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# (54) DETECTION OF PERIODIC BREATHING DURING CPAP THERAPY

DETEKTION VON PERIODISCHER ATMUNG WÄHREND DER CPAP-THERAPIE

DÉTECTION DE RESPIRATION PERIODIQUE PENDANT UNE THÉRAPIE CPAP

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## Description

### *Field of the Invention*

**[0001]** This invention relates generally to the field of breathing therapy machines of the type used to treat obstructive and/or central sleep disorders and specifically to the treatment of such sleep disorders when periodic breathing patterns are detected.

### *Background of the Invention*

**[0002]** The term "periodic breathing" describes a respiratory pattern in which clusters of breaths exhibit a waxing and waning of the amplitude of the tidal volume of ventilation in a cyclic pattern, typically with a period of one minute or less, causing the subject to oscillate between hyperpnea and hypopnea with a crescendo-decrescendo pattern. Cyclic patterns with periods greater than one minute typically indicate a high likelihood of impaired cardiac systolic or diastolic function. In a more extreme version the clusters of breaths may be separated by periods of apnea, instead of hypopnea. Frequently the hypopneic or apneic episodes of periodic breathing contain both obstructive and central events.

**[0003]** Although the exact cause of periodic breathing in adults has not been firmly established, it is thought that the cause may be related to excessive loop gain in the feedback control involved in the regulation of respiratory drive. In adults, periodic breathing is considered abnormal, and is often associated with subjects having neurologic dysfunction or heart failure..

**[0004]** During CPAP therapy, detection of periodic breathing is crucial, as it may be desirable to alter the therapy delivered to the subject if periodic breathing is present. For example, a normal reaction to the detection of an obstructive apnea may be to gradually raise the pressure delivered to the subject until the apneas are eliminated or converted to hypopneas. However, this rise in pressure can actually aggravate a periodic breathing respiratory pattern. Thus, it may be desirable to alter the treatment delivered by the device when periodic breathing is detected.

**[0005]** Current prior art devices are somewhat adept in detecting periodic breathing, but they lack sensitivity and the ability to distinguish between mild periodic breathing and severe periodic breathing. Therefore, it would be desirable to be able to detect periodic breathing with more sensitivity and to be able to distinguish between mild and severe periodic breathing such that delivered therapy may be adjusted accordingly.

**[0006]** Examples of prior art devices are given in US 2007/016093 A1 and WO 2013/177621 A1.

### *Summary of the Invention.*

**[0007]** Detecting periodic breathing in a subject using a breathing therapy device is useful to ensure proper pressure therapy is administered to the subject, and to determine the ongoing suitability of breathing therapy for the subject. Periodic breathing exists in a range of patterns from obvious, almost mechanical rhythmic patterns to more visually obscure and less self-similar patterns which are nevertheless still biologically significant for the subject. The goal of the present invention is to detect periodic breathing with a sensitivity that detects a broad range of periodic breathing, from less obvious marginal periodic breathing to the obvious 'text book' periodic breathing, and to categorize the periodic breathing in multiple classes of severity, which is also useful in determining the overall severity of the subject's propensity to exhibit this pattern.

**[0008]** The present invention uses numerous signal processing techniques to detect periodic breathing patterns. Hilbert transforms are used to calculate analytical representations of a plurality of breathing measures. Ranking filters are used to remove "momentary" discontinuities in the periodic breathing crescendo/decrescendo signal, which allows periodic breathing detection to span across discontinuities in phase due to arousals. The device also grades the severity of the detected periodic breathing (none, mild, moderate, severe).

**[0009]** The result is a device of detecting periodic breathing which is more sensitive than existing prior art devices. In addition, an apparatus consisting of a breathing therapy device is also presented, which is capable of altering the therapy strategy based on the rated severity of the detected periodic breathing.

### *Description of Drawings*

**[0010]**

Figure 1a shows an example of generalized periodic breathing. Figure 1b shows an example of periodic breathing which would be classified as Cheyne-Stokes respiration.

Figures 2-5 show a flow chart.

Figure 6 is a block diagram of a breathing therapy machine.

Figure 7 shows various intermediate waveforms.

### *Detailed Description of the Invention*

**[0011]** The device of the present invention would typically be implemented as firmware in a breathing therapy device, such as a CPAP or Bi-PAP machine of the type shown in Figure 6. Referring now to Fig. 6, there is shown a typical breathing gas delivery system. The breathing gas delivery system comprises a processor 10 having control software / firmware 12 stored in local memory. Motor control system 14 controls the speed of blower 16 under the control of processor 10. Flow element 18 is connected to a patient interface (not shown) for the delivery of pressurized airflow. Mass flow sensor 20 senses the total flow (tidal volume) through flow element 18, and

pressure sensor 22 detects the system pressure. Both flow sensor 20 and pressure sensor 22 interface with processor 10 to provide feedback regarding the patient's breathing patterns. Using interface 24 allows a patient and/or therapist to control the device.

**[0012]** The device of detecting periodic breathing will be described in reference to Figures 2-5. Now with reference to Figure 2, in Step 1 of the process, in box 101, raw total flow rate data from flow sensor 20 is sampled and A/C coupled. A Butterworth 2nd order, high-pass filter is applied to remove residual DC, which may be present due to bias flow and leakage, and which would interfere with subsequent signal processing steps. This results in a signal representing the patient flow data sampled at 250 Hz and labeled "A" on Figure 2. An exemplary wave form of patient flow data can be Figure 7, Reference "A".

**[0013]** In Step 2 of the process in Figure 2, the patient flow signal is decimated or down-sampled to create a waveform more suitable for analytical processing. For example, the 250 Hz waveform may be down sampled at 32 Hz. At box 201, the data is sampled at the lower rate and at box 202, an additional high-pass filter is applied to filter out any additional DC that may be present.

**[0014]** In Step 3 in Figure 2, the breathing signal is again down-sampled and filtered via a two point accumulator filter and a Butterworth 2nd order band pass filter is applied at boxes 301 with normal respiration upper and lower limit rates. In a preferred embodiment of the invention, the lowpass filter has a cut-off frequency of 1.25 Hz and the high-pass filter has a cut-off frequency of 0.2 Hz. This results in signal B, which is fed into Step 4 of the process, shown in Figure 3.

**[0015]** In Step 4, shown in Figure 3, the true respiration is computed utilizing signal B as the input. Signal B is down sampled at 16 Hz in box 401 and the Hilbert Transformation is applied in box 402. 2 The Hilbert Transformation applied in box 402 produces the envelope of respiration and represents the power of the respiration itself. This signal represents a continuous tidal volume. Further filtering is applied in box 403, resulting in a signal that represents the true respiration power, which is used as input to Step 5 of the process.

**[0016]** In Step 5, also shown in Figure 3, the respiration power signal is again down-sampled using a four point accumulator, and the respiration power envelope is computed via a 7.5 second moving average. An example of this signal, labeled "C" in Figure 3, is shown in Figure 7 as Reference C, and represents a true measure of respiration (in L/Min). Signal "D" is also produced in Step 5 of the process and is used as an input for Step 6.

**[0017]** In Step 6, shown in Figure 4, signal "D" is used to create a second respiration power signal to be used as a long-term respiration reference signal. The signal is again down-sampled at box 601 and filtered at box 602. The result is shown as signal "F" in Figure 4 and a example if this signal is shown in Figure 7 as Reference "F".

**[0018]** In Step 7, through a series of ranking filters and further bandpass filtering in the range of expected cyclic waning and waxing cycles, a ratio of a fast moving average vs. a slow moving average is computed resulting in a signal with normalized amplitude (and therefore adaptive to amplitude) representing waxing/waning cycles of periodic breathing. Referring to Step 7 on Figure 4, the small moving average is calculated by boxes 701 and takes as input Signal "F" from Step 6. The fast moving average is computed by boxes 702 using Signal C produced by Step 5 of the process. The ratio is calculated at box 703 and represents the normalized amplitude Signal "G", which is utilized as an input to Step 8a and an example of which is shown in Figure 7 as Reference "G". This signal represents the crescendo and decrescendo pattern of the patient flow signal A as a sine-like waveform. The presence of the sine-like waveform represents periods of periodic breathing. It can be seen in Figure 7 that the sine-like waveform goes away during the period of normal breathing shown in Signal "A".

**[0019]** In Step 8a, also shown on Figure 4, the true waxing and waning power is computed as the envelope of the normalized amplitude Signal "G" via the application of a Hilbert Transform in box 801. This signal is shown as Signal "H" in Figure 4 and an example of this signal is shown in Figure 7 as Reference "H". Signal "H" is used as an input to Step 9 of the process to compute the severity of the periodic breathing. It should be noted that the higher the value of this signal, the higher the severity of the periodic breathing.

**[0020]** In Step 8b, also shown in Figure 5, a moving cyclic variance calculation is performed on the normalized amplitude to Signal "G" to create an analytical representation of cyclic regularity. This is shown as Signal "I" in Figure 7 and represents the variance in the zero crossings between the sign-like waveform of Signal "G" and a true sine waveform. In general, the lower this number, the more regular the periodic breathing.

**[0021]** In Step 9, also shown in Figure 5, the two input signals, namely the crescendo-decrescendo envelope Signal "H" and the crescendo-decrescendo zero crossing variance Signal "I" are input to a minimal distance statistical classification technique that classifies the inputs with four degrees of periodic breathing, (i.e., none, mild, moderate and severe). The final output signal of the process is shown as Signal "J" in Figure 7. In this particular case, during the periods of patient flow data shown as Signal "A" in Figure 7, the algorithm has rated the periodic breathing as moderate, while the regular breathing is noted as having no periodic breathing component.

**[0022]** The calculation of the rating of the severity of the periodic breathing used as Signal "H" (the crescendo-decrescendo envelope) and Signal "I" (the crescendo-decrescendo zero crossing variance) as inputs. For each of these signals, a band of values is defined representing each of the four categories of the severity of periodic breathing. The membership of each data point from Signals H and I are analyzed using a minimal distance estimation technique, which is a statistical method for fitting

a mathematical model to empirical data. The algorithm may be tweaked by changing the values that define the bands for Signals H and I. In general, the larger the value for the crescendo-decrescendo envelope (Signal H) and the lower the crescendo-decrescendo zero crossing variance (Signal I), the more severe and/or the more likelihood of period breathing being present.

**[0023]** The Applicants note that the algorithm presented is optimized for one minute cycles. However, this can be easily changed by varying the parameters of the filtering which is applied to the signals. Also note that in the preferred example, Butterworth 2nd order filters are used throughout, however, any other type of filter producing a suitable result may be used. In addition, the cutoff values for the filters have been selected to capture the vast majority of periodic breathing scenarios.

**[0024]** Also, as part of this example, as implemented in a breathing therapy machine, the therapy pressure may be varied based upon the detection of periodic breathing. For example, if periodic breathing is determined to be mild and respiratory events are detected, then the machine may not respond to the respiratory events by increasing pressure. Therefore, when obstructive apnea, for example is detected, when it is time to make a pressure change decision, if periodic breathing is also present, no increases in pressure may be implemented. In the event that the periodic breathing transitions to moderate or severe, if it stays there for a minimum period of time, then the therapy pressure may be dropped. As it is known that increased pressure may aggravate periodic breathing. The actual device altering the therapy pressure based upon the presence or lack thereof of periodic breathing may be tweaked based upon desired outcomes. However, the decision to change or not change the therapy pressure utilizes the presence or lack thereof of the periodic breathing as an input to that decision.

**[0025]** Although a specific embodiment of the process has been described herein, it should be realized by one of skill in the art that many implementations are possible which would fall within the scope of the invention, which is represented by the following claims.

## Claims

**1.** A breathing therapy device comprising:

a. a blower (16);
b. a processor (10);
c. a motor control component (14), under control of said processor, for controlling the speed of said blower; and
d. a flow sensing element (18), for sensing total flow of air from said blower, said processor to provide the following functions:

i. collecting flow data from said flow sensing element;
ii. analyzing said flow data to detect patterns of periodic breathing in a user of said device;
iii. rating a severity of said periodic breathing, wherein rating the severity of said periodic breathing comprises configuring said processor to:

calculate a power envelope of a normalized amplitude signal representing waxing and waning of cycles of said patient flow data;
calculate a signal representing a zero crossing variance of said normalized amplitude signal; and
classify the severity of said periodic breathing using said power envelope of said normalized amplitude signal and said signal representing the zero crossing variance; and

iv. altering therapy delivered to said user based on said rated severity of said periodic breathing.

**2.** The breathing therapy device of claim 1 wherein said normalized amplitude signal is:
a ratio of a fast moving average and a slow moving average of a power envelope of a patient flow signal derived from said flow data.

**3.** The breathing therapy device of claim 2 wherein said power envelope of said patient flow signal and said power envelope of said normalized amplitude are calculated using Hilbert Transforms.

**4.** The breathing therapy device of claim 2 wherein in order to derive said patient flow signal from said flow data, said processor is further configured to:

a. down sample said flow data received from said flow sensing element; and
b. apply a high pass filter to filter out a DC component of said flow data, representing bias flow.

**5.** The breathing therapy device of claim 4 wherein said high pass filter is a 2nd order Butterworth filter.

**6.** The breathing therapy device of claim 2 wherein said in order to rate the severity of said periodic breathing, said processor is further configured to:

a. define ranges for said power envelope of said normalized amplitude signal and for said signal representing the zero crossing variance of said normalized amplitude signal for each category of severity; and
b. calculate said rating as a function of time

based on a membership of said power envelope of said normalized amplitude signal and said signal representing the zero crossing variance of said normalized amplitude signal in each of said category of severity.

**7.** The breathing therapy device of claim 6 wherein said membership in each of category of severity is calculated using a statistical analysis.

**8.** The breathing therapy device of claim 7 wherein said statistical analysis utilizes a minimum distance estimation algorithm.

**9.** The breathing therapy device of claim 2 wherein altering therapy delivered to said user includes ceasing an increase in pressure when apnea events are detected.

**10.** The breathing therapy device of claim 2 wherein altering therapy delivered to said user includes decreasing pressure when sustained periods of periodic breathing are detected.

**Patentansprüche**

**1.** Atemtherapievorrichtung, umfassend:

a. eine Blasvorrichtung (16);
b. einen Prozessor (10);
c. eine Motorsteuerungskomponente (14) unter der Steuerung des Prozessors zum Steuern der Geschwindigkeit der Blasvorrichtung; und
d. ein Flusssensorelement (18) zum Erfassen des Gesamtflusses von Luft aus der Blasvorrichtung,

wobei der Prozessor folgende Funktionen bereitstellt:

i. Aufnehmen von Flussdaten von dem Flusssensorelement;
ii. Analysieren der Flussdaten, um Muster von periodischer Atmung bei einem Anwender der Vorrichtung zu erfassen;
iii. Bewerten einer Stärke der periodischen Atmung, wobei das Bewerten der Stärke der periodischen Atmung Konfigurieren des Prozessors umfasst, um:

die Leistungshüllkurve eines Signals mit normalisierter Amplitude zu berechnen, das Zunehmen und Abnehmen von Zyklen der Patienten-Flussdaten darstellt;
ein Signal zu berechnen, das die Nulldurchgangvarianz des Signals mit normalisierter Amplitude darstellt; und
die Stärke der periodischen Atmung unter Verwendung der Leistungshüllkurve des Signals mit normalisierter Amplitude und des Signals, das die Nulldurchgangvarianz darstellt, einzustufen; und

iv. Verändern der Therapie, die dem Anwender gegeben wird, auf der Grundlage der bewerteten Stärke der periodischen Atmung.

**2.** Atemtherapievorrichtung gemäß Anspruch 1, wobei das Signal mit normalisierter Amplitude ist:
ein Verhältnis eines schnell gleitenden Mittelwerts und eines langsam gleitenden Mittelwerts einer Leistungshüllkurve eines aus den Flussdaten abgeleiteten Patientenflusssignals.

**3.** Atemtherapievorrichtung gemäß Anspruch 2, wobei die Leistungshüllkurve des Patientenflusssignals und die Leistungshüllkurve der normalisierten Amplitude unter Verwendung von Hilbert-Transformationen berechnet werden.

**4.** Atemtherapievorrichtung gemäß Anspruch 2, wobei der Prozessor zum Ableiten des Patientenflusssignals aus den Flussdaten ferner konfiguriert ist zum:

a. Downsampling der von dem Flusssensorelement erhaltenen Flussdaten; und
b. Anwenden eines Hochpassfilters zum Ausfiltern einer DC-Komponente der Flussdaten, die Leckfluss darstellen.

**5.** Atemtherapievorrichtung gemäß Anspruch 4, wobei der Hochpassfilter ein Butterworth-Filter der 2. Ordnung ist.

**6.** Atemtherapievorrichtung gemäß Anspruch 2, wobei der der Prozessor zum Bewerten der Stärke der periodischen Atmung ferner konfiguriert ist zum:

a. Definieren von Bereichen für die Leistungshüllkurve des Signals mit normalisierter Amplitude und für das Signal, das die Nulldurchgangvarianz des Signals mit normalisierter Amplitude darstellt, für jede Stärkekategorie; und
b. Berechnen der Bewertung als Funktion der Zeit auf der Grundlage des Vorhandenseins der Leistungshüllkurve des Signals mit normalisierter Amplitude und des Signals, das die Nulldurchgangvarianz des Signals mit normalisierter Amplitude darstellt, in jeder der Stärkekategorien.

**7.** Atemtherapievorrichtung gemäß Anspruch 6, wobei das Vorhandensein in jeder der Stärkekategorien unter Verwendung einer statistischen Analyse berechnet wird.

**8.** Atemtherapievorrichtung gemäß Anspruch 7, wobei die statistische Analyse einen Algorithmus zur Minimalabstand-Abschätzung verwendet.

**9.** Atemtherapievorrichtung gemäß Anspruch 2, wobei das Verändern der dem Anwender gegebenen Therapie Beenden einer Druckzunahme umfasst, wenn Apnoeereignisse nachgewiesen werden.

**10.** Atemtherapievorrichtung gemäß Anspruch 2, wobei das Verändern der dem Anwender gegebenen Therapie Drucksenkung umfasst, wenn anhaltende Perioden von periodischer Atmung nachgewiesen werden.

**Revendications**

**1.** Dispositif de thérapie respiratoire, comprenant :

a. une soufflante (16) ;
b. un processeur (10) ;
c. un composant de commande de moteur (14), commandé par ledit processeur, pour commander la vitesse de ladite soufflante ; et
d. un élément de détection de flux (18) pour détecter le flux d'air total provenant de ladite soufflante, ledit processeur devant fournir les fonctions suivantes :

i. recueillir des données de flux provenant dudit élément de détection de flux ;
ii. analyser lesdites données de flux pour détecter des motifs de respiration périodique chez un utilisateur dudit dispositif ;
iii. évaluer la sévérité de ladite respiration périodique, l'évaluation de la sévérité de ladite respiration périodique comprenant la configuration dudit processeur de manière à ce qu'il :

calcule une enveloppe de puissance d'un signal d'amplitude normalisé représentant la croissance et la décroissance de cycles desdites données de flux du patient ;
calcule signal représentant une variance de passage par zéro dudit signal d'amplitude normalisé ; et
classifier la sévérité de ladite respiration périodique en utilisant ladite enveloppe de puissance dudit signal d'amplitude normalisé et ledit signal représentant la variance de passage par zéro ; et

iv. modifier la thérapie administrée audit utilisateur sur la base de ladite sévérité établie de ladite respiration périodique.

**2.** Dispositif de thérapie respiratoire selon la revendication 1, dans lequel ledit signal d'amplitude normalisé est :
un rapport d'une moyenne mobile rapide et d'une moyenne mobile lente d'une enveloppe de puissance d'un signal de flux d'un patient dérivé desdites données de flux.

**3.** Dispositif de thérapie respiratoire selon la revendication 2, dans lequel ladite enveloppe de puissance dudit signal de flux d'un patient et ladite enveloppe de puissance de ladite amplitude normalisée sont calculées en utilisant les transformées de Hilbert.

**4.** Dispositif de thérapie respiratoire selon la revendication 2, dans lequel, afin de dériver ledit signal de flux d'un patient desdites données de flux, ledit processeur est en outre configuré pour :

a. sous-échantillonner lesdites données de flux reçues depuis ledit élément de détection de flux ; et
b. appliquer un filtre passe-haut pour éliminer par filtrage une composante CC desdites données de flux, représentant un flux parasite.

**5.** Dispositif de thérapie respiratoire selon la revendication 4, dans lequel ledit filtre passe-haut est un filtre de Butterworth de deuxième ordre.

**6.** Dispositif de thérapie respiratoire selon la revendication 2, dans lequel ledit afin d'évaluer la sévérité de ladite respiration périodique, ledit processeur est en outre configuré pour :

a. définir des plages pour ladite enveloppe de puissance dudit signal d'amplitude normalisé et pour ledit signal représentant la variance de passage par zéro dudit signal d'amplitude normalisé pour chaque catégorie de sévérité ; et
b. calculer ladite évaluation en fonction du temps sur la base de l'appartenance de ladite enveloppe de puissance dudit signal d'amplitude normalisé et dudit signal représentant la variance de passage par zéro dudit signal d'amplitude normalisé à chacune desdites catégories de sévérité.

**7.** Dispositif de thérapie respiratoire selon la revendication 6, dans lequel ladite appartenance à chaque catégorie de sévérité est calculée en utilisant une analyse statistique.

**8.** Dispositif de thérapie respiratoire selon la revendication 7, dans lequel ladite analyse statistique utilise un algorithme d'estimation de distance minimale.

**9.** Dispositif de thérapie respiratoire selon la revendication 2, dans lequel la modification de la thérapie administrée audit utilisateur comprend d'interrompre l'augmentation de pression lorsque des événements d'apnée sont détectés.

**10.** Dispositif de thérapie respiratoire selon la revendication 2, dans lequel la modification de la thérapie administrée audit utilisateur comprend la diminution de la pression lorsque des périodes prolongées de respiration périodique sont détectées.

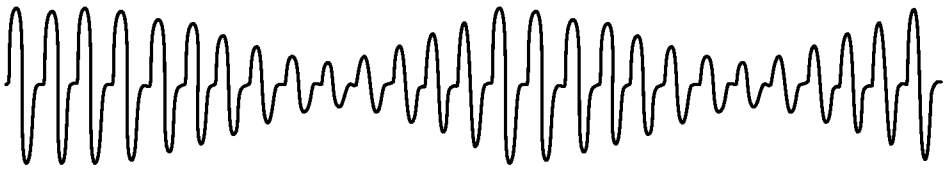

FIG. 1A
(Prior Art)

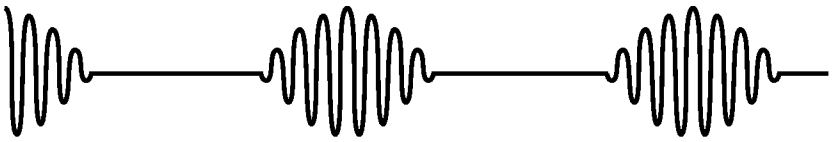

FIG. 1B
(Prior Art)

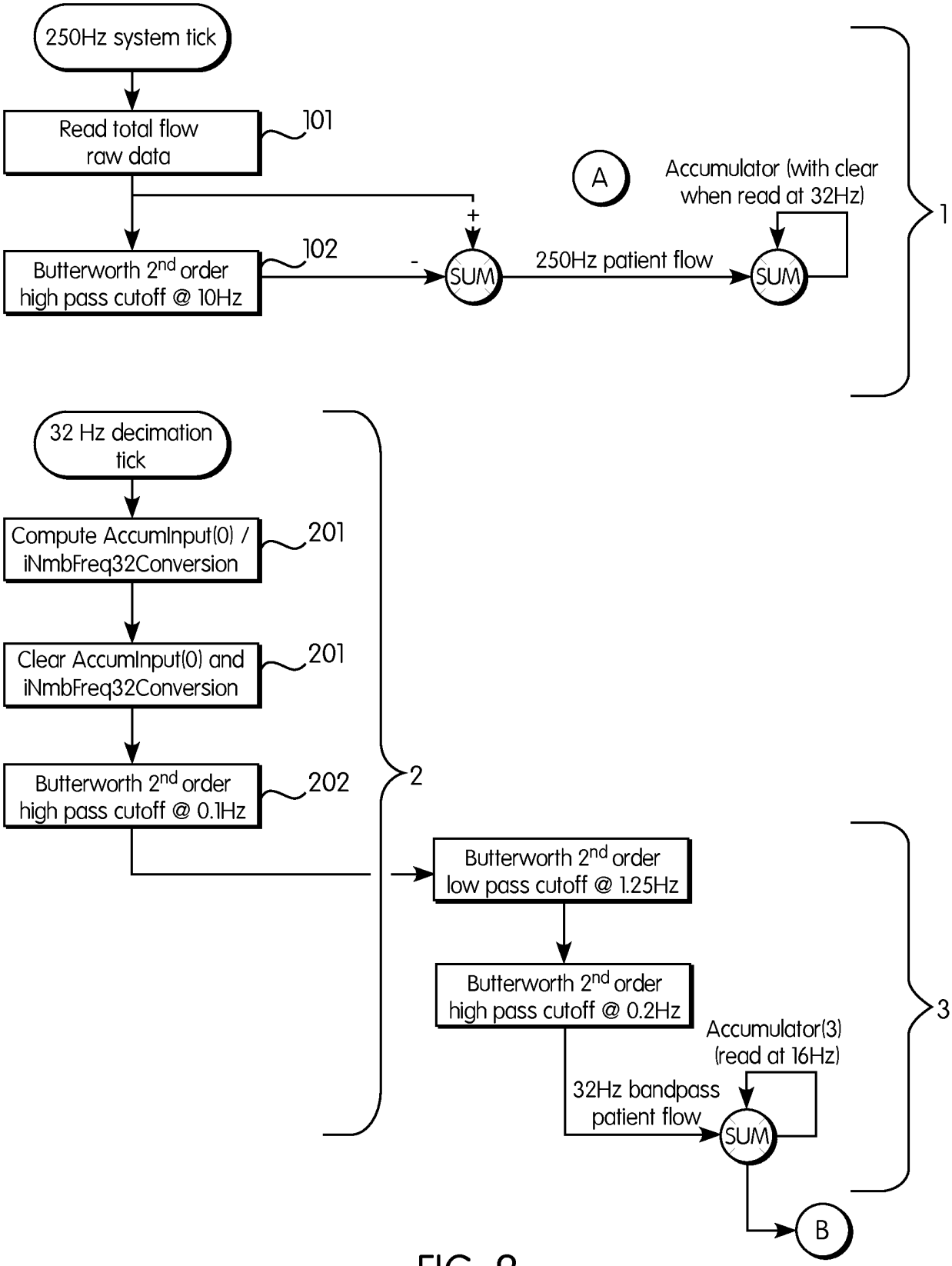
250Hz system tick
Read total flow raw data
101
Butterworth 2nd order high pass cutoff @ 10Hz
102
+
-
SUM
A
Accumulator (with clear when read at 32Hz)
250Hz patient flow
SUM
1
32 Hz decimation tick
Compute AccumInput(0) / iNmbFreq32Conversion
201
Clear AccumInput(0) and iNmbFreq32Conversion
201
Butterworth 2nd order high pass cutoff @ 0.1Hz
202
2
Butterworth 2nd order low pass cutoff @ 1.25Hz
Butterworth 2nd order high pass cutoff @ 0.2Hz
Accumulator(3) (read at 16Hz)
32Hz bandpass patient flow
SUM
3
B

FIG. 2

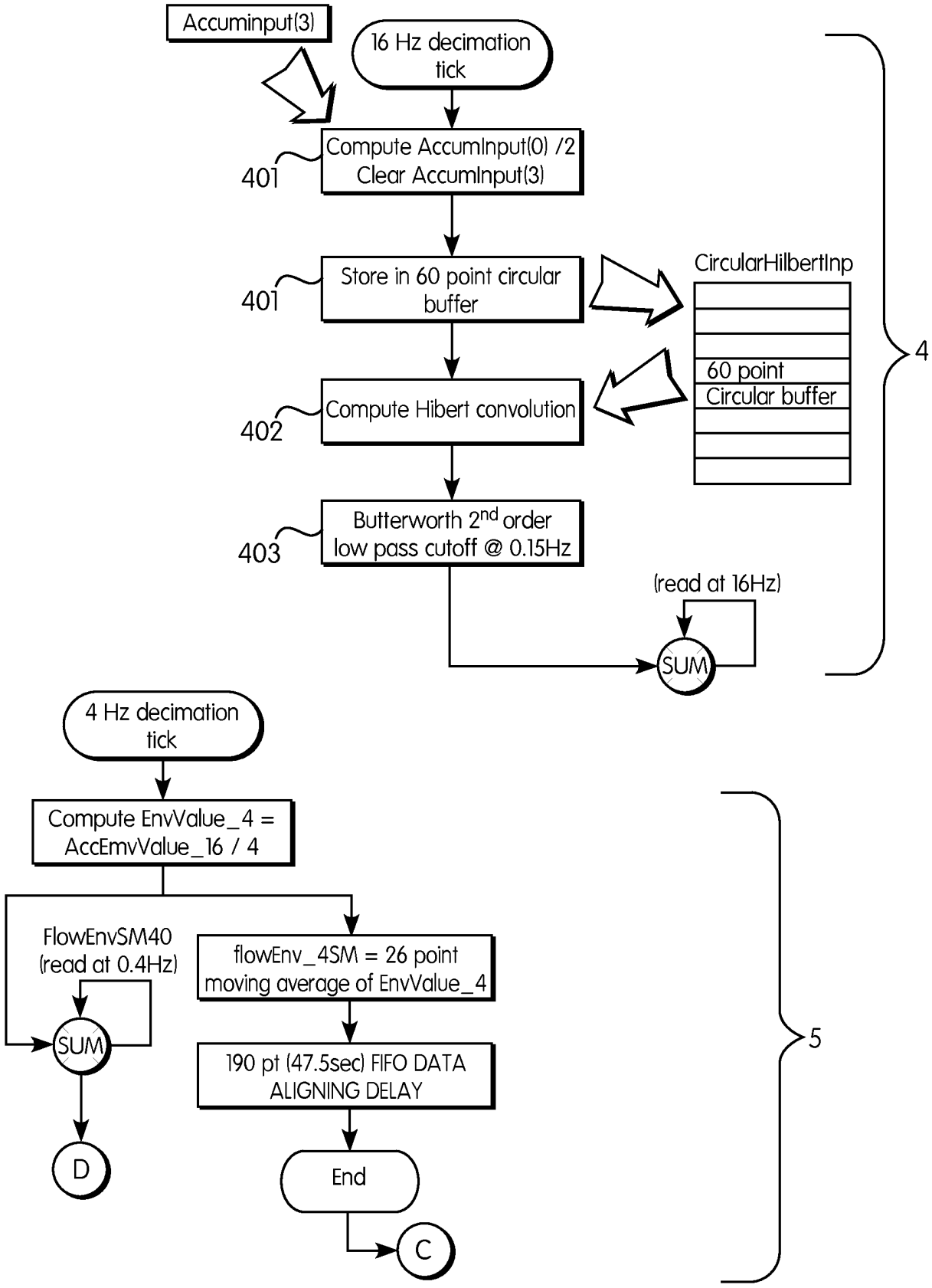
AccumInput(3)
16 Hz decimation tick
401
Compute AccumInput(0) /2
Clear AccumInput(3)
401
Store in 60 point circular buffer
CircularHilbertInp
60 point
Circular buffer
402
Compute Hibert convolution
403
Butterworth 2nd order low pass cutoff @ 0.15Hz
(read at 16Hz)
SUM
4
4 Hz decimation tick
Compute EnvValue_4 = AccEmvValue_16 / 4
FlowEnvSM40
(read at 0.4Hz)
SUM
D
flowEnv_4SM = 26 point moving average of EnvValue_4
190 pt (47.5sec) FIFO DATA ALIGNING DELAY
End
C
5

FIG. 3

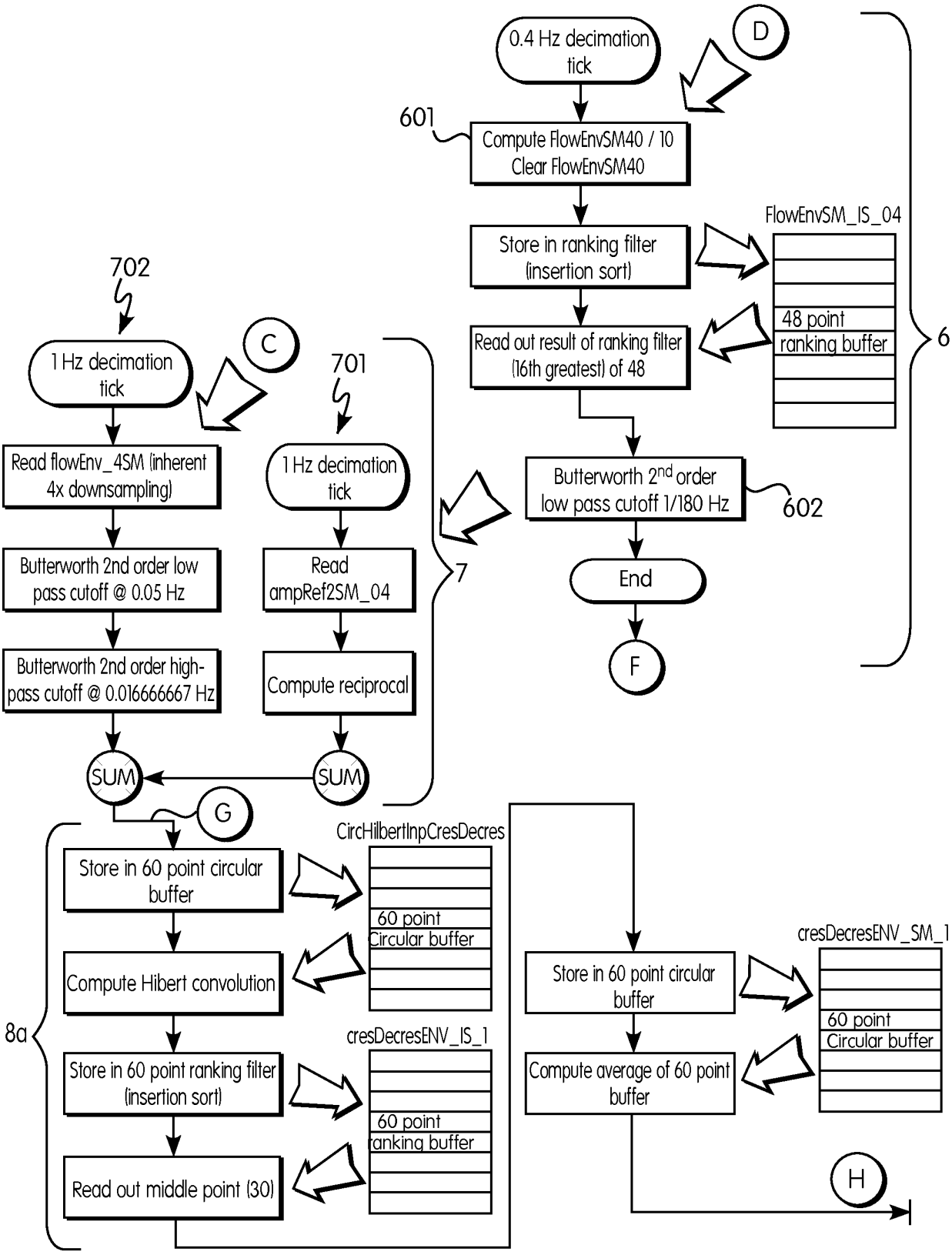
0.4 Hz decimation tick
D
601
Compute FlowEnvSM40 / 10
Clear FlowEnvSM40
Store in ranking filter (insertion sort)
FlowEnvSM_IS_04
48 point ranking buffer
Read out result of ranking filter (16th greatest) of 48
6
Butterworth 2nd order low pass cutoff 1/180 Hz
602
End
F
702
1 Hz decimation tick
C
701
1 Hz decimation tick
Read flowEnv_4SM (inherent 4x downsampling)
Butterworth 2nd order low pass cutoff @ 0.05 Hz
Butterworth 2nd order high-pass cutoff @ 0.016666667 Hz
Read ampRef2SM_04
Compute reciprocal
7
SUM
SUM
G
CircHilbertInpCresDecres
Store in 60 point circular buffer
60 point Circular buffer
Compute Hibert convolution
cresDecresENV_IS_1
Store in 60 point ranking filter (insertion sort)
60 point ranking buffer
Read out middle point (30)
8a
cresDecresENV_SM_1
Store in 60 point circular buffer
60 point Circular buffer
Compute average of 60 point buffer
H

FIG. 4

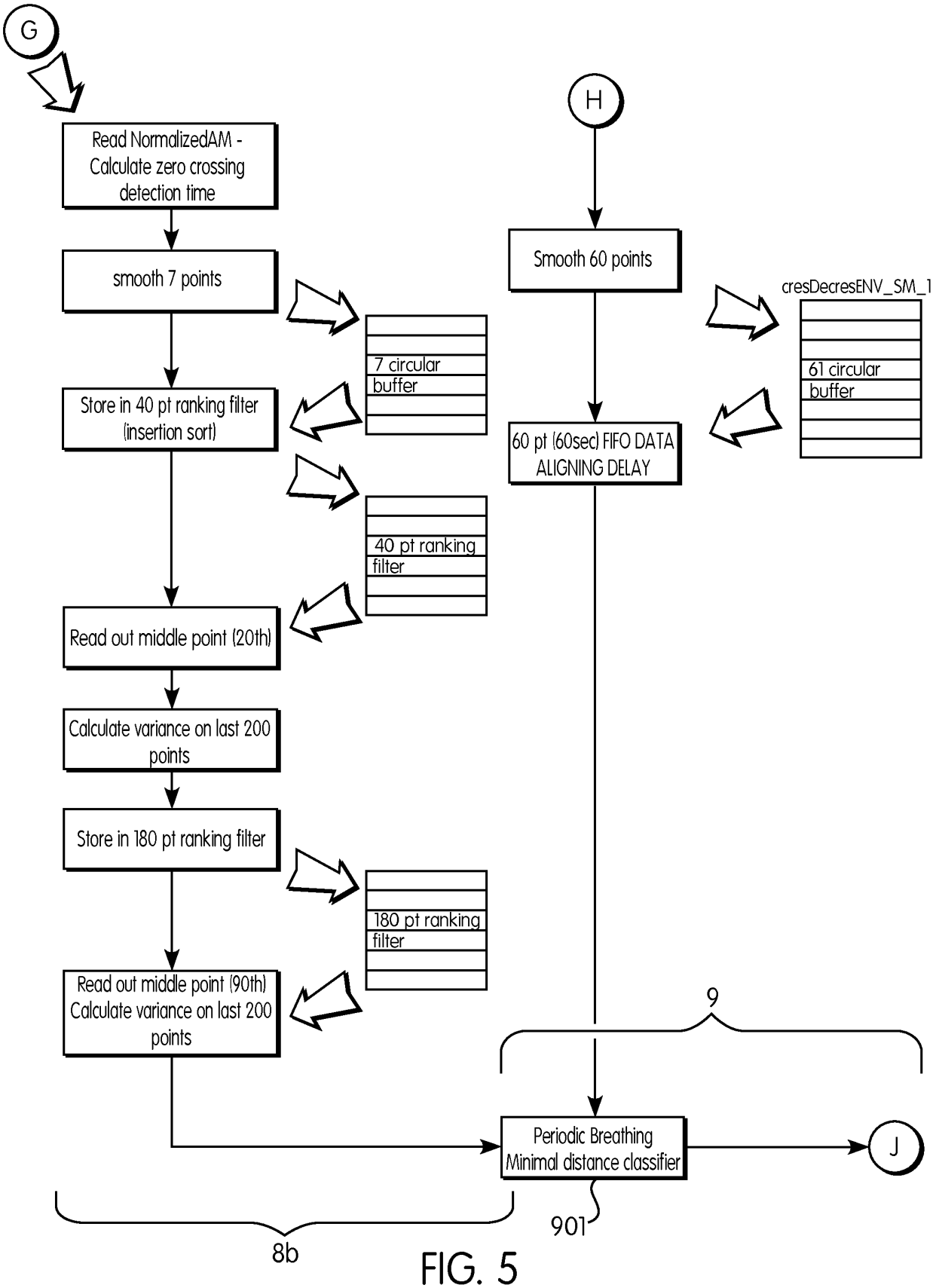
G
H
Read NormalizedAM - Calculate zero crossing detection time
smooth 7 points
Store in 40 pt ranking filter (insertion sort)
Read out middle point (20th)
Calculate variance on last 200 points
Store in 180 pt ranking filter
Read out middle point (90th) Calculate variance on last 200 points
7 circular buffer
40 pt ranking filter
180 pt ranking filter
Smooth 60 points
60 pt (60sec) FIFO DATA ALIGNING DELAY
cresDecresENV_SM_1
61 circular buffer
9
Periodic Breathing Minimal distance classifier
J
901
8b

FIG. 5

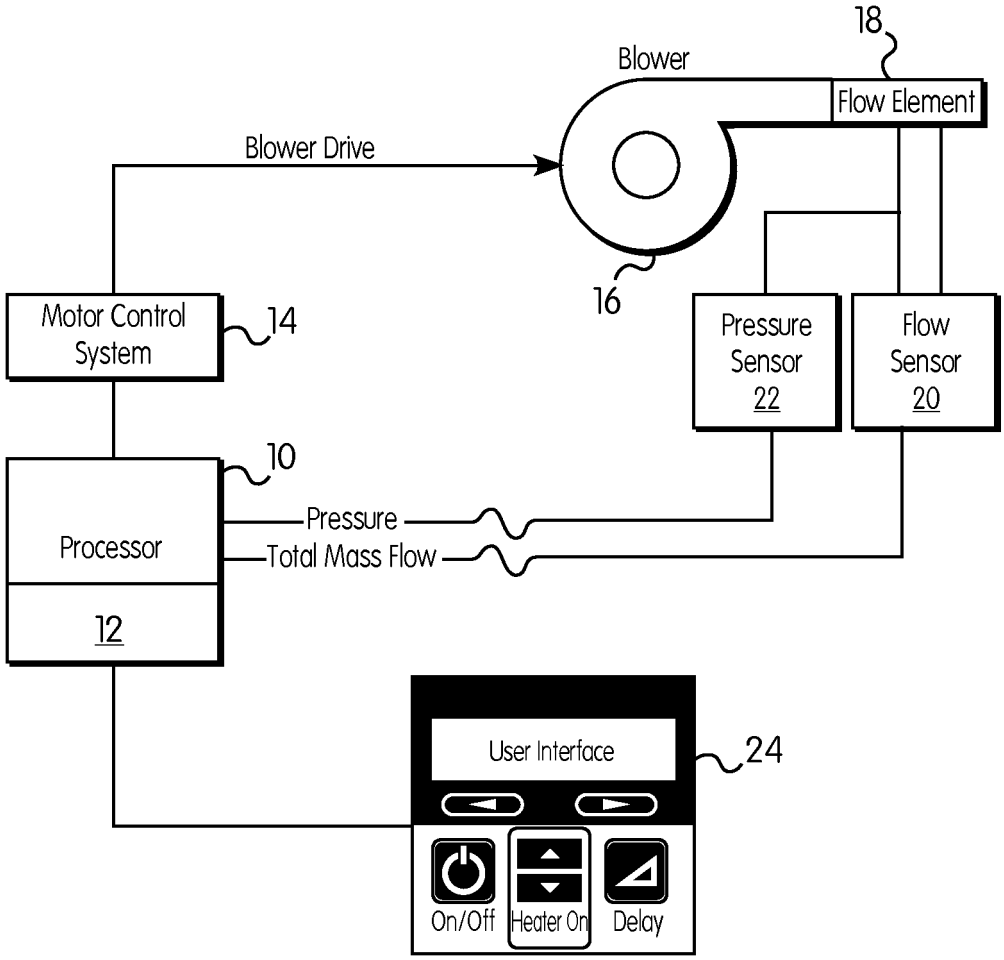
18
Blower
Flow Element
Blower Drive
16
Motor Control System
14
Pressure Sensor 22
Flow Sensor 20
10
Processor
12
Pressure
Total Mass Flow
User Interface
24
On/Off
Heater On
Delay

FIG. 6

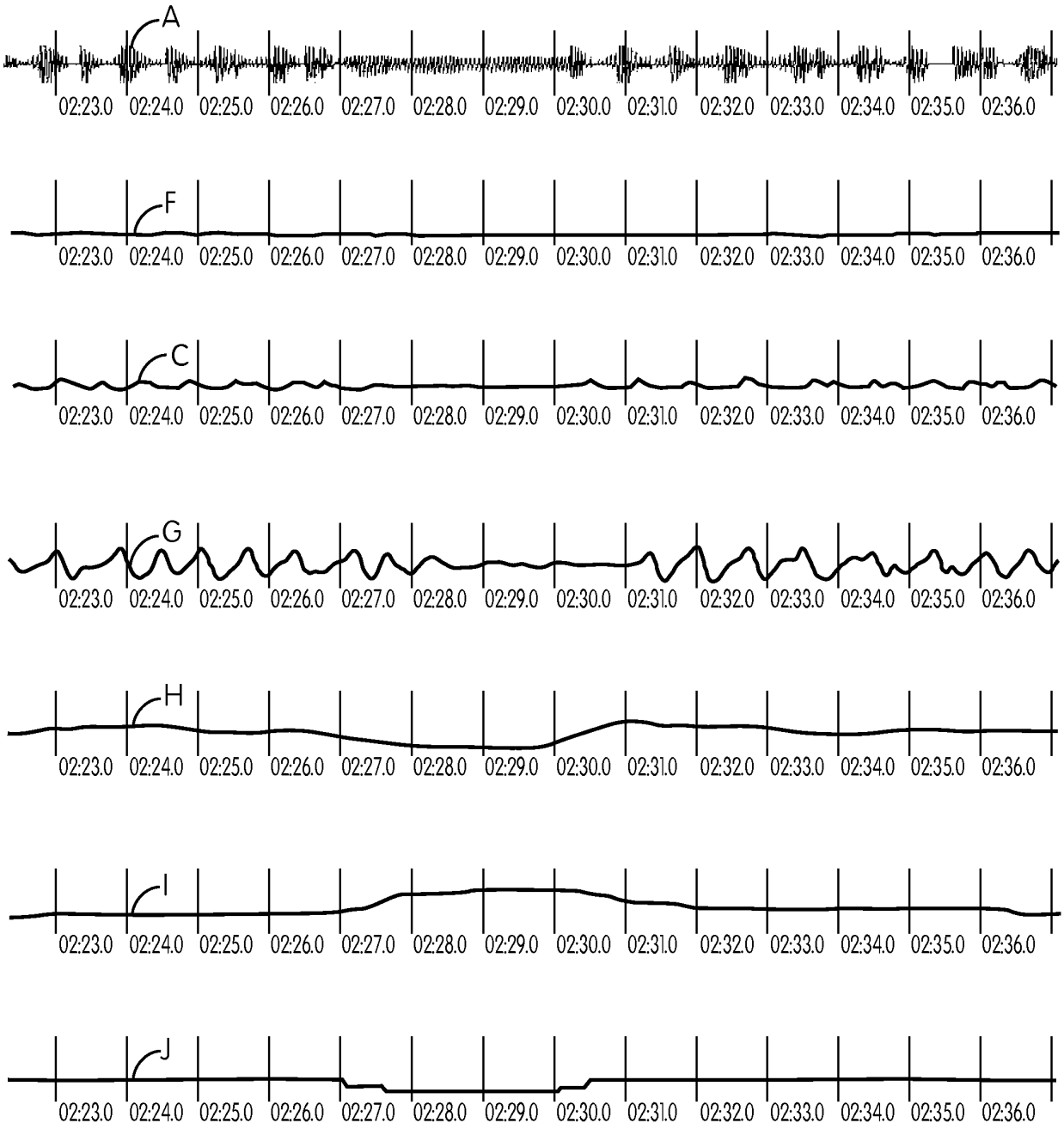
A
F
C
G
H
I
J
02:23.0
02:24.0
02:25.0
02:26.0
02:27.0
02:28.0
02:29.0
02:30.0
02:31.0
02:32.0
02:33.0
02:34.0
02:35.0
02:36.0

FIG. 7

## REFERENCES CITED IN THE DESCRIPTION

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### Patent documents cited in the description


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- WO 2013177621 A1 **[0006]**

| | | | |
|---|---|---|---|
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| 外部链接 | Espacenet | | |


摘要(译)

一种对呼吸治疗机的改进，用于检测和评估周期性呼吸的发生并且基于该评级改变传递给该装置的用户的治疗。


FIG. 1A
(Prior Art)

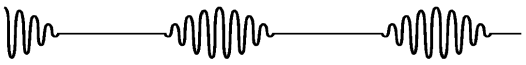

FIG. 1B
(Prior Art)