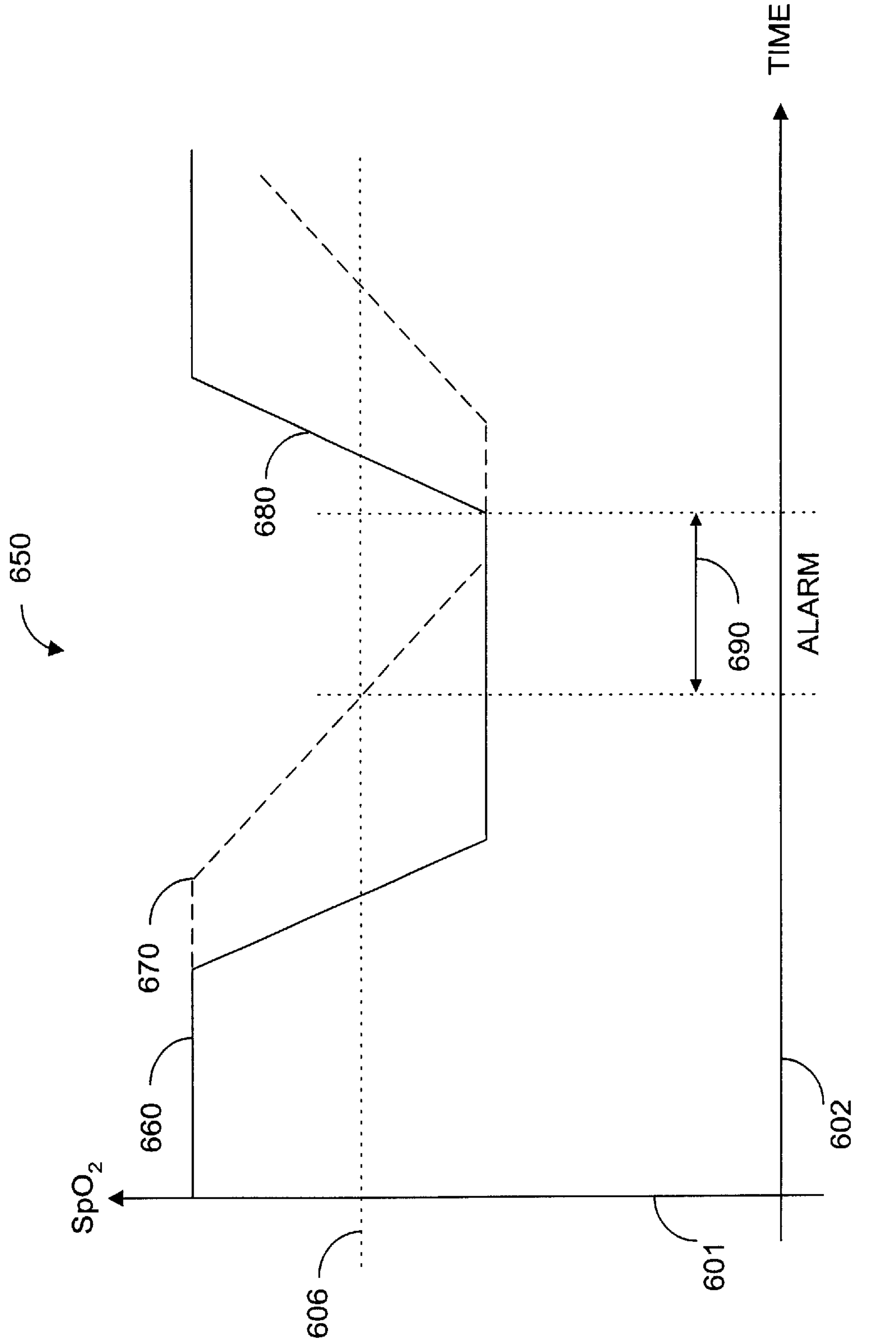


FIG. 6B

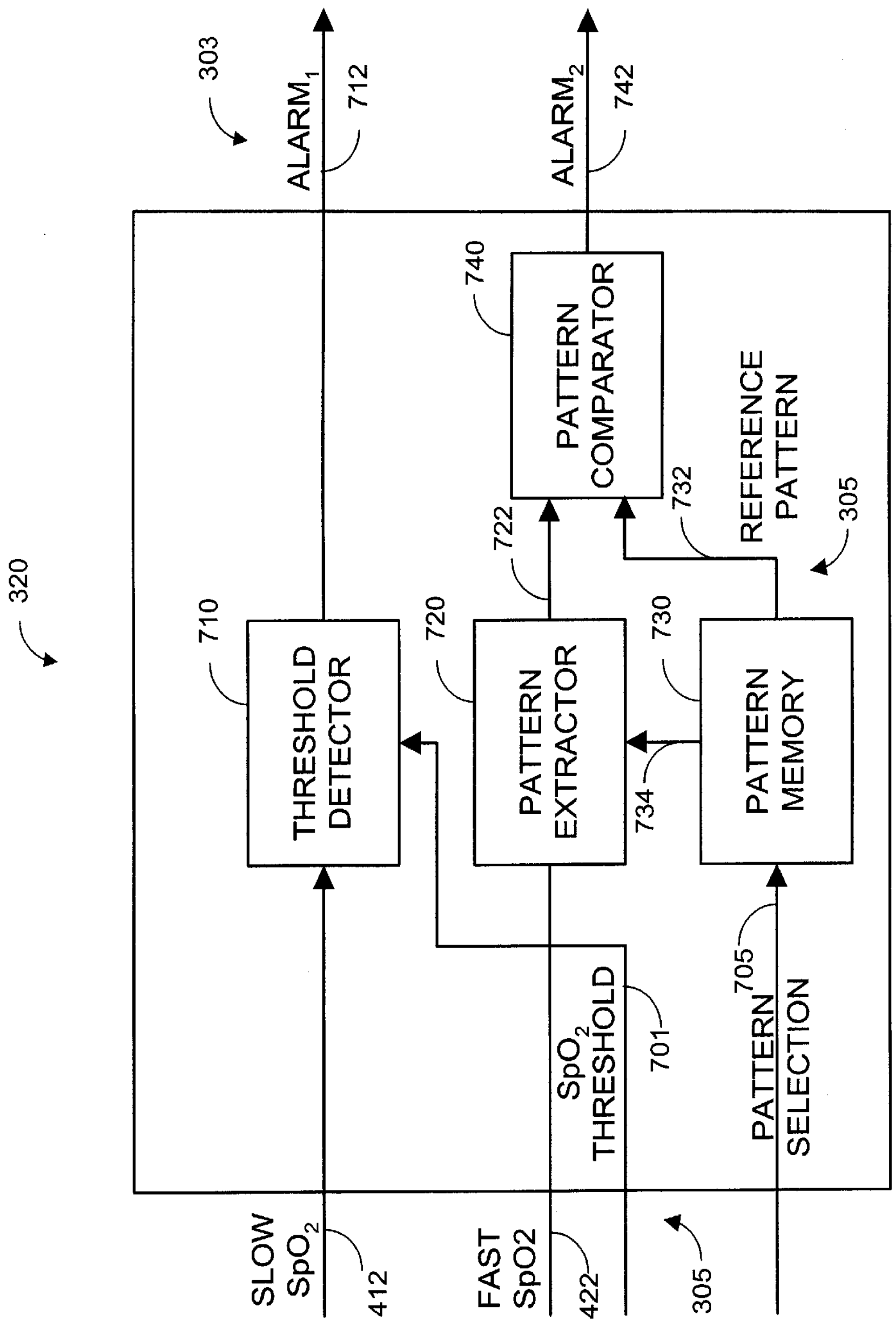

320
303
ALARM$_1$
712
ALARM$_2$
742
740
PATTERN COMPARATOR
REFERENCE PATTERN
732
305
722
710
THRESHOLD DETECTOR
720
PATTERN EXTRACTOR
730
PATTERN MEMORY
734
SpO$_2$ THRESHOLD
701
705
PATTERN SELECTION
SLOW SpO$_2$
412
FAST SpO2
422
305

FIG. 7

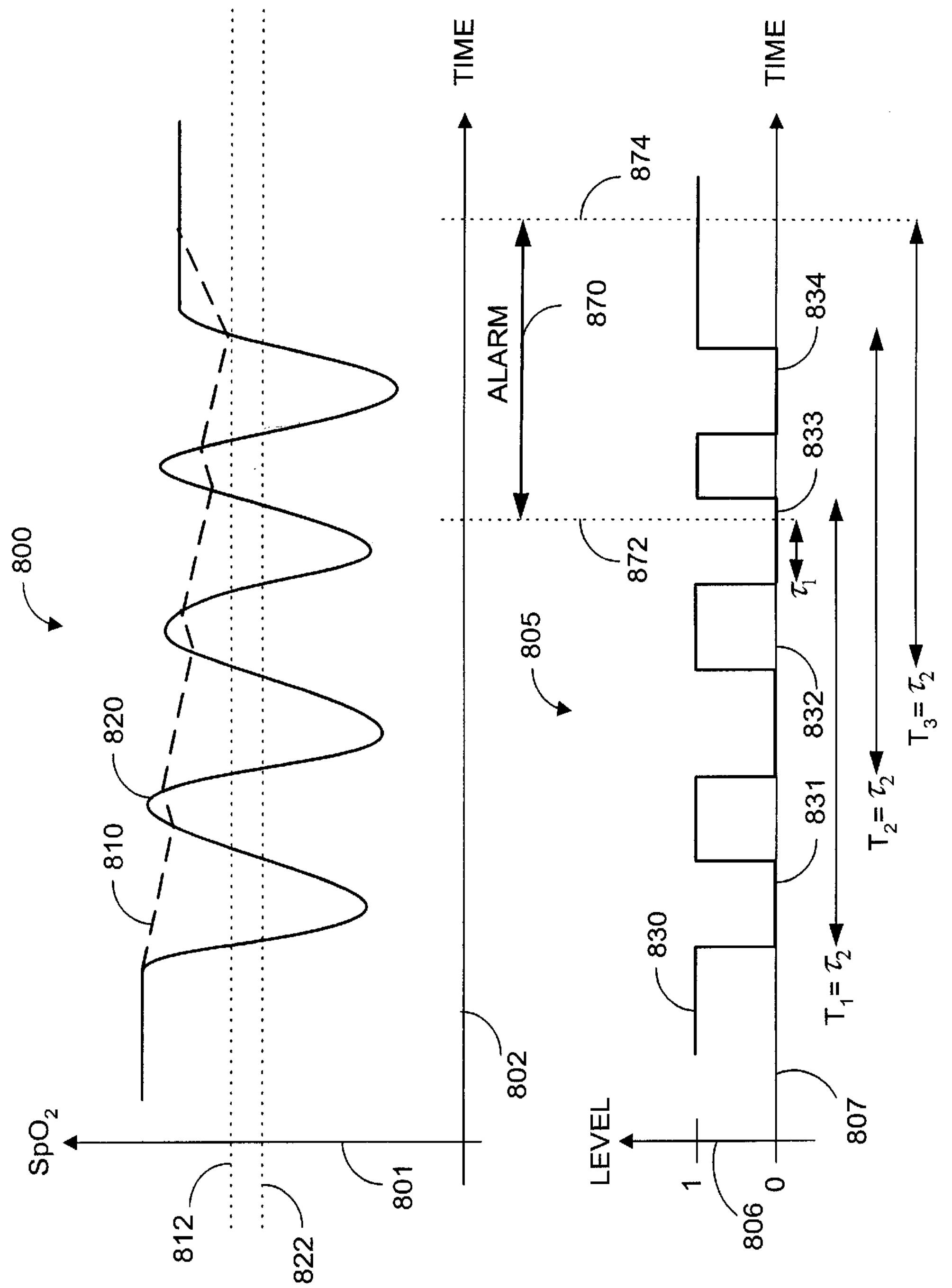

800
SpO$_2$
TIME
810
820
812
822
801
802
ALARM
870
872
874
805
LEVEL
1
0
806
807
830
831
832
833
834
τ_1
$T_1 = \tau_2$
$T_2 = \tau_2$
$T_3 = \tau_2$

FIG. 8

PARALLEL MEASUREMENT ALARM PROCESSOR

CROSS REFERENCE TO RELATED APPLICATION

The present application 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," which is incorporated herein by reference.

BACKGROUND OF THE INVENTION

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.

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.

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

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.

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.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a block diagram of a prior art pulse oximeter portion;

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

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

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

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;

FIGS. **6**A–B are graphs of oxygen saturation versus time illustrating operation of the alarm indicator according to FIG. **5**;

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

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 EMBODIMENT

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, now U.S. Pat. No. 6,684,090, 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**.

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.

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, now U.S. Pat. No. 6,430,525, entitled "Variable Mode Averager," assigned to Masimo Corporation, Irvine, Calif. and incorporated by reference herein.

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.

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.

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**.

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**.

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**.

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.

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.

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**.

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 τ_1 must occur during a maximum period τ_2, where the value of τ_1 and τ_2 are illustrated along the time axis **807**. The below threshold time periods **831–834** are each greater in duration than τ_2 and a first set of three, below-threshold time periods **831–833** occurs within a time period $T_1=\tau_2$, 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 $T_2=\tau_2$, 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 $T_3=\tau_2$, 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**.

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 to name a few, and other physiological parameters such as blood pressure, pulse rate, respiration rate, and EKG to name a few.

A parallel measurement 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 alarm processor which outputs at least one alarm signal when an indication of a blood oxygen saturation of a patient crosses at least one associated threshold value, the alarm processor comprising:

a signal input responsive to a blood oxygen saturation of a patient;

a plurality of parameter processors responsive to said signal input so as to provide a plurality of measurements indicative of said blood oxygen saturation, said measurements having differing characteristics;

an alarm condition applicable to at least one of said measurements so as to define a limit for said measurement; and

an alarm indicator operating on said measurements and said alarm condition so as to provide an alarm output that changes state to indicate that said measurement may have exceeded said limit.

2. An alarm processor comprising:

a signal input responsive to a physiological parameter;

a plurality of parameter processors responsive to said signal input so as to provide a plurality of measurements of said parameter, said measurements having differing characteristics;

an alarm condition applicable to at least one of said measurements so as to define a limit for said parameter; and

an alarm indicator operating on said measurements and said alarm condition so as to provide an alarm output that changes state to indicate that said parameter may have exceeded said limit, wherein said parameter processors include:

a first processor configured to derive a smoothed measurement of said physiological parameter from said signal input; and

a second processor configured to derive a predictive measurement of said physiological parameter from said signal input.

3. The alarm processor according to claim **2** wherein said alarm condition is a threshold and said alarm indicator comprises:

a threshold detector that inputs said smoothed measurement and said threshold and provides a threshold detector output responsive to said smoothed measurement crossing said threshold;

a slope detector that inputs said predictive measurement and provides a slope detector output responsive to a slope of said predictive measurement; and

an alarm detector that inputs said threshold detector output and said slope detector output and generates said alarm output, said alarm output responsive to said slope being negative at the same time said smoothed measurement is less than said threshold.

4. An alarm processor comprising:

a signal input responsive to a physiological parameter;

a plurality of parameter processors responsive to said signal input so as to provide a plurality of measurements of said parameter, said measurements having differing characteristics;

an alarm condition applicable to at least one of said measurements so as to define a limit for said parameter;

an alarm indicator operating on said measurements and said alarm condition so as to provide an alarm output that changes state to indicate that said parameter may have exceeded said limit; and

a second alarm condition applicable to at least one of said measurements so as to define a corresponding second limit for said parameter, wherein said alarm indicator also operates on said second alarm condition so as to provide a second alarm output that changes state to indicate that said parameter may have exceeded said second limit.

5. The alarm processor according to claim 4 wherein said parameter processors include:

a first processor configured to derive a smoothed measurement of said physiological parameter from said signal input; and

a second processor configured to derive a predictive measurement of said physiological parameter from said signal input.

6. The alarm processor according to claim 5 wherein said first alarm condition and said second alarm condition comprise a measurement threshold and a reference pattern, said alarm indicator comprising:

a threshold detector that inputs said smoothed measurement and said measurement threshold and provides said alarm output, said alarm output responsive to said smoothed measurement crossing said threshold;

a pattern extractor that inputs said predictive measurement and a pattern threshold and provides an extracted pattern responsive to a plurality of predictive measurement features;

a reference pattern that specifies a plurality of pattern features; and

a pattern comparator that inputs said extracted pattern and said reference pattern and generates said second alarm output, said second alarm output being responsive to the matching of said pattern features with said measurement features.

7. The alarm processor according to claim 6 further comprising:

a pattern memory having a memory output in communications with said pattern comparator;

a plurality of patterns stored within said pattern memory; and

a memory input to said pattern memory;

said pattern memory responsive to said pattern selection on said memory input so as to retrieve a particular one of said patterns as said reference pattern to said memory output.

8. The alarm processor according to claim 7 wherein one of said pattern features is indicative of the time duration that said predictive measurement is below said pattern threshold.

9. The alarm processor according to claim 7 wherein one of said pattern features is indicative of the number of times said predictive measurement is below said pattern threshold within a specific time period.

10. A alarm method comprising the steps of:

inputting a sensor signal responsive to a physiological parameter;

processing said sensor signal to provide an smoothed measurement of said parameter and a predictive measurement of said parameter; and

triggering an alarm based on both said smoothed measurement and said predictive measurement.

11. The alarm method according to claim 10 wherein said trigger step comprising the substeps of:

specifying an alarm condition; and

applying said alarm condition to at least one of said smoothed measurement and said predictive measurement to generate an alarm output.

12. The alarm method according to claim 11 wherein said alarm condition is a threshold and said applying substep comprises the substeps of:

changing a first output state in response to the value of said smoothed measurement relative to said threshold;

changing a second output state in response to the slope of said predictive measurement; and

combining said first output state and said second output state to generate said alarm output.

13. The alarm method according to claim 11 wherein said parameter is oxygen saturation and said applying substep comprises the substeps of:

not asserting said alarm output when the value of said smoothed measurement is above said threshold or when the slope of said predictive measurement is positive, so as to suppress alarms when said parameter indicates oxygen saturation is in a normal range or is recovering toward a normal range; and

asserting said alarm output when the value of said smoothed measurement is below said threshold and when the slope of said predictive measurement is non-positive, so as to suppress alarms when said parameter indicates oxygen saturation is below normal and is not recovering toward a normal range.

14. The alarm method according to claim 11 wherein said at least one alarm condition is a measurement threshold and a reference pattern and said applying substep comprises the substeps of:

changing a first output state in response to the value of said smoothed measurement relative to said threshold;

extracting a feature pattern from said predictive measurement using a pattern threshold;

changing a second output state in response to a comparison of said reference pattern with said feature pattern;

generating said alarm output in response to said first output state; and

generating a second alarm output in response to said second output state.

15. The alarm method according to claim 14 comprising the further substeps of:

storing a plurality of patterns and an associated plurality of pattern thresholds;

selecting one of said patterns to output as said reference pattern; and

generating one of said associated pattern thresholds.

16. The alarm method according to claim 11 wherein said parameter is oxygen saturation and said applying substep comprises the substeps of:

asserting a first one of said at least one alarm output when the value of said smoothed measurement is below a first threshold, so as to indicate when oxygen saturation is below a normal range; and

asserting a second one of said at least one alarm output when said predictive measurement crosses a second threshold a specified number of times within a specified time period so as to indicate when oxygen saturation is unstable.

17. A pulse oximeter capable of generating at least one alarm when at least one signal indicative of blood oxygen saturation is outside acceptable ranges, the pulse oximeter comprising:

a processor means for deriving a plurality of differing measurements indicative of a blood oxygen saturation of blood pulsing within body tissue;

a condition means for specifying a limit on said measurement, said condition means applied to at least one of said measurements; and

an indicator means for generating an alarm in response to said condition means.

18. An alarm processor comprising:

a processor means for deriving a plurality of measurements of a physiological parameter;

a condition means for specifying a limit on said parameter, said condition means applied to at least one of said measurements; and

an indicator means for generating an alarm in response to said condition means and said measurement means, wherein said processor means comprises:

an integrator means for providing a smoothed measurement of said parameter; and

a predictor means for providing a predictive measurement of said parameter.

19. The alarm processor according to claim **18** wherein said condition means comprises:

a threshold applied to a smoothed measurement to determine a normal range for said parameter; and

a pattern applied to a predictive measurement to determine an abnormal feature of said parameter.

20. The alarm processor according to claim **18** wherein said indicator means comprises:

a threshold means to indicate the state of said smoothed measurement;

a slope means to indicate a trend of said predictive measurement; and

a alarm means for suppressing the output of said threshold means with the output of said slope means.

21. A patient monitoring device capable of reducing a number of false alarms in a pulse oximetry system, wherein the pulse oximetry system comprises the patient monitoring device and a noninvasive optical probe including at least one emitter and a light-sensitive detector capable of outputting at least one signal indicative of oxygen saturation in pulsing blood based on light from the at least one emitter that has been attenuated by body tissue, the patient monitoring device comprising:

an input capable of receiving a signal responsive to a blood oxygen level in pulsing blood;

processing circuitry capable of generating from the signal a plurality of measurements indicative of the blood oxygen level, wherein the plurality of measurements include at least one measurement that is comparatively slow and at least one measurement that is comparatively fast;

an alarm indicator capable of generating at least one alarm signal when the comparatively slow measurement is below a threshold value and the fast measurement meets defined alarm criteria.

22. The patient monitoring device of claim **21**, wherein the alarm criteria comprise trend analysis criteria.

23. The patient monitoring device of claim **22**, wherein the trend analysis criteria comprises analysis of a direction of change in the fast measurement.

24. The patient monitoring device of claim **21**, wherein the alarm criteria comprise pattern recognition criteria.

25. The patient monitoring device of claim **24**, wherein the pattern recognition criteria comprises analysis of a patterns in the fast measurement.

26. The patient monitoring device of claim **21**, wherein the comparatively slow measurement comprises a smoothed measurement.

27. The patient monitoring device of claim **21**, wherein the comparatively fast measurement comprises a predictive measurement.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE
CERTIFICATE OF CORRECTION

PATENT NO. : 6,822,564 B2
APPLICATION NO. : 10/351735
DATED : November 23, 2004
INVENTOR(S) : Ammar Al-Ali

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

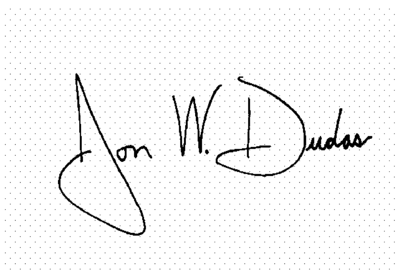
In Column 4, Line 11, please delete “SPO^2” and insert -- SpO_2 --, therefore.

In Column 8, Line 3, Claim 10, please delete “A” and insert -- An --, therefore.

In Column 10, Line 3, Claim 20, please delete “a” and insert -- an --, therefore.

Signed and Sealed this

Thirty-first Day of July, 2007



JON W. DUDAS
Director of the United States Patent and Trademark Office

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摘要(译)

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