Exhibit F

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Snyder et al.

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(54) **CIRCUIT AND METHOD FOR ANALYZING A PATIENT'S HEART FUNCTION USING OVERLAPPING ANALYSIS WINDOWS**

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A61N 1/39 (2006.01)

(52) **U.S. Cl.** **607/5**

(58) **Field of Classification Search** 607/2–5, 607/7, 9, 13, 6, 14
See application file for complete search history.

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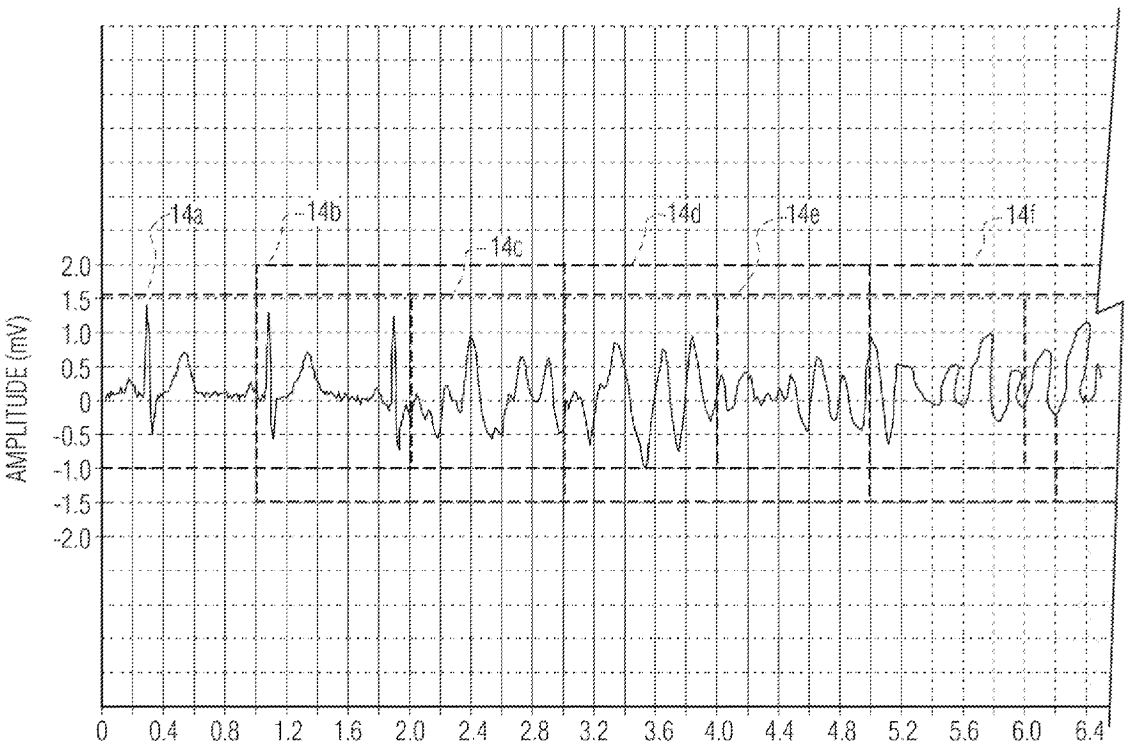
(57) **ABSTRACT**

A circuit includes a sensor coupled to a processor. The sensor senses an electrical signal that is representative of a patient parameter, and the processor determines a condition of the patient by analyzing first and second overlapping portions of the sensed electrical signal. For example, a portable AED can include such a circuit to sense first and second overlapping sections of an ECG. By utilizing this overlapping-window technique, the AED can obtain and analyze multiple sections of ECG data, and thus can make a shock/no-shock decision, more quickly than an AED using contiguous-window analysis. Thus, the overlapping-window technique allows one to use both longer ECG sections (better accuracy per window) and more of these longer sections (better voting accuracy) over a given analysis time. Furthermore, this overlapping-window technique significantly reduces or eliminates boundary problems because the boundary of one ECG section is within the interior of either the preceding or the following overlapping ECG section.

9 Claims, 11 Drawing Sheets



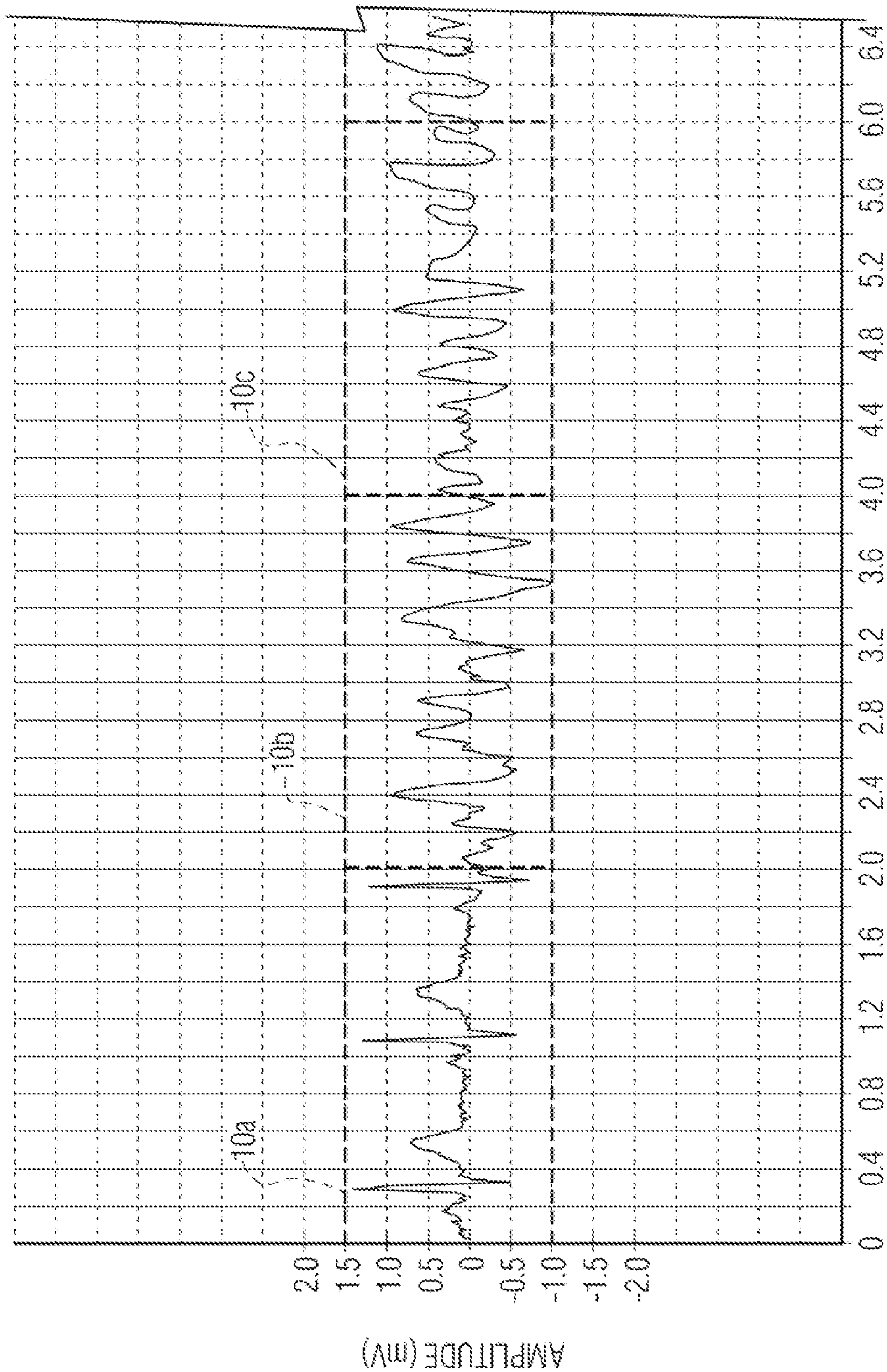
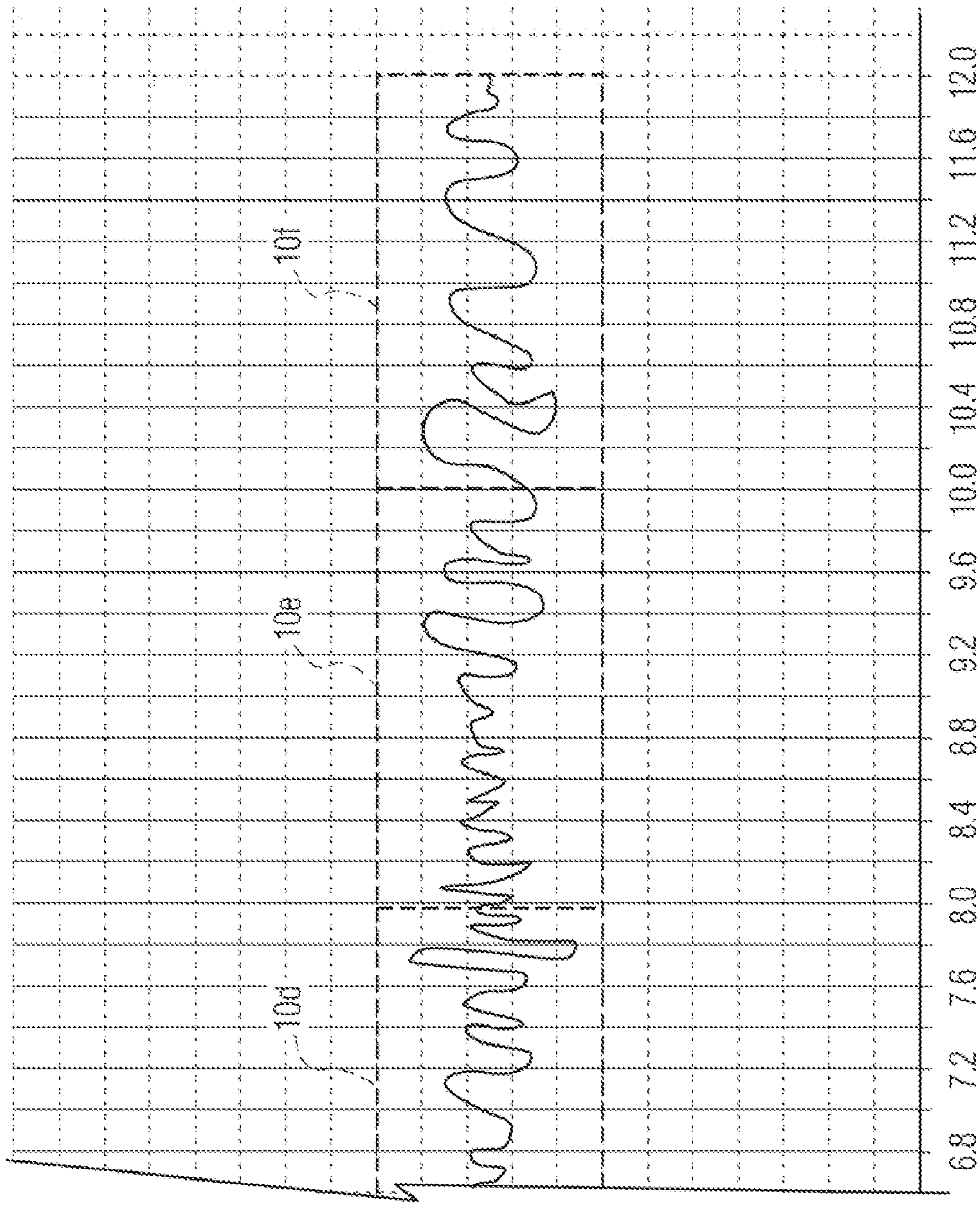


FIG. 1A
PRIOR ART

FIG. 1B
PRIOR ART



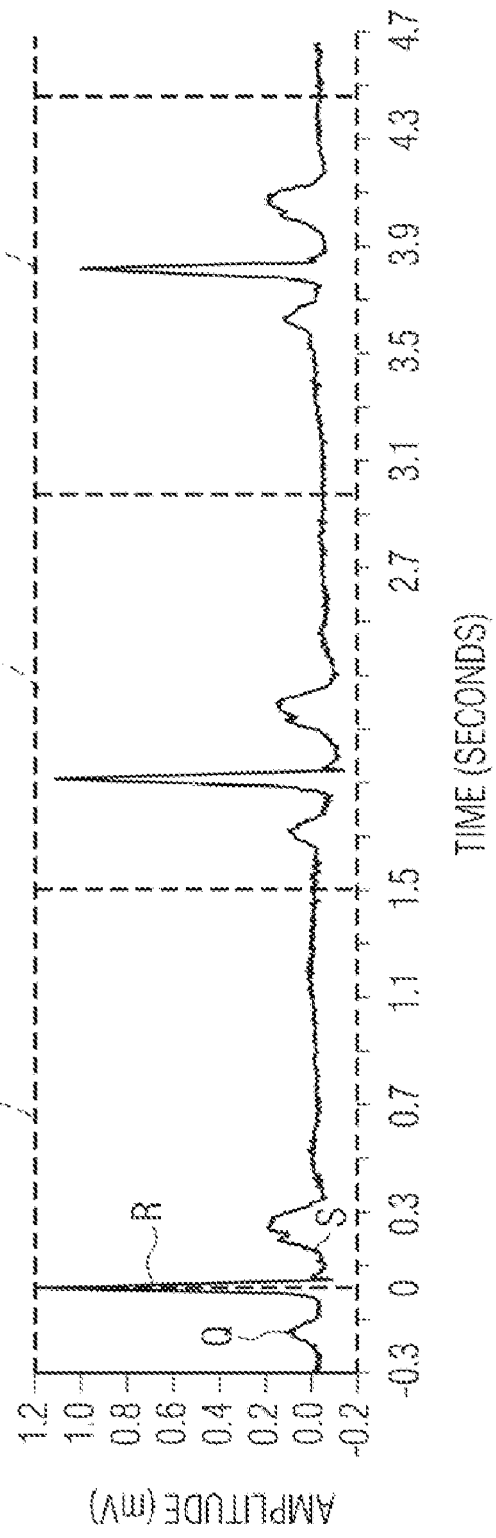
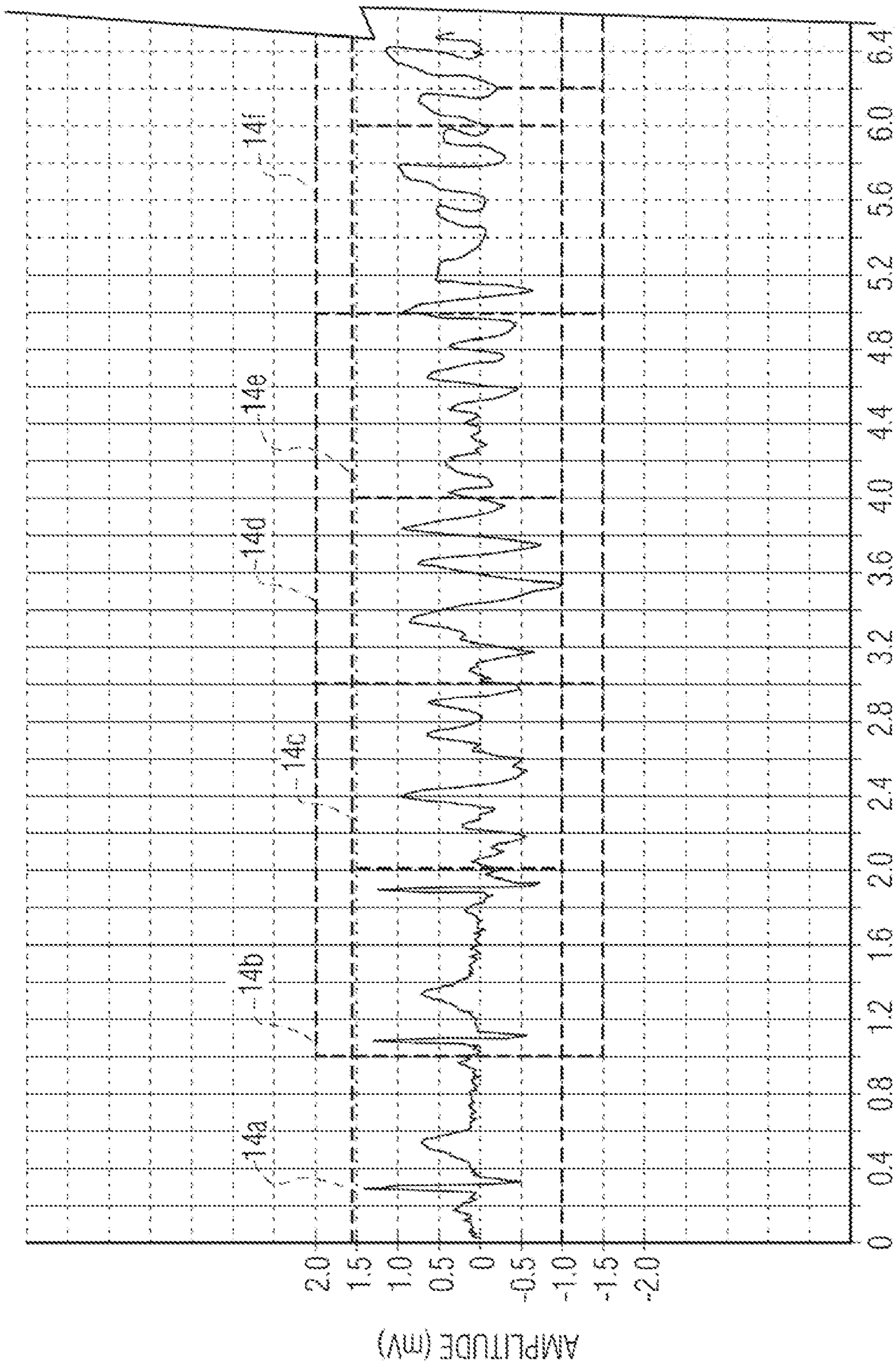


FIG. 2
PRIOR ART


14a
14b
14c
14d
14e
14f
0
0.4
0.8
1.2
1.6
2.0
2.4
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3.2
3.6
4.0
4.4
4.8
5.2
5.6
6.0
6.4
2.0
1.5
1.0
0.5
0
-0.5
-1.0
-1.5
-2.0
AMPLITUDE (mV)

FIG. 3A

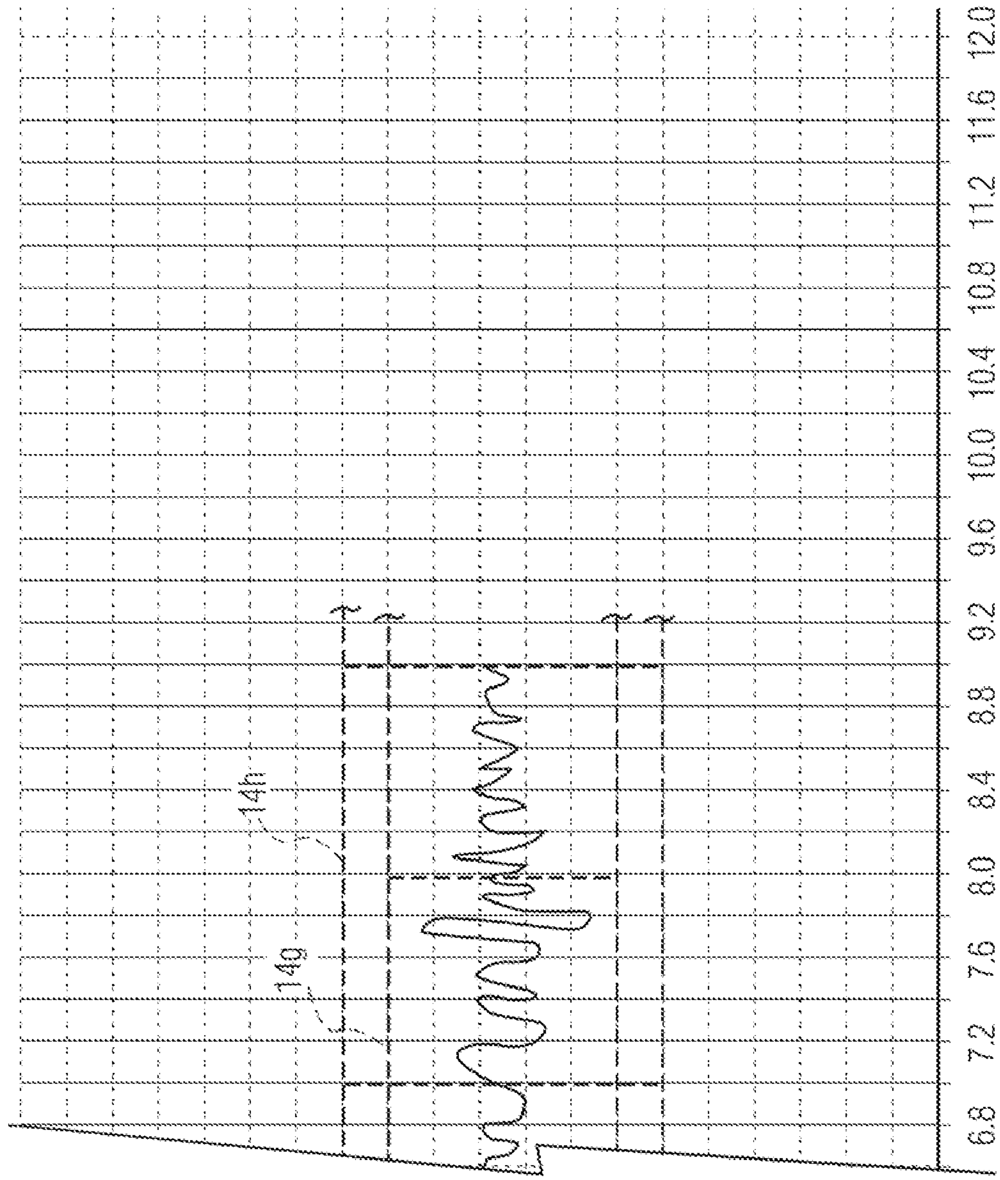


FIG. 3B

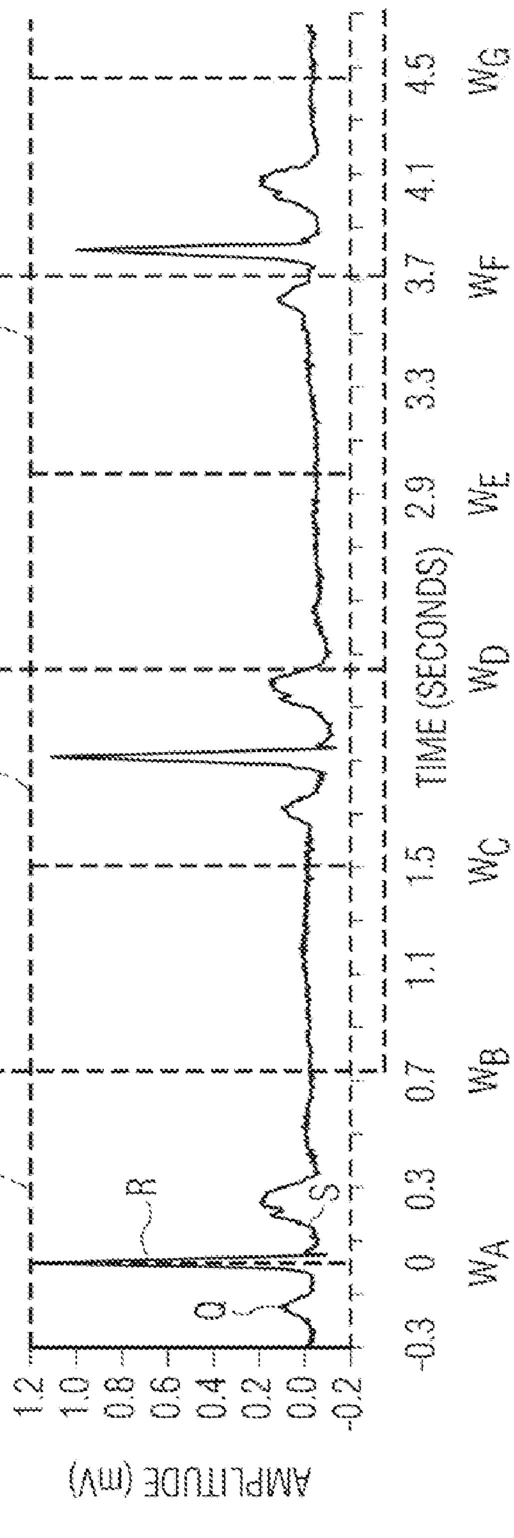


FIG. 4
PRIOR ART

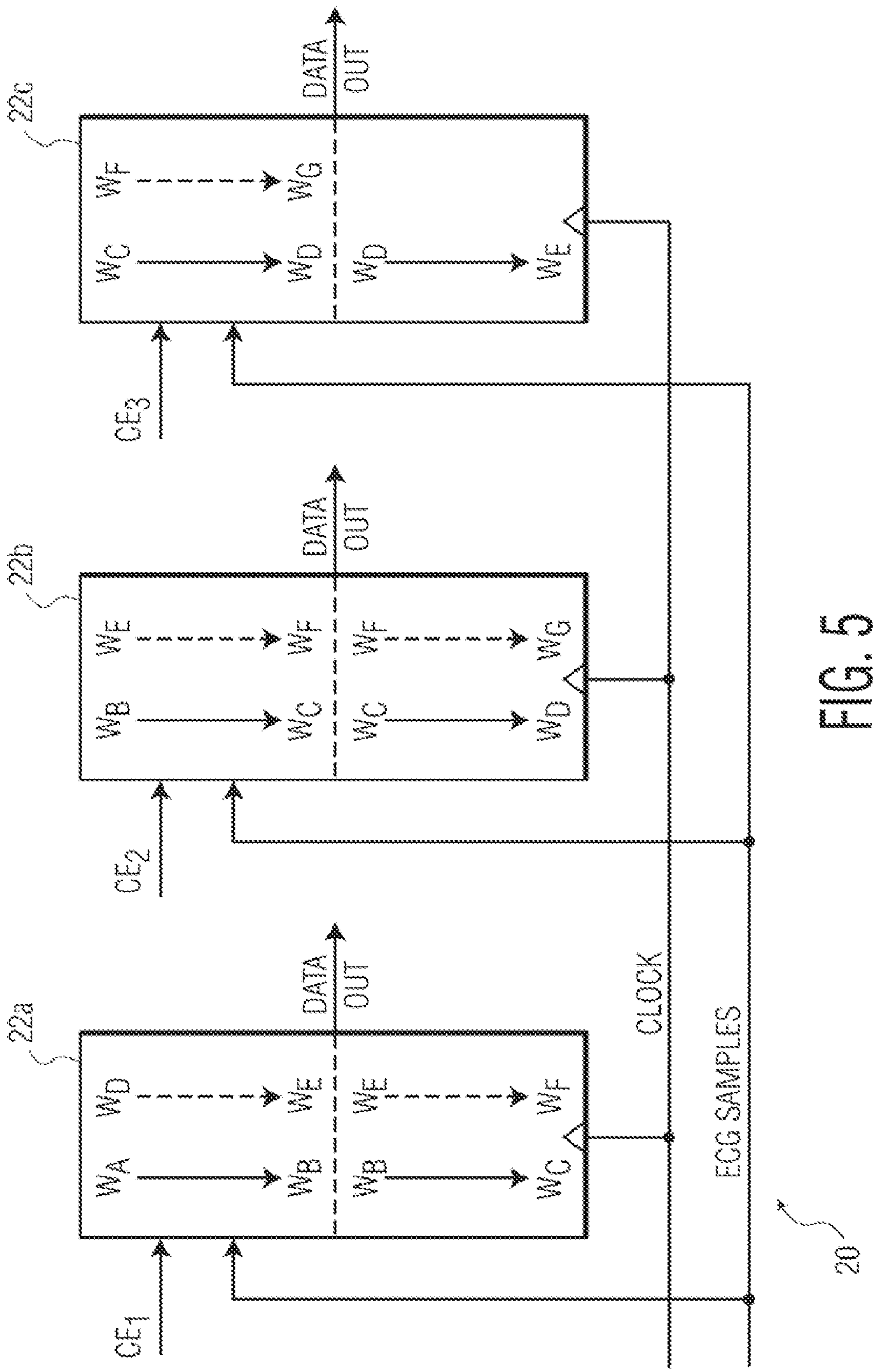

22a
22b
22c
DATA OUT
DATA OUT
DATA OUT
W_A W_B W_B W_C
W_D W_E W_E W_F
W_B W_C W_C W_D
W_E W_F W_F W_G
W_C W_D W_D W_E
W_F W_G
CE_1
CE_2
CE_3
CLOCK
ECG SAMPLES
20

FIG. 5

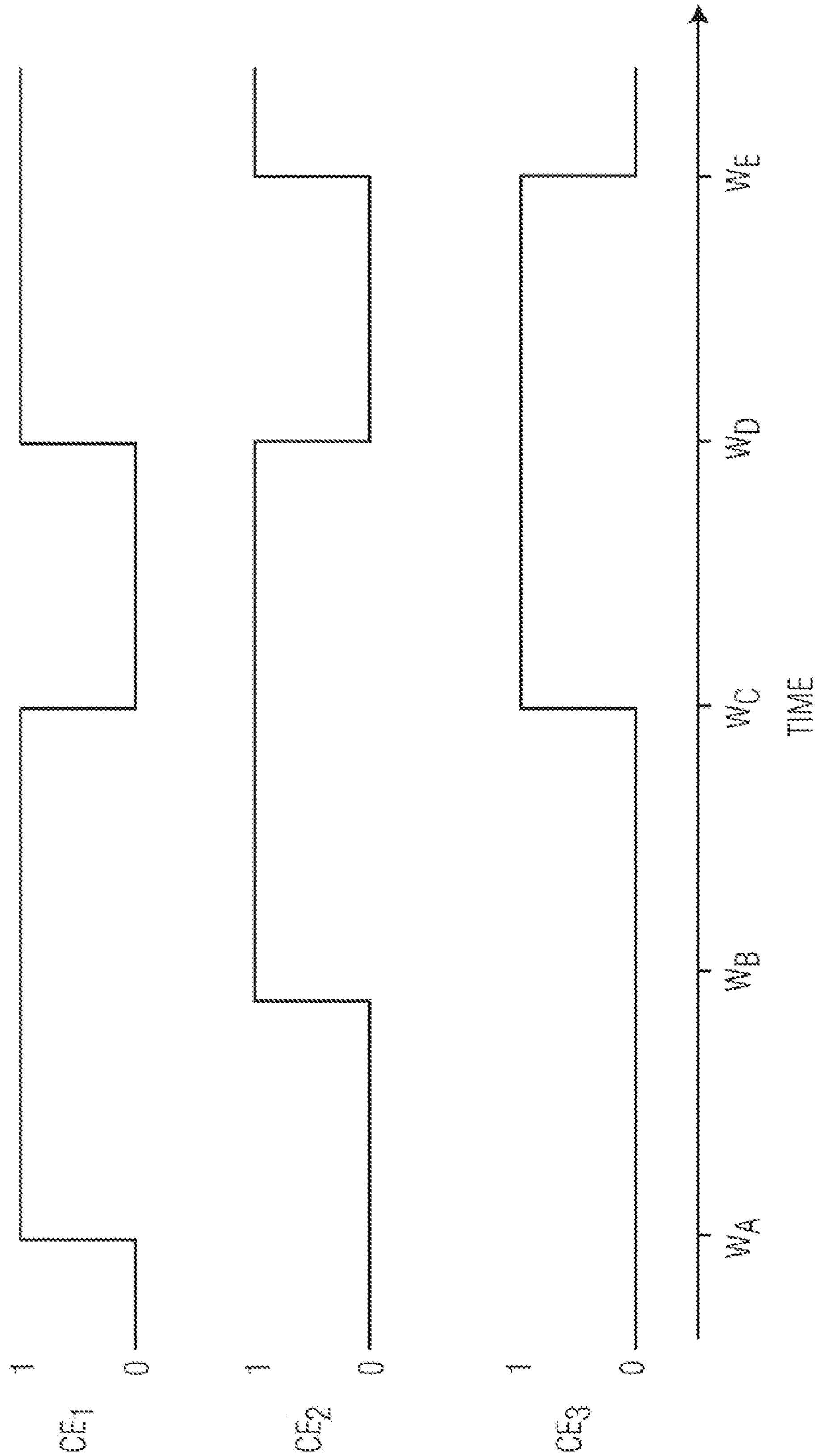


FIG. 6

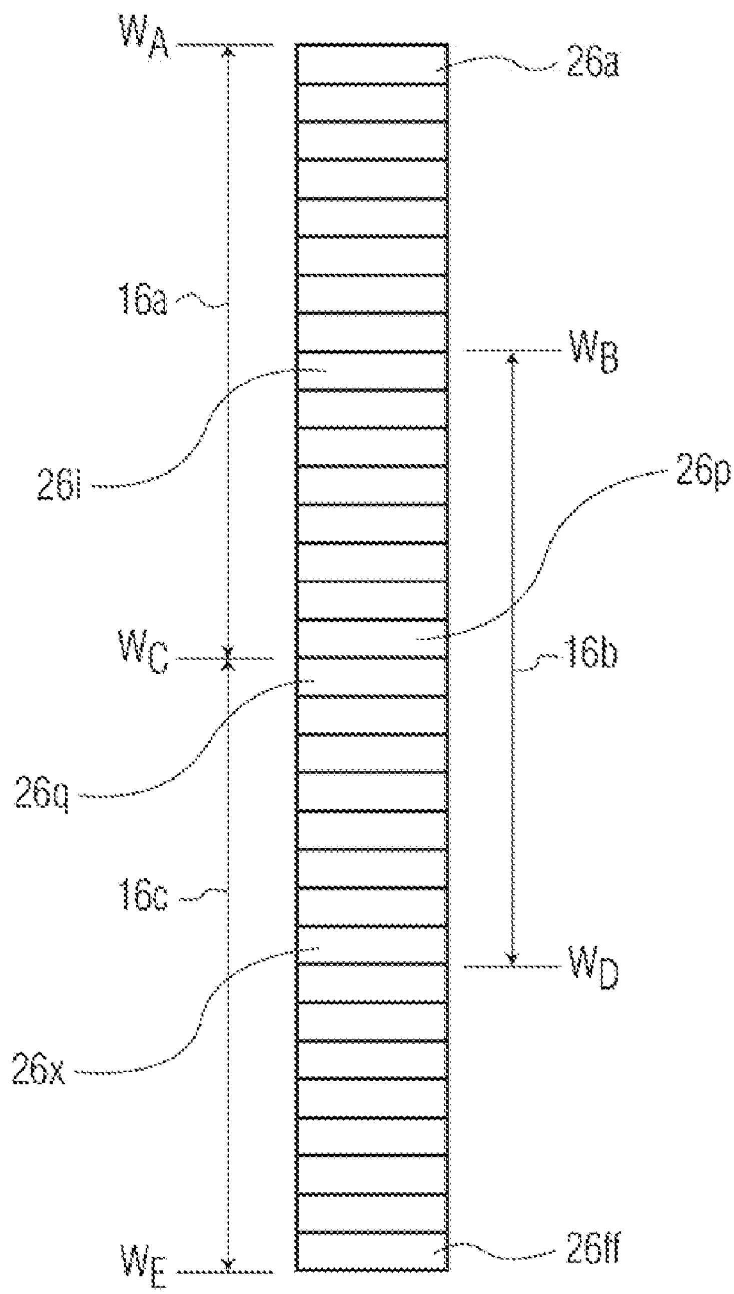
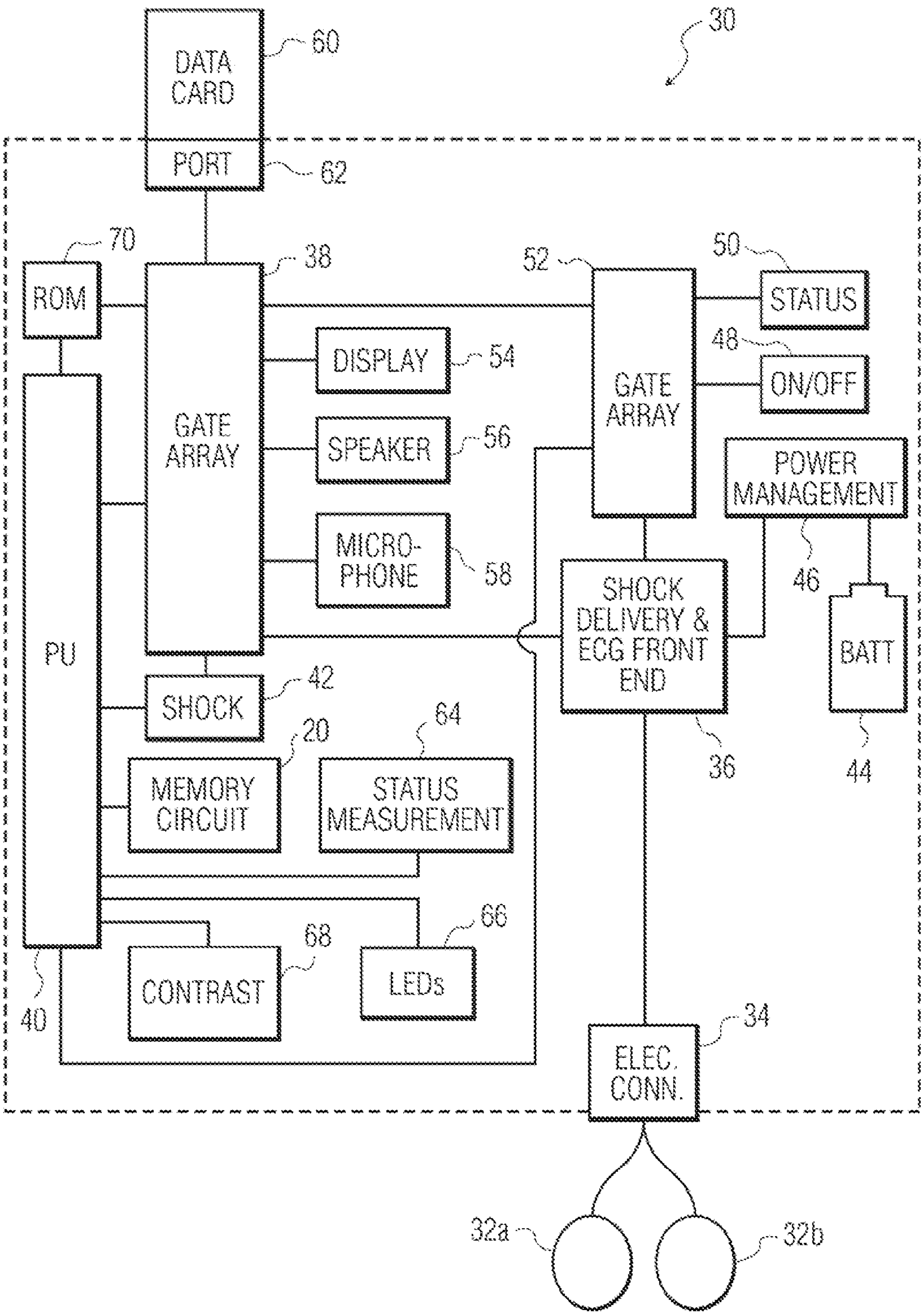


FIG. 7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PORT
62
ROM
70
38
GATE ARRAY
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GATE ARRAY
50
STATUS
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ON/OFF
DISPLAY
54
SPEAKER
56
MICRO-PHONE
58
POWER MANAGEMENT
46
BATT
44
PU
SHOCK
42
SHOCK DELIVERY & ECG FRONT END
36
MEMORY CIRCUIT
20
STATUS MEASUREMENT
64
CONTRAST
68
LEDs
66
40
ELEC. CONN.
34
32a
32b

FIG. 8

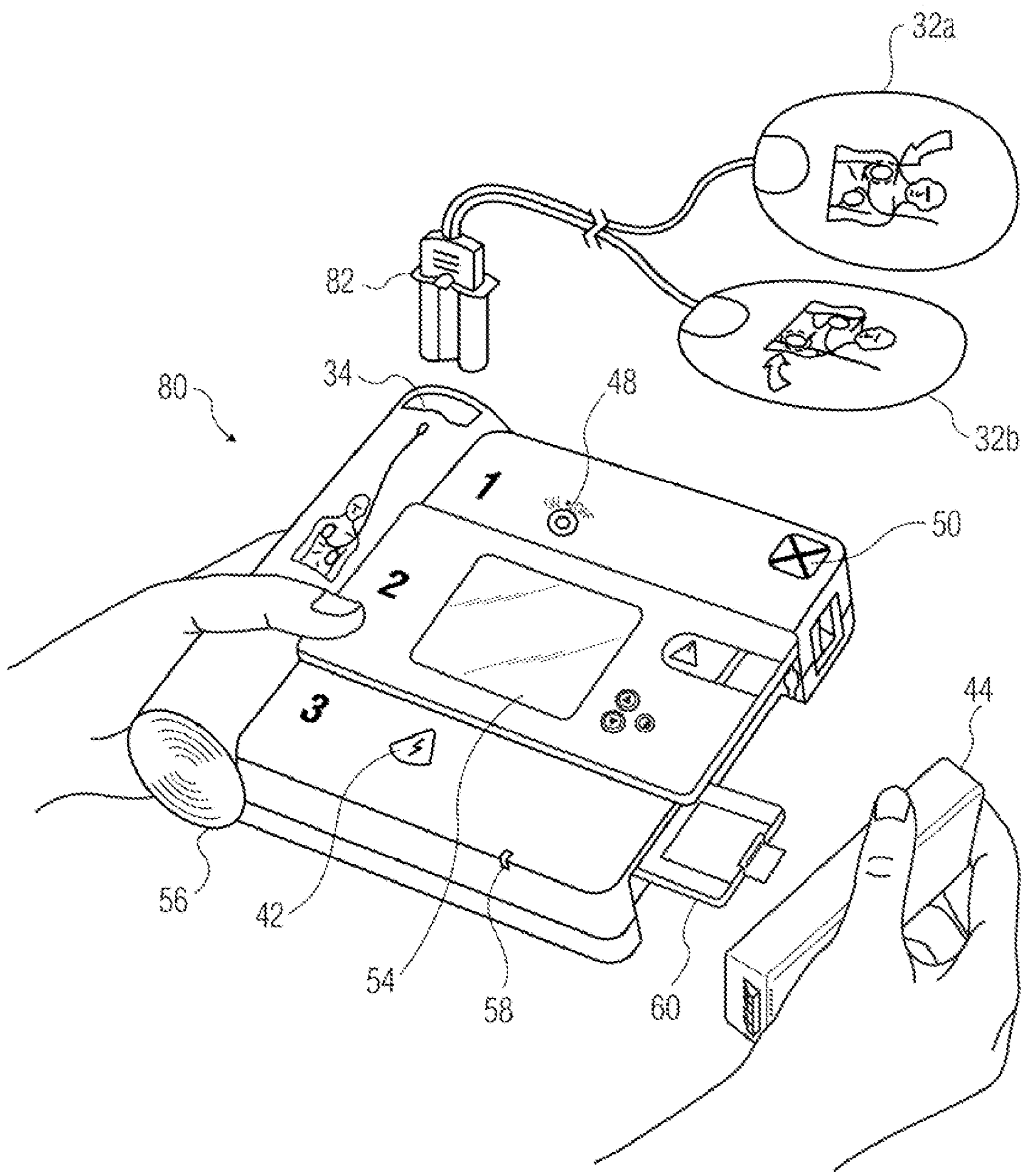

FIG. 9

CIRCUIT AND METHOD FOR ANALYZING A PATIENT'S HEART FUNCTION USING OVERLAPPING ANALYSIS WINDOWS

TECHNICAL FIELD

The invention relates generally to electronic circuits and systems, and more particularly to a circuit and method for analyzing a patient's heart function using overlapping analysis windows. For example, a portable automatic external defibrillator (AED) can analyze overlapping portions of an electrocardiogram (ECG) to determine if a patient's heart would benefit from a defibrillating shock. By analyzing overlapping portions of the patient's ECG, the AED often makes a shock/no-shock decision more quickly and more accurately than AEDs using other analysis techniques.

BACKGROUND OF THE INVENTION

Portable AEDs have saved many lives in non-hospital settings and, as a result of advances in AED technology, the number of lives saved per year is rising. Typically, a portable AED analyzes a patient's heart function and instructs an operator to administer an electrical shock if appropriate. For example, a shock can often revive a patient who is experiencing ventricular fibrillation (VF). Because older models of portable AEDs include only basic diagnostic and safety features, they are often difficult to operate. Therefore, only specially trained persons such as emergency medical technicians (EMTs) can use these older models to administer shocks. Newer models, however, often include advanced diagnostic and safety features that allow minimally trained persons to administer shocks. Consequently, more people are using portable AEDs to save lives.

Because a heart condition that responds to an electrical shock can cause permanent damage or death within a short time if left untreated, a portable AED should be able to diagnose a shockable heart condition and be ready to shock a patient within seconds. Without cardiopulmonary resuscitation (CPR), a person in cardiac arrest will typically suffer permanent anoxia-induced brain damage within 4-6 minutes from the onset. Unfortunately, many people do not know how to administer CPR. And, even in the best of circumstances, it can take 1-4 minutes to retrieve the AED and 1-2 additional minutes to attach the pads to the patient, connect the pads to the AED, and activate the AED. Therefore, even if the patient is discovered immediately, the AED often has less than a minute to diagnose and shock the patient before he/she is in danger of suffering permanent brain damage. Clearly, the faster the AED can diagnose and shock the patient, the better the chances that the patient will survive with no permanent brain damage.

Unfortunately, many portable AEDs implement heart-analysis techniques that require a relatively long time to analyze the patient's ECG and to make a shock/no-shock decision based on the analysis.

FIGS. **1** and **2** illustrate contiguous windowing, which is a heart-analysis technique used by many portable AEDs. For example, referring to FIG. **1**, a portable AED (not shown in FIG. **1**) samples and analyzes contiguous "windows", i.e., sections **10**_a_-**10**_f_, of a patient's ECG. Typically, the AED individually analyzes multiple ECG sections **10**, compares the respective analysis results to one another or to predetermined comparison values, and makes a shock/no-shock decision based on this comparison.

Referring to FIG. **1**, an AED (not shown in FIG. **1**) using contiguous windowing often requires a relatively long time to make a shock/no-shock decision. For example purposes, assume that the AED is programmed to analyze at least ten ECG sections **10** before making a decision, and that each section **10** is two seconds long. Therefore, the AED requires a minimum of twenty seconds to make a shock/no shock decision. Even though twenty seconds may not seem like a long time, every second required to make a shock/no-shock decision decreases the chances that a patient will survive with no permanent damage.

In addition, changes in the patient's heart function may increase the time that the AED requires to make a shock/no-shock decision. For example purposes, assume that before the AED can make a shock/no-shock decision, it is programmed to analyze ECG sections **10** until at least a predetermined number of ten sequential sections give consistent analysis results. The AED then bases its shock/no-shock decision on one or more of these consistent analysis results. This decision-making process is often called "voting". The theory behind voting is that if a predetermined percentage of analyzed ECG sections yield consistent, i.e., similar results, then these results are more likely to be accurate than inconsistent results yielded by other ECG sections. For example, an AED may be programmed to accept the result yielded by the majority of analyzed ECG sections and ignore different results from the minority of analyzed ECG sections. In the illustrated example, the ECG section **10**_a_ indicates that the patient's heart is beating with a normal sinus rhythm, but the sections **10**_b_-**10**_f_ indicate that the patient is in VF. Therefore, because the analysis results obtained from the ECG section **10**_a_ will clearly be inconsistent with the results obtained from the sections **10**_b_-**10**_f_, the AED must analyze at least seven ECG sections—the inconsistent section **10**_a_ plus at least six (a majority of ten) consistent sections starting with the section **10**_b_—before making a shock/no-shock decision. If the six ECG sections starting with the section **10**_b_ are inconsistent, however, then the AED must analyze more ECG sections **10**. Thus, the AED requires a minimum of fourteen seconds to make a shock/no-shock decision in this situation. Furthermore, although in this example the transition from normal sinus rhythm to VF occurs near the boundary between the ECG sections **10**_a_ and **10**_b_, the same problem often arises when the transition occurs within a section **10**.

Still referring to FIG. **1**, one way to reduce the time that an AED requires to make a shock/no-shock decision is to shorten each of the ECG sections **10**. For example, assuming that the AED is programmed to analyze at least ten sections **10** as discussed above, reducing the length of each section **10** from two seconds to one second reduces the minimum decision time from twenty to ten seconds. As the lengths of the ECG sections **10** decrease, the chances of an AED making an incorrect shock/no-shock decision increases. Specifically, as their lengths decrease, each of the sections **10** represents a smaller portion of the ECG. If a section **10** is too small, it does not contain enough ECG information to support an accurate analysis of the section. If all the sections **10** are too small, the AED makes a series of inaccurate analyses that may cause the AED to make an inaccurate shock/no-shock decision.

Another way to view this problem is as a tradeoff between section length and the number of sections. For example, for a given analysis time, e.g., 20 seconds, one can use longer sections (better accuracy per section) with fewer results to vote from (less voting accuracy) or shorter sections (less accuracy per section) with more results to vote from (more voting accuracy).

In addition, referring to FIG. **2**, even when the ECG sections are not too short, an AED (not shown in FIG. **2**) using contiguous windowing may incorrectly diagnose a patient's heart condition, and thus may determine that a defibrillating shock will benefit a patient when in actuality the shock may harm the patient. In the illustrated example, the patient is experiencing bradycardia, which is characterized by abnormalities in the patient's QRS wave and by an abnormally low heart rate. Unfortunately, shocking a patient experiencing bradycardia is at best useless and at worst can send the patient into VF or cause other cardiac damage. Therefore, it is important that the AED recognize bradycardia and other unshockable heart conditions and generate a no-shock decision if it determines that a patient is experiencing any of these conditions.

More specifically, if a boundary, i.e., the beginning or end, of an ECG section **12** intersects an important part of the ECG, then the AED's analysis of that section may yield an incorrect diagnosis, and the AED may make an incorrect shock/no-shock decision based on this incorrect diagnosis. In the illustrated example, the AED analyzes contiguous ECG sections **12***a*, **12***b*, **12***c*, which are each one and a half seconds long. Unfortunately, the beginning of the section **12***a* intersects a QRS complex, and thus the section **12***a* contains only part of the complex. Because there are no other full complexes within the section **12***a*, the AED's analysis of the section **12***a* may yield an incorrect result. But if the ECG sections **12***b* and **12***c* and a predetermined number of following sections **12** respectively include full QRS complexes, the AED can use voting to ignore the result from the section **12***a* and correctly make a no-shock decision as discussed above. Although as discussed above this may increase the time that the AED requires to make a shock/no-shock decision, the AED makes a correct decision. Conversely, if the ECG sections are shortened, e.g., to 0.5 seconds in order to obtain a quicker response, a majority of the sections will be lacking a QRS complex. These sections may be incorrectly interpreted as benefiting from a shock, resulting in an inappropriate shock diagnosis.

Still referring to FIG. **2**, there are currently no analysis techniques for overcoming the intersecting-boundary problem other than to vote among multiple contiguous ECG sections, thereby delaying diagnosis, or to have a skilled operator (not shown in FIG. **2**) study the ECG and determine if the AED's shock/no-shock decision is correct.

Therefore, the need has arisen for a heart-condition analysis technique that is faster and more accurate than the contiguous-window analysis technique.

SUMMARY OF THE INVENTION

In one aspect of the invention, a circuit includes a sensor coupled to a processor. The sensor senses an electrical signal that is representative of activity in a patient's heart, and the processor determines a condition of the patient's heart by analyzing first and second overlapping portions of the sensed electrical signal.

For example, a portable AED can include such a circuit to sense a first section of an ECG during a first time period and to sense a second section of the ECG during a second time period that overlaps the first time period. By utilizing this overlapping-window technique, the AED can obtain and analyze multiple sections of ECG data, and thus can make a shock/no-shock decision, more quickly than an AED using contiguous-window analysis. Thus, the overlapping-window technique allows one to use both longer ECG sections (better accuracy per window) and more of these longer sections (better voting accuracy) over a given analysis time. Furthermore, this overlapping-window technique significantly reduces or eliminates boundary problems because the boundary of one ECG section is within the interior of one or more of the either the preceding or the following overlapping ECG sections.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** illustrates a conventional contiguous-window analysis of the ECG of a patient who suddenly enters VF.

FIG. **2** illustrates a conventional contiguous-window analysis of the ECG of a patient experiencing bradycardia.

FIG. **3** illustrates an overlapping-window analysis of a portion of the ECG of FIG. **1** according to an embodiment of the invention.

FIG. **4** illustrates an overlapping-window analysis of the ECG of FIG. **2** according to an embodiment of the invention.

FIG. **5** is a block diagram of a memory circuit for storing overlapping sections of an ECG according to an embodiment of the invention.

FIG. **6** is a timing diagram of some of the signals shown in FIG. **5**.

FIG. **7** is a block diagram of a memory circuit for storing overlapping sections of an ECG according to another embodiment of the invention.

FIG. **8** is a block diagram of an AED circuit that implements an overlapping-window analysis according to an embodiment of the invention.

FIG. **9** is a perspective view of a portable AED that incorporates the AED circuit of FIG. **8** according to an embodiment of the invention.

DESCRIPTION OF THE INVENTION

FIGS. **3** and **4** illustrate overlapping-window analysis of an ECG according to respective embodiments of the invention. As discussed below, an AED using overlapping-window analysis often can diagnose a patient's heart condition more quickly and more accurately than an AED using contiguous-window analysis. Furthermore, an AED using overlapping-window analysis is often more immune to boundary problems than an AED using contiguous-window analysis. Moreover, although overlapping-window analysis is described below in terms of a portable AED analyzing an ECG, other types of medical equipment can use this technique to analyze other types of signals, such as an electrogram that represent a patient's heart activity, or an electroencephalogram that represents a patient's brain activity.

FIG. **3** illustrates an overlapping-window analysis of a portion of the ECG of FIG. **1** according to an embodiment of the invention. Like the contiguous ECG sections **10** of FIG. **1**, each section **14** is two seconds long, although in other embodiments the sections **14** may be longer or shorter than two seconds or may not all have the same length. But unlike the sections **10**, the sections **14** overlap one another. For example, the beginning of the second section **14***b* coincides with the midpoint of the first section **14***a*, and the end of the section **14***b* coincides with the midpoint of the third section **14***b*. Thus, the first half of each ECG section **14** overlaps the last half of the respective preceding section, and the last half of each ECG section **14** overlaps the first half of the respective following section. This is referred to as 50% overlap, although in other embodiments the overlap can be greater or less than 50%. Therefore, overlapping-window analysis allows an AED circuit (not shown in FIG. **3**) to analyze overlapping sections of an ECG or other heart signal. Because the AED can use conventional algorithms to analyze each of the overlapping ECG sections, a detailed discussion of these algorithms is omitted.

By analyzing overlapping sections of a patient's ECG, an AED can often make a shock/no-shock decision more quickly than it can by analyzing contiguous ECG sections. Specifically, because the ECG sections **14** overlap one another, the AED can analyze more sections **14** of the ECG within a given time period than it can contiguous sections **10** (FIG. **1**). For example, the AED can analyze ten overlapping sections **14** in eleven seconds as compared to analyzing ten contiguous sections **10** in twenty seconds. Thus, 50% overlapping cuts the analysis time almost in half!

Furthermore, analyzing overlapping sections of a patient's ECG is often more accurate than analyzing contiguous sections of the ECG. As discussed above in conjunction with FIGS. **1** and **2**, if an ECG section is too small, it often contains too little information to yield an accurate indication of the patient's heart condition. Therefore, analyzing a number of longer, overlapping ECG sections of an ECG segment is often more accurate than analyzing a similar number of shorter, contiguous ECG sections of the same segment. For example, analyzing an eleven-second ECG segment with ten overlapping two-second sections **14** is often more accurate than analyzing the ECG segment with eleven contiguous one-second ECG sections. Because a section **14** is twice as long as a one-second section, it contains approximately twice as much information as the one-second section. Therefore, the longer sections **14** each provide a "bigger picture" of the patient's ECG than do the shorter contiguous sections, and thus tend to yield a more accurate indication of the patient's heart condition.

Moreover, by analyzing overlapping sections of a patient's ECG, an AED can often detect changes in a patient's heart condition more quickly than by analyzing contiguous sections. For example, assume that before an AED can make a shock/no-shock decision, it is programmed to analyze ECG sections until a majority of five sequential sections gives consistent analysis results. Referring to FIG. **1**, because the ECG does not indicate VF until the beginning of the section **10***b*, an AED using contiguous windowing must analyze at least four ECG sections **10***a*-**10***d*, and thus requires at least eight seconds to determine that the patient is in VF. Conversely, referring to FIG. **3**, an AED using the illustrated overlapping-windowing technique may be able to diagnose VF in as few as six seconds. Specifically, because the ECG does not indicate VF until the middle of the section **14***b*, an AED using the illustrated overlapping-windowing technique analyzes at least five ECG sections **14***a*-**14***e*. But because the sections **14** overlap one another by 50%, five ECG sections **14** occupy a shorter period of time (six seconds) than four of the contiguous ECG sections **10** (eight seconds) of FIG. **1**. Of course, increasing the overlap or decreasing the length of the sections **14** may further reduce the minimum analysis time.

FIG. **4** illustrates an overlapping-window analysis of the ECG of FIG. **2** according to an embodiment of the invention. Like the ECG sections **12** of FIG. **2**, the ECG sections **16***a*-**16***f* are each 1.5 seconds long, although in other embodiments the sections **16** may be longer or shorter. But unlike the sections **12**, the sections **16** overlap one another by 50%, although in other embodiments the sections **16** may overlap one another by more or less than 50%. Therefore, the beginning of a section **16** is within the preceding section and the end of the section **16** is within the following section. For example, the beginning of the second section **16***b* at time W_B coincides with the midpoint of the first section **16***a*, and the end of the section **16***b* at time W_D coincides with the midpoint of the third section **16***c*. Thus, if an important part of the ECG intersects the boundary of a section **16**, this ECG part is most often wholly within another section **16**. Therefore, an AED can analyze ECG sections **16** that wholly contain important parts of the ECG. For example, if the QRS complexes of the ECG were to intersect with the boundaries of the sections **16***a*, **16***c*, and **16***e* at the respective times W_A, W_C, and W_E, then these same QRS complexes also intersect the midpoints of the alternate sections **16***b*, **16***d*, and **16***f*. Therefore, by analyzing the alternate sections **16***b*, **16***d*, **16***f*, and so on, the AED can analyze whole QRS complexes and thus correctly diagnose bradycardia and make a no-shock decision.

FIG. **5** is a block diagram of a memory circuit **20** that can store overlapping sections of an ECG according to an embodiment of the invention. The memory circuit **20** includes three memories **22***a*, **22***b*, and **22***c*, which may be disposed within a common memory array or within respective memory arrays. Each of the memories **22***a*, **22***b*, and **22***c* stores data representing a respective overlapping ECG section in response to a common signal CLOCK and respective memory-enable signals CE**1**, CE**2**, and CE**3**. For example, referring to FIG. **4** and as discussed below, at various points during the ECG analysis, the memory **22***a* stores data representing the ECG section **16***a*, the memory **22***b* stores data representing the section **16***b*, and the memory **22***c* stores data representing the section **16***c*. In one embodiment, the stored data are conventional analog or digital samples—typically voltage samples—of the ECG. Once the data representing an ECG section is stored in a memory **22**, the AED (not shown in FIG. **5**) can analyze the overlapping ECG section stored within that memory **22**. As discussed below, once the AED analyzes the stored data, the memory **22** begins to store another ECG section. Therefore, for 50% overlap, the three memories **22***a*, **22***b*, and **22***c* can sequentially store data for all of the overlapping ECG sections regardless of how many sections the AED analyzes. But more or fewer memories **22** may be needed for different amounts of overlap.

Referring to FIGS. **4**-**6**, the operation of the memory circuit **20** is discussed according to an embodiment of the invention. FIG. **6** is a timing diagram of the signals CE**1**, CE**2**, and CE**3** of FIG. **5**, where the times W_A-W_E respectively correspond to the same times W_A-W_E in FIG. **4**, and where CE**1**, CE**2**, and CE**3** are active logic 1 and inactive logic 0.

Before time W_A, CE**1**, CE**2**, and CE**3** are inactive logic 0 such that the memories **22***a*-**22***c* are disabled from storing samples of the ECG.

Next, between times W_A and W_B, the memory **22***a* stores data representing the first half of the ECG section **16***a*. Specifically, a sample circuit (not shown in FIGS. **4**-**6**) generates a stream of ECG samples, which are coupled to the memories **22***a*-**22***c*. At time W_A, CE**1** transitions to an active logic 1, and thus enables the memory **22***a* to begin storing the ECG samples that represent the ECG section **16***a*. Therefore, at time W_B, the memory has stored samples that represent the first half of the section **16***a*. To clearly illustrate this, FIG. **5** shows that half the memory **22***a* is filled between the times W_A and W_B, thus indicating that the memory **22***a* has just enough capacity to store the ECG samples representing the section **16***a*. In other embodiments, however, the memories **22***a*-**22***c* may have larger capacities.

Then, between the times W_B and W_C, the memory **22***a* stores data representing the second half of the ECG section **16***a*, and the memory **22***c* stores data representing the first half of the ECG section **16***b*. Specifically, at time W_B, the signal CE**2** transitions to an active logic 1, and thus enables the memory **22***b* to begin storing the ECG samples that represent the second ECG section **16***b*. Furthermore, the memory **22***a* begins storing the same samples, which also represent the second half of the ECG section **16***a*. Thus, by storing the same portion of the ECG—the overlapping portion between times

W_B and W_C—in two memories **22***a* and **22***b*, the memory circuit **20** stores overlapping ECG sections **16***a* and **16***b*.

Next, between the times W_C and W_D, the AED analyzes the data stored in the memory **22***a*, the memory **22***b* stores data representing the second half of the ECG section **16***b*, and the memory **22***c* stores data representing the first half of the ECG section **16***c*. Specifically, at time W_C, CE**3** transitions to active logic 1 and CE**1** transitions to inactive logic 0. Furthermore, the memory **22***a* contains ECG samples that represent the entire ECG section **16***a*, and the memory **22***b* contains ECG samples that represent the first half of the ECG section **16***b*. Between W_C and W_D, the AED analyzes the data in the memory **22***a*, and thus analyzes the first ECG section **16***a*, while the memory **22***b* stores the second half of the ECG section **16***b* and the memory **22***c* stores the first half of the ECG section **16***c*. Therefore, while the AED analyzes data in one memory **22**, the other two memories **22** continue to store ECG samples.

Then, between the times W_D and W_E, the AED analyzes the data stored in the memory **22***b*, the memory **22***a* stores data representing the first half of the ECG section **16***d*, and the memory **22***c* stores data representing the second half of the ECG section **16***c*. Specifically, at time W_D, CE**1** transitions to active logic 1 and CE**2** transitions to inactive logic 0. Furthermore, the memory **22***b* contains ECG samples that represent the entire ECG section **16***b*, and the memory **22***c* contains ECG samples that represent the first half of the ECG section **16***c*. Between W_D and W_E, the AED analyzes the data in the memory **22***b*, and thus analyzes the second ECG section **16***b*, while the memory **22***c* stores the second half of the section **16***c* and the memory **22***a* stores the first half of the section **16***d*.

This cycle of storing and analyzing data continues until the AED analyzes the desired number of overlapping ECG sections **16**.

Referring to FIG. **5**, other embodiments of the memory circuit **20** are discussed. For example, although described as storing ECG sections having a 50% overlap, the memory **20** for storing ECG sections can be modified to have a smaller or larger overlap. Furthermore, although they are described as storing the same ECG samples for the overlapping portion of two ECG sections, the memories **22***a*-**22***c* may store different samples for the same overlapping portion. For example, as discussed above, between the times W_B and W_C the memories **22***a* and **22***b* store the same ECG samples for the second half of the ECG section **16***a* and the first half of the ECG section **16***b*, respectively.

Moreover, as discussed below in conjunction with FIG. **7**, other circuits can be used or designed, such as a linear register to store overlapping portions of a patient's ECG.

FIG. **7** is a block diagram of a linear memory circuit **24** that can store overlapping sections of an ECG according to another embodiment of the invention. Specifically, the memory circuit **24** is more efficient than the memory circuit **20** of FIG. **5** because it can store the same number of contiguous ECG sections as the memory circuit **20** with fewer storage locations.

The memory circuit **24** includes a number of storage locations **26**, which each store a sample of the patient's ECG. Assuming for example purposes that each window **16** (FIG. **4**) is sixteen samples long, initially the circuit **24** stores the ECG section **16***a* in locations **26***a*-**26***p*, section **16***b* in locations **26***i*-**26***x*, and section **16***c* in locations **26***q*-**26***ff* Therefore, in this example, the memory circuit **20** (FIG. **5**) requires forty eight storage locations to store three windows **16**, but the memory circuit **24** requires only thirty two storage locations **26** to store three windows **16**.

Referring to FIGS. **4** and **7**, in operation, between times W_A-W_E, the memory circuit **24** sequentially stores the ECG samples for the ECG sections **16***a*-**16***c* starting at the location **26***a* and ending at the location **26***ff*. Once an entire section **16** stored, the AED analyzes it while the circuit **24** finishes storing the remaining samples of the next section **16**. Similarly, between times W_E-W_I (W_H and W_I omitted from FIG. **4** for clarity), the circuit **24** stores the ECG samples for the next three windows **16***d*-**16***f* by sequentially overwriting the locations **26***a*-**26***ff*. The circuit **24** repeats this process until AED stores and analyzes the desired number of ECG sections **16**.

Still referring to FIG. **7**, although the memory circuit **24** is described as being large enough to store three overlapping ECG sections **16**, in other embodiments the circuit **24** may be able to store more or fewer sections **16**.

FIG. **8** is a block diagram of an AED circuit **30**, which analyzes overlapping sections of a patient's ECG (not shown in FIG. **8**) according to an embodiment of the invention. In the described embodiment, the circuit **30** includes the memory circuit **20** of FIG. **5**, although in other embodiments the circuit **30** may analyze overlapping ECG sections using the memory circuit **24** of FIG. **7** or another ECG-storage circuit.

Referring to FIG. **8**, conventional defibrillator pads **32***a* and **32***b* are coupled to the circuit **30** via a conventional connector **34** and are operable to sense a patient's ECG and to apply an electrical shock to the patient. A shock-delivery-and-ECG front-end circuit **36** samples the patient's ECG during an analysis mode of operation and provides a shock to the patient via the connector **34** and pads **32***a* and **32***b* during a shock-delivery mode of operation. A gate array **38** receives the ECG samples from the circuit **36** and provides them to a processor unit (PU) **40**, which stores the samples in the memory circuit **20** and analyzes the overlapping ECG sections that the stored samples represent as discussed above in conjunction with FIGS. **4**-**6**. Although the memory circuit **20** is shown coupled directly to the processor unit **40**, the circuit **20** may actually be part of the processor unit **40** or be coupled to the processor unit **40** through other circuits such as the gate array **38**. If the analysis of the overlapping ECG sections indicates that the patient is suffering from a shockable heart condition, then the processor unit **40** instructs the circuit **36** via the gate array **38** to enable delivery of a shock when an operator (not shown in FIG. **8**) presses a shock button **42**. Conversely, if the analysis of the overlapping ECG sections indicates that the patient is not suffering from a shockable heart condition, then the processor unit **40** disables the shock delivery circuitry **36** from delivering a shock to the patient.

Still referring to FIG. **8**, the circuit **30** includes a power-management circuit **46** for distributing power from a battery **44** to the subcircuits of the circuit **30**. An on/off switch **48** turns the circuit **30** on and off, a status circuit **50** indicates the status of the circuit **30**, and a gate array **52** interfaces the power-management circuit **46**, the on/off circuit **48**, and the status circuit **50** to the circuit **36**, the processor unit **40**, and the gate array **38**. A display **54** displays information to an operator (not shown in FIG. **7**), a speaker **56** provides audio instructions to the operator, and a microphone **58** records the operator's voice and other audible sounds. A data card **60** is connected to the gate array **38** via a port **62**. The card **60** stores the operator's voice and other audible sounds along with the patient's ECG and a record of AED events for later study. A status-measurement circuit **64** provides the status of the circuit **30** subcircuits to the processor unit **40**, and LEDs **66** provide information to the operator such as whether the processor unit **40** has enabled the circuit **36** to deliver a shock to the patient. A contrast button **68** allows the operator to control the contrast of the display screen **54**, and a memory such as a read only memory (ROM) **70** stores programming information for the processor unit **40** and the gate arrays **38** and **52**.

The AED circuit **30** and other AED circuits are further discussed in the following references, which are incorporated by reference: U.S. Pat. No. 5,836,993; U.S. Pat. Nos. 5,735,879, ELECTROTHERAPY METHOD AND APPARATUS, filed Aug. 6, 1993; 5,607,454, ELECTROTHERAPY METHOD AND APPARATUS, filed Apr. 14, 1994; and, 5,879,374, DEFIBRILLATOR WITH SELF-TEST FEATURES, filed May 10, 1994.

FIG. **9** is a perspective view of a portable AED **80**, which incorporates the circuit **30** of FIG. **8** according to an embodiment of the invention. For clarity, common elements in FIGS. **8** and **9** are referenced with like numerals.

During an emergency where it is determined that a patient (not shown in FIG. **9**) may need a shock, an operator (hands shown in FIG. **9**) retrieves the AED **80** and installs the battery **44** if it is not already installed. Next, the operator removes the pads **32***a* and **32***b* from a protective package (not shown in FIG. **9**) and inserts a pad connector **82** into the connector **32**. Then, the operator turns the on/off switch **48**, which is a key switch in this embodiment, to the "on" position to activate the AED **80**. Following the instructions displayed on the display **54** or "spoken" via the speaker **56**, the operator places the pads **32***a* and **32***b* on the patient in the respective positions shown in the pictures on the pads and on the AED **80**. After the operator places the pads **32***a* and **32***b* on the patient, the processor unit **40** (FIG. **8**) analyzes the patient's ECG to determine whether the patient is suffering from a shockable heart condition. If the processor unit **40** determines that the patient is suffering from a shockable heart condition, then the display **54** or the speaker **56** instructs the operator to depress the shock button **42** to deliver a shock to the patient. Conversely, if the processor unit **40** determines that the patient is not suffering from a shockable heart condition, the display **54** or the speaker **56** informs the operator to seek appropriate non-shock treatment for the patient. Furthermore, the processor unit **40** disables the shock-delivery circuit **36** such that even if the operator presses the shock button **42**, the circuit AED **80** does not shock the patient.

As discussed above in conjunction with FIG. **8**, the microphone **58** may record the voice of the operator and of other rescuers and, the data card **60** may store these voices and the patient's ECG for later study. Such study may be for the purposes of instructing others in rescue techniques, for evaluating the performances of the operator or other rescuers, or for improving the AED **80**.

From the foregoing it will be appreciated that, although specific embodiments of the invention have been described herein for purposes of illustration, various modifications may be made without deviating from the spirit and scope of the invention.

What is claimed:

1. An external defibrillator which analyzes an ECG signal for an indication of ventricular fibrillation (VF), comprising:

a sensor operable to sense an ECG segment; and

a processor unit coupled to the sensor and operable to analyze a plurality of ECG sections of the ECG segment for an indication of VF, each ECG section comprising digital samples of a continuous ECG heart waveform sensed during a window of time, wherein a window of one ECG waveform overlaps a portion of the window of at least one other ECG waveform and the processor is operable to analyze said window of the ECG waveform and said overlapping window of said ECG waveform to determine the indication of said VF; and

a shock delivery circuit responsive to the indication of VF to deliver a shock.

2. The external defibrillator of claim **1**, further comprising a memory coupled to the sensor and to the processor and operable to store the overlapping portions of the ECG sections.

3. The external defibrillator of claim **1** wherein the processor is operable to determine a shockable heart condition from the analysis of the ECG heart waveform of a plurality of overlapping ECG sections.

4. The external defibrillator of claim **1** wherein the processor is operable to determine from the analysis of the ECG heart waveform of a plurality of overlapping ECG sections that a patient is not suffering from a shockable heart condition.

5. The external defibrillator of claim **1**, wherein a plurality of the ECG sections overlap the windows of two other ECG sections.

6. A method for using an external defibrillator to analyze an ECG segment for an indication of ventricular fibrillation (VF), comprising:

sensing sections of digital samples of a continuous ECG heart waveform during a time interval, each of the sections comprising the ECG heart waveform of a period of time which overlaps the time period of another of the sections;

analyzing the ECG heart waveform sensed during each of the sections to generate respective analysis results; and

determining whether to deliver a shock to treat the VF based on the analysis results.

7. The method of claim **6** wherein the determining comprises determining from the analysis results whether shockable VF is or is not indicated.

8. The method of claim **7** wherein when the determining indicates shockable VF, enabling the external defibrillator to deliver a shock.

9. The method of claim **6**, wherein a plurality of the sections each overlap the time periods of a previous section and a subsequent section.

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