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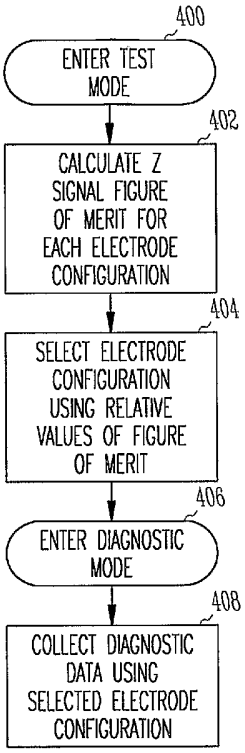

(57) Abstract: A cardiac function management device or other implantable medical device includes a test mode and a diagnostic mode. During a test mode, the device cycles through various electrode configurations for collecting thoracic impedance data. At least one figure of merit is calculated from the impedance data for each such electrode configuration. In one example, only non-arrhythmic beats are used for computing the figure of merit. A particular electrode configuration is automatically selected using the figure of merit. During a diagnostic mode, the device collects impedance data using the selected electrode configuration. In one example, the figure of merit includes a ratio of a cardiac stroke amplitude and a respiration amplitude. Other examples of the figure of merit are also described.

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THORACIC OR INTRACARDIAC IMPEDANCE SELECTING VECTOR AUTOMATICALLY

CLAIM OF PRIORITY

Benefit of priority is hereby claimed to U.S. Patent Application Serial Number 11/110,418, filed on April 20, 2005, which application is herein incorporated by reference.

TECHNICAL FIELD

This document pertains generally to implantable medical devices and more particularly, but not by way of limitation, to thoracic or intracardiac impedance detection with automatic vector selection.

BACKGROUND

Implantable medical devices include, among other things, cardiac function management (CFM) devices such as pacers, cardioverters, defibrillators, cardiac resynchronization therapy (CRT) devices, as well as combination devices that provide more than one of these therapy modalities to a subject. Such devices often include one or more diagnostic capabilities. Moreover, such diagnostic capabilities may be used as a basis for automatically providing therapy to the subject or for communicating diagnostic information to a physician or to the subject.

One example of a diagnostic capability is sensing intrinsic electrical heart signals. These intrinsic heart signals include depolarizations that propagate through heart tissue. The depolarizations cause heart contractions for pumping blood through the circulatory system. The intrinsic heart signals are typically sensed by an implantable medical device at implanted electrodes. The implantable medical device typically includes sense amplifier circuits and other signal processing circuits to extract useful diagnostic information from the intrinsic heart signals.

A different example of a diagnostic capability is sensing an interelectrode impedance, that is, detecting an impedance between electrodes. Such electrodes typically include, among other things, electrodes that are implanted in a subject's

thorax. Electrodes that are implanted in a subject's thorax may include, among other things, "intracardiac" electrodes located within the subject's heart. Another example of thoracic electrodes includes intravascular electrodes located in the subject's vasculature. A further example of thoracic electrodes includes epicardial electrodes that are located on an outer surface of the subject's heart. Yet another example of thoracic electrodes includes housing electrodes that are located on a typically hermetically sealed "can" of a pectorally or abdominally implanted CRM device electronics unit, or on an insulating "header" of such an electronics unit.

A tissue impedance between electrodes is typically obtained by introducing a test current into the tissue and sensing a responsive voltage between two electrodes (or vice-versa). The electrodes used for introducing a test current or test voltage need not be the same electrodes as those used for respectively measuring the responsive voltage or responsive current.

An impedance signal obtained between two intracardiac electrodes will be affected and modulated by, among other things, the subject's heart contractions and the subject's breathing. These two impedance-derived signals are sometimes referred to as the cardiac stroke signal and the respiration signal, respectively. Each provides useful diagnostic information. For example, the cardiac stroke signal may be used as an input variable to responsively adjust a pacing rate or another parameter of a "stroke volume" or other cardiac pacing therapy algorithm. Similarly, the respiration signal (e.g., amplitude, frequency, etc.) may be used as an input variable to responsively adjust a pacing rate or another parameter of a "minute ventilation" or other cardiac pacing therapy algorithm. In sum, the impedance-derived cardiac stroke and respiration signals can provide useful diagnostic information for a cardiac rhythm management device.

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings, which are not necessarily drawn to scale, like numerals describe substantially similar components throughout the several views. Like numerals having different letter suffixes represent different instances of substantially similar components. The drawings illustrate generally, by way of

example, but not by way of limitation, various embodiments discussed in the present document.

FIG. **1** illustrates one example of thoracic impedance data obtained using an atrial lead electrode.

FIG. **2** illustrates one example of thoracic impedance data obtained using a ventricular lead electrode.

FIG. **3** is a block diagram illustrating generally one example of a system and environment for measuring an intracardiac or transthoracic impedance in a diagnostic mode, and including a test mode for determining which electrode configuration to automatically select for use for collecting the impedance data in the diagnostic mode.

FIG. **4** is a flow chart of one example of a method of using the system of FIG. **3** or a similar system.

FIG. **5** is a block diagram of one illustrative example of more detail of portions of an impedance circuit.

FIG. **6** is a flow chart of another example of a process that is similar to that of FIG. **4**.

FIG. **7** is a flow chart of another example of a process that is similar to that of FIG. **4**.

FIG. **8** is an example of a system that includes an implantable electronics unit, and leads extending into the right atrium, right ventricle, and coronary sinus, respectively.

FIG. **9** illustrates an example of an impedance measurement and signal processing circuit that can be substituted for the impedance measurement and signal processing circuit of FIG. **5**.

FIG. **10** is a block diagram of an example in which the IMD **302** includes an arrhythmia detector **1000** that is coupled to the impedance measurement and signal processing circuit **319** or the controller **318** to control operation such that stroke and respiration amplitudes are only obtained from heartbeats characteristic of normal sinus rhythm (NSR).

DETAILED DESCRIPTION

The following detailed description includes references to the accompanying drawings, which form a part of the detailed description. The drawings show, by way of illustration, specific embodiments in which the invention may be practiced. These embodiments, which are also referred to herein as "examples," are described in enough detail to enable those skilled in the art to practice the invention. The embodiments may be combined, other embodiments may be utilized, or structural, logical and electrical changes may be made without departing from the scope of the present invention. The following detailed description is, therefore, not to be taken in a limiting sense, and the scope of the present invention is defined by the appended claims.

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Overview of Research Study

A rate responsive pacer may use an impedance sensor to measure trans-thoracic impedance. In one example, such thoracic impedance is measured between an intracardiac electrode on the pacer lead ("lead electrode") and another electrode on a pectorally-located pacer "can" housing electronics and a power source. This measured thoracic impedance includes, among other things, both a respiratory component and cardiac contraction volume ("cardiac stroke") component. At least some of the present inventors participated in conducting a research study that compared the thoracic impedance signal between different lead electrode locations (ventricular vs. atrial), and pacer can implant sites (left pectoral implant vs. right pectoral implant).

In this research study, thoracic impedance sensor signals were recorded

from 30 patients with PULSAR MAX I/II or INSIGNIA+ pacer devices from Guidant Corp. These patients were divided into four groups. The first group (designated the "AR" group) had thoracic impedance measured between (1) a lead electrode associated with a right atrium and (2) a right pectoral can electrode. The second group (designated the "AL" group) had thoracic impedance measured between (1) a lead electrode associated with a right atrium and (2) a left pectoral can electrode. The third group (designated the "VR" group) had thoracic impedance measured between (1) a lead electrode associated with a right ventricle and (2) a right pectoral can electrode. The fourth group (designated the "VL" group) had thoracic impedance measured between (1) a lead electrode associated with a right ventricle and (2) a left pectoral can electrode.

For each of these four groups of patients, the thoracic impedance signal was analyzed during a 30 second window of regular respiration while the patient was supine. The peak-to-peak respiration and cardiac contraction volume ("stroke") components of the thoracic impedance signal were extracted and averaged. The respiration/stroke amplitude ratio values were compared between the four groups of patients. Statistical significance was determined with an unpaired two-tailed t-test. The results are presented below as a mean ± standard deviation.

Atrial lead electrode thoracic impedance signals (from the AR and AL groups) typically exhibited a larger respiration/stroke amplitude ratio than ventricular-electrode thoracic impedance signals (from the VR and VL groups). The respiration/stroke amplitude ratio among AR patients (n=10) was 1.68 ± 0.93, among AL patients (n=2) was 0.80 ± 0.23, among VR patients (n=3) was 0.71 ± 0.69, and among VL patients (n=15) was 0.74 ± .35.

The respiration/stroke amplitude ratio for atrial lead electrode thoracic impedance signals, regardless of whether the can is implanted near the right or left pectoral region, was 1.53 ± 0.91. By contrast, the respiration/stroke amplitude for ventricular lead electrode thoracic impedance signals, regardless of whether the can is implanted near the right or left pectoral region, was 0.74 ± 0.39. This difference was deemed highly significant ($p < 0.005$). The respiration component of thoracic impedance was found to be larger in the AR

patients than all of the other tested electrode configurations. These other electrode configurations were found to be dominated by the cardiac stroke signal instead of the respiration signal.

In general, the different respiration and stroke amplitudes of the thoracic impedance signal depends on lead electrode location (atrium versus ventricle) and pocket location where the can electrode is located (left versus right pectoral region). For example, FIG. **1** illustrates one example of thoracic impedance data obtained from a first patient using an atrial lead electrode. FIG. **2** illustrates one example of thoracic impedance data obtained from a second patient using a ventricular lead electrode. Comparing FIG. **1** to FIG. **2**, it is seen that the atrial lead electrode of FIG. **1** yielded a stronger respiration component of thoracic impedance.

Therefore, different electrode positions exhibit different combinations of cardiac stroke information and respiration information. This observation can be used to select the electrode configuration that has the best signal-to-noise ratio (SNR) for the information component (e.g. cardiac stroke or respiration) that is desired.

Examples of Systems and Methods

FIG. **3** is a block diagram illustrating generally one example of a system **300** and environment for measuring an intracardiac or transthoracic impedance in a diagnostic mode, and including a test mode for determining which electrode configuration to automatically select for use in subsequently collecting the impedance data in the diagnostic mode. In this example, the system **300** includes a cardiac function management (CFM) or other implantable medical device (IMD) **302**, electrodes **304** to collect impedance data, and an external device **306** to communicate with the IMD **302**.

In the example of FIG. **3**, the electrodes **304** include a distal tip electrode **304A** and slightly more proximal ring electrode **304B**, each located on a portion of a right ventricular intravascular lead **308**. This example also includes a distal tip electrode **304C** and a slightly more proximal ring electrode **304D**, each located on a portion of a right atrial intravascular lead **310**. This example further includes a "can" or "housing" electrode **304E** located on an external housing **312** of an electronics unit portion of the IMD **302**. A "header" electrode **304F** is

located on an insulating header **314** of the electronics unit portion of the IMD **302**, wherein the header **314** typically extends outward from the housing **312**. As explained below, the system **300** need not include or use all of these electrodes **304**. The system **300** may also include additional or different electrodes such as, for example, defibrillation electrodes. Moreover, the illustrated electrodes may additionally be used for other purposes, such as for sensing intrinsic electric heart signals or for providing pacing therapy. FIG. **3** merely provides one illustrative example of electrodes for making impedance measurements.

FIG. **3** also illustrates one example of a block diagram of certain components included within the housing **312** of the IMD **302**. In this example, such components include an electrode connection switching circuit **316**. The electrode connection switching circuit **316** makes appropriate electrical connections to various combinations of the electrodes **304**, such as in response to one or more selection control signals received from a controller circuit **318**. These electrical connections to the desired electrodes **304** are routed to an impedance measurement and signal processing circuit ("impedance circuit") **319**. Examples of some electrode configurations and suitable circuits for performing thoracic impedance measurements and further signal processing are described in Hartley et al. U.S. Patent No. 6,076,015 entitled RATE ADAPTIVE CARDIAC RHYTHM MANAGEMENT DEVICE USING TRANSTHORACIC IMPEDANCE and Hauck et al. U.S. Patent No. 5,318,597 entitled RATE ADAPTIVE CARDIAC RHYTHM MANAGEMENT DEVICE CONTROL ALGORITHM USING TRANS-THORACIC VENTILATION, each of which are assigned to Cardiac Pacemakers, Inc., and each of which is incorporated herein by reference in its entirety, including their description of electrode configurations, impedance measurements, and further signal processing of impedance signals. The impedance circuit **319** provides resulting impedance information to the controller **318** for further processing.

The controller **318** is typically a microprocessor or any other circuit that is capable of sequencing through various control states such as, for example, by using a digital microprocessor having executable instructions stored in an associated instruction memory circuit, a microsequencer, or a state machine. In

one example, the controller **318** includes a digital signal processor (DSP) circuit. The digital signal processor circuit may performs digital filtering or other signal processing of the impedance signal, either instead of, or in addition to such processing being performed in the impedance circuit **319**. The digital signal processor circuit, therefore, may implement one or more filter circuits, and such filter circuits may be implemented as a sequence of executable instructions, rather than by dedicated filtering hardware.

The controller **318** typically includes a diagnostic mode in which the received impedance information is used as diagnostic information. In one example, the impedance-based diagnostic information is wirelessly or otherwise communicated, via a communication circuit **320**, from the IMD **302** to an external device **306**, such as for use by a remote or local physician or other caregiver. In another example, the impedance-based diagnostic information is used by pacing or other therapy algorithm, such as to establish an appropriate pacing rate, atrioventricular (AV) or other interelectrode delay, or other adjustable therapy parameter.

In one example, the controller **318** also includes a test mode. The test mode activates algorithmic or other test logic **322** that cycles through various electrode configurations. Such cycling allows the impedance circuit **319** to obtain an impedance signal from each such electrode configuration. The resulting test mode impedance data, corresponding to each of the tested electrode configurations, is stored in a test results data storage circuit **324**, such as in a memory circuit portion of the controller **318** or elsewhere. The controller **318** typically includes a results processing algorithm **326** to select a particular electrode configuration by analyzing the impedance data resulting from the various tested electrode configurations. Information defining the particular selected electrode configuration is stored in a memory location **328**. In one example, after the test mode data is collected and the particular electrode configuration is selected, the device **302** exits the test mode and enters a diagnostic mode. The electrode configuration that was selected during the test mode is used in the diagnostic mode to obtain impedance data for diagnostic purposes. In one example, the test mode is initiated by the external device **306**, for example, either automatically or under manual control of a physician or other

caregiver. In another example, the test mode is internally initiated automatically by the IMD **302**, such as by being occasionally or periodically triggered by an interrupt provided by a clock circuit **330** of the controller **318** or elsewhere within the IMD **302**. In yet another example, the test mode is internally initiated automatically by the IMD **302**, such as by being automatically triggered by a change in posture or heart rate respectively detected by a posture detector or heart rate detector included within the IMD **302** and coupled to an input of the test logic **322**.

The illustrative example of FIG. **3** includes multiple electrode configurations from which impedance data can be obtained. For example, a first electrode configuration includes delivering a test current from the right atrial tip electrode **304C** to the housing electrode **304E** and determining an impedance by measuring a resulting voltage between the right atrial ring electrode **304D** and the header electrode **304F**. A second electrode configuration includes delivering the test current from the right ventricular tip electrode **304A** to the housing electrode **304E** and determining an impedance by measuring a resulting voltage between the right ventricular ring electrode **304B** and the header electrode **304F**. These are merely illustrative examples of different electrode configurations for performing impedance measurements. Other examples exist. Moreover, such impedance measurements need not require the use of four different electrodes, as described above, but can also use two electrodes, three electrodes, or more than four electrodes. Furthermore, one or more of the electrodes may be electrically connected in common with one or more other electrodes for performing the impedance measurements.

FIG. **4** is a flow chart of one example of a method of using the system **300** of FIG. **3** or a similar system. In this example, at **400**, a test mode is entered, such as upon manual initiation by a physician or other caregiver using the external device **306**, or automatically, such as upon a scheduled interrupt received from the clock circuit **320** or otherwise. At **402**, an impedance signal figure of merit is calculated for each electrode configuration, for example, in a predefined list of available electrode configurations for measuring an impedance. This typically constitutes using each such available electrode configuration to measure an impedance signal, perform signal processing on the impedance

signal to extract a desired component of the impedance signal (e.g., the respiration modulation component, the cardiac stroke signal modulation component, the ultra low frequency edema/hypotension component, postural component, etc.), and measuring a desired characteristic (e.g., modulation amplitude), undesired characteristic (e.g., noise), or combination characteristic (e.g., signal-to-noise ratio). In this context, the noise can be from one or several sources, including myopotential noise, electromagnetic interference, or even from one or more of the undesired frequency components of the impedance signal. For example, if respiration is the desired component of the impedance signal, then, in one example, modulation of the impedance signal due to heart contractions (i.e., the cardiac stroke signal) is regarded as noise. Similarly, modulation of a thoracic impedance signal due to thoracic fluid shifts (e.g., edema, hypotension, postural changes, blood resistivity changes, etc.) are, in one example, regarded as noise when the desired component of the impedance signal is the respiration or cardiac stroke component. If the cardiac stroke signal is the desired component of the impedance signal, then, in one example, modulation of the impedance signal due to respiration is regarded as noise. In one example, the figure of merit is computed based upon a single measurement. In another example, the figure of merit is averaged from multiple measurements, or a central tendency of the figure of merit is otherwise computed and used as the figure of merit.

At **404**, relative values of the figure of merit are compared to each other to select the most suitable electrode configuration for subsequent diagnostic data collection. For example, if respiration is the desired data of interest from the impedance signal, then the electrode configuration having the largest respiration signal amplitude (or variability or dynamic range of the respiration signal amplitude), the smallest noise, or the largest signal-to-noise ratio is selected. In one example, more than one of these figures of merit are collected, optionally weighted, and combined to form a composite figure of merit; the relative values of the composite figure of merit (or a computed central tendency of the composite figure of merit) are compared to select the most appropriate electrode configuration. In one example, the selection process includes at least one technique for breaking a "tie" resulting from equivalent relative values of the

determinative figure(s) of merit. In one example, in which the available electrode configurations are listed in an ordered list, a tie between two or more electrode configurations yielding the same values of the determinative figure of merit is broken by selecting from among these tied candidate electrode configurations by selecting the electrode configuration that is closest to the beginning of the list.

After an electrode configuration is selected at **404**, then, at **406**, the test mode is exited and a diagnostic mode is entered. At **408**, diagnostic data is collected using the selected electrode configuration. As discussed above, such diagnostic data can be used as an input variable for adjusting a cardiac rhythm management or other therapy, or can simply be communicated from the IMD **302**, such as to a physician or other caregiver.

FIG. **5** is a block diagram of one illustrative example of more detail of portions of the impedance circuit **319**. In this example, the impedance circuit **319** includes an impedance measurement circuit **500**, which is coupled to various configurations of the electrodes **304** via the electrode connection switching circuit **316**. The impedance measurement circuit **500** typically includes an exciter circuit that provides a test current to the tissue between two electrodes in the heart or elsewhere in the thorax. The impedance measurement circuit **500** also typically includes preamplifier, demodulation, bandpass filter, and analog-to-digital converter circuits that are used to measures a responsive voltage between the same or different two electrodes to determine the impedance. Examples of such suitable subcircuits of the impedance measurement circuit **500** are described in Hartley et al. U.S. Patent No. 6,076,015 entitled RATE ADAPTIVE CARDIAC RHYTHM MANAGEMENT DEVICE USING TRANSTHORACIC IMPEDANCE, which is assigned to Cardiac Pacemakers, Inc., and which is incorporated herein by reference in its entirety, including its description of such subcircuits and their operation.

In the example of FIG. **5**, the impedance circuit **319** also includes a cardiac stroke filter circuit **502** and a respiration filter circuit **504** for respectively extracting a cardiac stroke component and a respiration component of the impedance signal. Such filter circuits can be implemented in dedicated analog or digital hardware, or as a sequence of instructions carried out on a general

purpose digital signal processing circuit or more generic processor of the controller **318**, such as described in the above-incorporated Hartley et al. U.S. Patent No. 6,076,015. Moreover, such filtering may use a heart rate dependent or other variable cutoff frequency filter, such as described in the above-incorporated Hartley et al. U.S. Patent No. 6,076,015. In this example, the impedance circuit **319** also includes a cardiac stroke amplitude measurement circuit **506** and a respiration amplitude measurement circuit **508** for respectively measuring amplitudes of the extracted cardiac stroke and respiration amplitude signals. In this illustrative example, these measured amplitudes are then fed to a comparative measurement circuit **510**. In one example, the comparative measurement circuit **510** calculates at least one indication of the relative values of the cardiac stroke and respiration amplitudes, such as a respiration/stroke amplitude ratio, a stroke/respiration amplitude ratio, a respiration – stroke amplitude difference, or a stroke – respiration amplitude difference. In one example, the calculated indication of the relative values of the cardiac stroke and respiration amplitudes is stored in the test results data storage **324**, and used as the electrode configuration figure of merit in the process described with respect to FIG. **4**. For example, if respiration is the desired diagnostic component of the impedance, and the comparative measurement is a respiration/stroke ratio, then the electrode configuration having the largest relative value of respiration/stroke ratio is selected during the test mode for subsequent data collection in the diagnostic mode.

FIG. **6** is a flow chart of another example of a process that is similar to that of FIG. **4**. In the example of FIG. **6**, at **400**, a test mode is entered and, at **402**, at least one impedance signal figure of merit is calculated for each electrode configuration, as discussed above. However, the process of FIG. **6** then includes a screening, at **600**, that compares at least one impedance signal figure of merit to a threshold value to select a subset of electrode configurations from which a particular electrode configuration is then selected, at **604**, using relative values of the same or different figure of merit. The screening at **600** may, for example, compare a respiration amplitude to a minimum threshold value, such that only those electrode configurations yielding a minimum respiration amplitude become part of the subset of electrode configurations from which the particular

electrode configuration is then selected at **604**. As another example, the screening at **600** may compare noise figure of the respiration component of the impedance signal to a threshold value, such that only those electrode configurations yielding a sufficiently noise-free respiration component of the impedance signal become part of the subset of electrode configurations from which the particular electrode configuration is then selected at **604**. The subset may be empty, in which case, the particular impedance-based diagnostic function is disabled, in one example. The subset may alternatively yield some or even all of the available electrode configurations. In the process illustrated in FIG. **6**, after the particular electrode configuration is selected at **604**, then the test mode is exited. The diagnostic mode is then entered, at **406**. Diagnostic data is then collected at **408** using the selected electrode configuration.

FIG. **7** is a flow chart of another example of a process that is similar to that of FIG. **4**. In the example of FIG. **7**, at **400**, a test mode is entered and, at **402**, at least one impedance signal figure of merit is calculated for each electrode configuration, as discussed above. However, the process of FIG. **7** then includes, at **700**, storing the figure(s) of merit in memory, together with any previously stored historical values of the figure(s) of merit. In one example, such storage of each particular figure of merit occurs in a buffer that, when full, drops the oldest historical value of that figure of merit from the buffer. For example, if the amplitude of the respiration component of the impedance signal is used as the figure of merit, then the buffer would include its most recent value and other previously acquired values over an appropriate period of time. At **702**, an electrode configuration is selected using the stored figure of merit data. As an illustrative example, suppose that respiration is of interest, and the dynamic range or variation of the respiration amplitude is of particular interest. Then in one example, a secondary figure of merit (e.g., variance, standard deviation, etc.) of the respiration amplitude is computed from the stored historical values of the primary figure of merit (respiration amplitude). Relative values of the secondary figure of merit are used at **702** to select the particular electrode configuration used for collecting diagnostic data. Then, at **406**, the test mode is exited and the diagnostic mode is entered. At **408**, diagnostic data is collected for a period of

time using the selected electrode configuration. Process flow then returns to **400** to re-enter the test mode to again collect and store the figure of merit data.

Examples of Particular Electrode Configurations

The above-described systems and methods can be used to select between any different present or future electrode configuration to obtain a desirable SNR for the information sought (e.g., cardiac stroke information or respiration information, exclusively).

As an illustrative example (but not by way of limitation), suppose the system **800** of FIG. **8** includes an implantable electronics unit **802**, leads **804A-C** (extending into the right atrium, right ventricle, and coronary sinus, respectively), and the available electrodes include: a header electrode such as **806**, a can electrode such as **808**, a right ventricular shock coil electrode **810**, a right atrial shock coil electrode **812**, a right atrial tip electrode **814**, a right atrial ring electrode **816**, a right ventricular tip electrode **818**, a right ventricular ring electrode **820**, a left ventricular distal electrode **822**, and a left ventricular proximal electrode **824**.

In this example, some of the possible voltage sensing or test excitation current vectors include, for pairs of electrodes: can electrode **808** to right ventricular shock coil electrode **810**, can electrode **808** to right atrial shock coil electrode **812**, can electrode **808** to right atrial tip electrode **814**, can electrode **808** to right atrial ring electrode **816**, can electrode **808** to right ventricular tip electrode **818**, can electrode **808** to right ventricular ring electrode **820**, can electrode **808** to left ventricular distal electrode **822**, can electrode **808** to left ventricular proximal electrode **824**, header electrode **806** to right ventricular shock coil electrode **810**, header electrode **806** to right atrial shock coil electrode **812**, header electrode **806** to right atrial tip electrode **814**, header electrode **806** to right atrial ring electrode **816**, header electrode **806** to right ventricular tip electrode **818**, header electrode **806** to right ventricular ring electrode **820**, header electrode **806** to left ventricular distal electrode **822**, header electrode **806** to left ventricular proximal electrode **824**, right ventricular shock coil electrode **810** to right atrial shock coil electrode **812**, right ventricular shock coil electrode **810** to right atrial tip electrode **814**, right ventricular shock coil electrode **810** to right atrial ring electrode **816**, right ventricular shock coil electrode **810** to right

ventricular tip electrode **818**, right ventricular shock coil electrode **810** to right ventricular ring electrode **820**, right ventricular shock coil electrode **810** to left ventricular distal electrode **822**, right ventricular shock coil electrode **810** to left ventricular proximal electrode **824**, right atrial shock coil electrode **812** to right atrial tip electrode **814**, right atrial shock coil electrode **812** to right atrial ring electrode **816**, right atrial shock coil electrode **812** to right ventricular tip electrode **818**, right atrial shock coil electrode **812** to right ventricular ring electrode **820**, right atrial shock coil electrode **812** to left ventricular distal electrode **822**, right atrial shock coil electrode **812** to left ventricular proximal electrode **824**, right atrial tip electrode **814** to right atrial ring electrode **816**, right atrial tip electrode **814** to right ventricular tip electrode **818**, right atrial tip electrode **814** to right ventricular ring electrode **820**, right atrial tip electrode **814** to left ventricular distal electrode **822**, right atrial tip electrode **814** to left ventricular proximal electrode **824**, right atrial ring electrode **816** to right ventricular tip electrode **818**, right atrial ring electrode **816** to right ventricular ring electrode **820**, right atrial ring electrode **816** to left ventricular distal electrode **822**, right atrial ring electrode **816** to left ventricular proximal electrode **824**, right ventricular tip electrode **818** to left ventricular distal electrode **822**, right ventricular tip electrode **818** to left ventricular proximal electrode **824**, right ventricular ring electrode **820** to left ventricular distal electrode **822**, right ventricular ring electrode **820** to left ventricular proximal electrode **824**, and left ventricular distal electrode **822** to left ventricular proximal electrode **824**. Other vectors may be formed, for example, by tying one or more other electrodes in common with one or the other of the electrodes of the pair. Moreover, as discussed above, the same electrodes may be used both to inject a test excitation current and to measure a responsive voltage (e.g., a two-point measurement). Alternatively, the test current introduction can share one electrode in common with the responsive voltage measurement, such as in a three-point measurement. In yet another alternative, the test current introduction can use different electrodes from the responsive voltage measurement, such as in a four-point measurement.

Additional or Other Impedance Components

Although the above description has been described with particular emphasis on impedance-derived cardiac stroke and respiration signals, the above techniques can be used to select electrodes with respect to other impedance signals of interest, such as a near-DC signal representative of a subject's thoracic fluid status, including such excess of thoracic fluid such as due to pulmonary edema or pleural effusion, or deficiency of thoracic fluid such as due to orthostatic or other hypotension. In this document, the near-DC component of the thoracic impedance signal refers to the frequencies below which respiration and cardiac contractions significantly influence the thoracic impedance signal (e.g., at least an order of magnitude lower than the respiration component). In one example, the near-DC component of the thoracic impedance signal refers to signal frequencies below a cutoff frequency having a value of about 0.05 Hz, such as at signal frequencies between about 5×10^{-7} Hz and 0.05 Hz, because the cardiac stroke and respiration components of the thoracic impedance signal lie at higher frequencies.

FIG. **9** illustrates an example of an impedance measurement and signal processing circuit **900** that can be substituted for the impedance measurement and signal processing circuit **319** of FIG. **5**. In the example of FIG. **9**, the impedance measurement and signal processing circuit **900** that includes a near-dc fluid status filter circuit **901** to measure thoracic fluid shifts, and a fluid status amplitude measurement circuit **902** to measure the amplitude of any such thoracic fluid shifts. In this example, the comparative measurement **904** is between at least one pair of the three input channels (e.g., cardiac stroke, respiration, and fluid status). Therefore, the impedance measurement and signal processing circuit **900** need only include two, but may include all three, of such channels.

In a further example, at least one integration, root-mean-square (RMS), or other signal aggregation circuit is included, such as between the cardiac stroke filter circuit **502** and the stroke amplitude measurement circuit **506** of FIG. **5** or FIG. **9** and between the respiration filter circuit **504** and the respiration amplitude measurement circuit **508** in FIG. **5** or FIG. **9**. This permits the stroke or respiration amplitude measurement to be performed on the stroke or

respiration signal after it has been processed to represent an aggregate signal value (e.g., over a period of time) rather than a single point amplitude measurement. This aggregation can be carried out over a single cardiac cycle (e.g., for an RMS stroke signal), a single respiration cycle (e.g., for an RMS respiration cycle), or over multiple such cardiac or respiration cycles, respectively. This aggregation represents an alternative technique for obtaining a central tendency of the stroke or respiration signal, instead of averaging, taking a median, or otherwise computing a central tendency of stroke or respiration amplitude measurements obtained at a single point in time.

FIG. **10** is a block diagram of an example in which the IMD **302** includes an arrhythmia detector **1000** that is coupled to the impedance measurement and signal processing circuit **319** or the controller **318** to control operation such that stroke and respiration amplitudes are only obtained from heartbeats characteristic of normal sinus rhythm (NSR). In this example, arrhythmic heartbeats (e.g., premature ventricular contractions (PVCs), etc.) are excluded as a basis for calculating the ratios, differences, or other figures of merit discussed above. Excluding arrhythmic heartbeats may involve, among other things, inhibiting the impedance measurement circuit **500** during such beats or, more typically, discarding any stroke or respiration amplitudes, etc., measured during such PVCs or other beats deemed arrhythmic.

There are a number of ways in which NSR can be distinguished from arrhythmic heartbeats. For example, timer methods deem ventricular contractions that are detected before expected using the underlying NSR as being PVCs. In one example, a counter is incremented each time a PVC is detected, and any impedance measurements corresponding to such counter increments are invalidated. In another example morphology methods use the shape of the depolarization artifact to discriminate between NSR and arrhythmic beats. Examples of morphology-based techniques for such discrimination are described in Hsu U.S. Patent No. 6,449,503, Hsu et al. U.S. Patent No. 6,308,095, Hsu et al. U.S. Patent No. 6,266,554, and Hsu et al. U.S. Patent No. 6,438,410, each of which is incorporated by reference herein in its entirety, including its description of techniques for discriminating between NSR and arrhythmias. In one example, the impedance-based respiration or stroke measurements described above are

invalidated for any beats deemed arrhythmic using such a morphological or other discrimination technique.

Conclusion

It is to be understood that the above description is intended to be illustrative, and not restrictive. For example, the above-described embodiments (and/or aspects thereof) may be used in combination with each other. Many other embodiments will be apparent to those of skill in the art upon reviewing the above description. The scope of the invention should, therefore, be determined with reference to the appended claims. In the appended claims, the terms "including" and "in which" are used as the plain-English equivalents of the respective terms "comprising" and "wherein." Also, in the following claims, the terms "including" and "comprising" are open-ended, that is, a system, device, article, or process that includes elements in addition to those listed after such a term in a claim are still deemed to fall within the scope of that claim. Moreover, in this document and in the following claims, the terms "first," "second," and "third," etc. are used merely as labels, and are not intended to impose numerical requirements on their objects.

WHAT IS CLAIMED IS:

1. A system comprising:

an implantable medical device (IMD), the IMD comprising:

an impedance detector circuit, including inputs configured to receive impedance signals from different electrode configurations in a subject's thorax; and

a processor circuit, including instructions executable or otherwise interpretable to a compute at least one figure of merit from each of the different electrode configurations, and using values of the figure of merit from the different electrode configurations for automatically selecting a particular electrode configuration for use in subsequently obtaining impedance data.

2. The system of claim **1,** in which the IMD comprises:

a cardiac stroke signal filter circuit, coupled to the impedance detector circuit to receive the impedance signals and extract therefrom corresponding cardiac stroke signals;

a respiration signal filter circuit, coupled to the impedance detector circuit to receive the impedance signals and to extract therefrom corresponding respiration signals;

a cardiac stroke amplitude measurement circuit, coupled to the cardiac stroke signal filter circuit to receive the cardiac stroke signals and to extract therefrom corresponding cardiac stroke amplitudes;

a respiration amplitude measurement circuit, coupled to the respiration signal filter circuit to receive the respiration signals and to extract therefrom corresponding respiration amplitudes; and

in which the processor circuit, includes instructions executable or otherwise interpretable to compute a comparative measurement between each cardiac stroke amplitude and each corresponding respiration amplitude

from the same electrode configuration and, based on relative values of the comparative measurement associated with each electrode configuration, to select a particular electrode configuration for use in obtaining at least one of a selected cardiac stroke signal and a selected respiration signal.

3. The system of claim **2**, in which the comparative measurement is a ratio between the cardiac stroke amplitude and the respiration amplitude associated with the same electrode configuration as the cardiac stroke amplitude.

4. The system of claim **3**, in which at least one of the selected cardiac stroke signal and the selected respiration signal is a cardiac stroke signal, and the ratio is the cardiac stroke amplitude divided by the respiration amplitude, and the processor circuit operates to select the particular electrode configuration that is associated with the largest value of the corresponding ratio relative to the value of ratios corresponding to another at least one electrode configuration.

5. The system of claim **3**, in which at least one of the selected cardiac stroke signal and the selected respiration signal is a respiration signal, and the ratio is the respiration amplitude divided by the cardiac stroke amplitude, and the processor circuit operates to select the particular electrode configuration that is associated with the largest value of the corresponding ratio relative to the value of another one or more ratios corresponding to another one or more electrode configurations.

6. The system of claim **3**, in which the processor is configured to compare a value of at least one ratio associated with an electrode configuration to a predefined threshold value, and to disable the obtaining at least one of a selected cardiac stroke signal and a selected respiration signal if the value of at least one ratio does not exceed the threshold value.

7. The system of claim 1, in which the processor includes:

a test mode for performing the acts of measuring the first and second impedance signals, calculating the first and second figures of merit, and automatically selecting one of the first and second electrode configurations; and

a diagnostic mode to extract diagnostic impedance data using the selected one of the first and second electrode configurations.

8. The system of claim 7, further including a clock circuit to schedule repeated execution of the test mode.

9. The system of claim 1, in which the first and second figures of merit comprise an amplitude measurement of a respiration component of the first and second impedance signals, respectively.

10. The system of claim 9, in which the first and second figures of merit comprise an amplitude measurement of a cardiac stroke component of the first and second impedance signals, respectively.

11. The system of claim 1, in which the first and second figures of merit comprise a noise measurement of a respiration component of the first and second impedance signals, respectively.

12. The system of claim 11, in which the noise measurement of the respiration component of the respective first and second impedance signals comprises a cardiac stroke component of the respective first and second impedance signals.

13. The system of claim 1, in which the first and second figures of merit comprise a noise measurement of a cardiac stroke component of the first and second impedance signals, respectively.

14. The system of claim **13**, in which the noise measurement of the cardiac stroke component of the respective first and second impedance signals comprises a respiration component of the respective first and second impedance signals.

15. A method comprising:

measuring a first impedance signal between at least first and second electrodes, which define a first electrode configuration, in a subject's thorax;

calculating a first figure of merit using the first impedance signal;

measuring a second impedance signal between at least third and fourth electrodes, which define a second electrode configuration, in a subject's thorax, wherein at least one of the third and fourth electrodes is a different electrode from at least one of the first and second electrodes;

calculating a second figure of merit using the second impedance signal; and

using values of the first and second figures of merit as a basis for automatically selecting one of the first and second electrode configurations for subsequent diagnostic extraction of one of the first and second impedance signals.

16. The method of claim **15,** comprising:

extracting a first cardiac stroke signal from the first impedance signal;

extracting a first respiration signal from the first impedance signal;

extracting a first cardiac amplitude measurement from the first cardiac stroke signal;

extracting a first respiration amplitude measurement from the first cardiac stroke signal;

computing a first comparative measurement between the first cardiac amplitude measurement and the first respiration amplitude measurement;

extracting a second cardiac stroke signal from the second impedance signal;

extracting a second respiration signal from the second impedance signal;

extracting a second cardiac amplitude measurement from the second cardiac stroke signal;

extracting a second respiration amplitude measurement from the second cardiac stroke signal;

computing a second comparative measurement between the second cardiac amplitude measurement and the second respiration amplitude measurement; and

using the first and second comparative measurements as a basis for selecting one of the first and second electrode configurations for subsequent extraction of at least one of the respiration and cardiac stroke signals.

17. The method of claim **16**, in which:

the computing the first comparative measurement includes computing a ratio between the first cardiac amplitude measurement and the first respiration amplitude measurement; and

the computing the second comparative measurement includes computing a ratio between the second cardiac amplitude measurement and the second respiration amplitude measurement.

18. The method of claim **16**, in which the using the first and second comparative measurements as a basis for selecting one of the first and second electrode configurations includes selecting the first electrode configuration if first comparative measurement exceeds the second comparative measurement.

19. The method of claim **18**, in which the respiration signal is of interest and in which the first comparative measurement is one of: (1) a ratio of the first respiration signal to the first cardiac signal; and (2) a difference of the first respiration signal less the first cardiac signal; and in which the second comparative measurement is a comparable one of: (1) a ratio of the second respiration signal to the second cardiac signal; and (2) a difference of the second respiration signal less the second cardiac signal.

20. The method of claim **16**, further comprising:

comparing the first and second comparative measurements to a threshold value; and

if the first and second comparative measurements are both less than the threshold value, then disabling the subsequent extraction of at least one of the respiration and cardiac stroke signals.

21. The method of claim **16**, in which at least one of:

the extracting the first cardiac amplitude measurement includes determining a central tendency of the first cardiac amplitude measurement over a plurality of cardiac cycles;

the extracting the second cardiac amplitude measurement includes determining a central tendency of the second cardiac amplitude measurement over a plurality of cardiac cycles;

the extracting the first respiration amplitude measurement includes determining a central tendency of the first respiration amplitude measurement over a plurality of respiration cycles; and

the extracting the second respiration amplitude measurement includes determining a central tendency of the second respiration amplitude measurement over a plurality of respiration cycles.

22. The method of claim **16**, including excluding the first cardiac amplitude measurement from consideration if a corresponding heartbeat is deemed arrhythmic.

23. The method of claim **16**, in which:

the first and third electrodes are configured as a common electrode that is located on a housing of a pectorally-implanted implantable medical device, and the second electrode is located in association with an atrium of the subject, and the fourth electrode is located in association with a ventricle of the subject.

24. The method of claim **16**, comprising:

computing ratios between amplitudes of each cardiac stroke signal and the corresponding respiration signal; and

selecting a particular one of the electrode configurations for subsequently measuring an impedance signal to obtain at least one of an respiration signal and a cardiac stroke signal impedance-derived respiration, the selecting the particular one of the electrode configurations determined using values of the ratios relative to at least one of each other and a predefined threshold value.

25. The method of claim **24**, in which the selecting the particular one of the electrode configurations includes choosing the particular one of the electrode configurations that corresponds to a largest respiration/stroke amplitude ratio among the computed ratios, and further comprising using the selected particular one of the electrode configurations for subsequently obtaining a respiration signal.

26. The method of claim **24**, in which the selecting the particular one of the electrode configurations includes choosing the particular one of the electrode configurations that corresponds to a largest stroke/respiration amplitude ratio among the computed ratios, and further comprising using the selected particular one of the electrode configurations for subsequently obtaining a cardiac stroke signal.

27. The method of claim **15**, further comprising:

placing an implantable medical device in a test mode for performing the acts of measuring the first and second impedance signals, calculating the first and second figures of merit, and automatically selecting one of the first and second electrode configurations;

exiting the test mode and placing an implantable medical device in a diagnostic mode; and

extracting diagnostic impedance data, in the diagnostic mode, using the selected one of the first and second electrode configurations.

28. The method of claim **27**, further comprising repeatedly placing the implantable medical device in a test mode for performing the acts of measuring the first and second impedance signals, calculating the first and second figures of merit, and automatically selecting one of the first and second electrode configurations.

29. The method of claim **27**, further comprising triggering the test mode upon detecting at least one of a change in heart rate and a change in posture.

30. The method of claim **15**, in which the first and second figures of merit comprise an amplitude measurement of a near-DC fluid status component of the first and second impedance signals, respectively.

31. The method of claim **15**, in which the first and second figures of merit comprise a noise measurement of a respiration component of the first and second impedance signals, respectively.

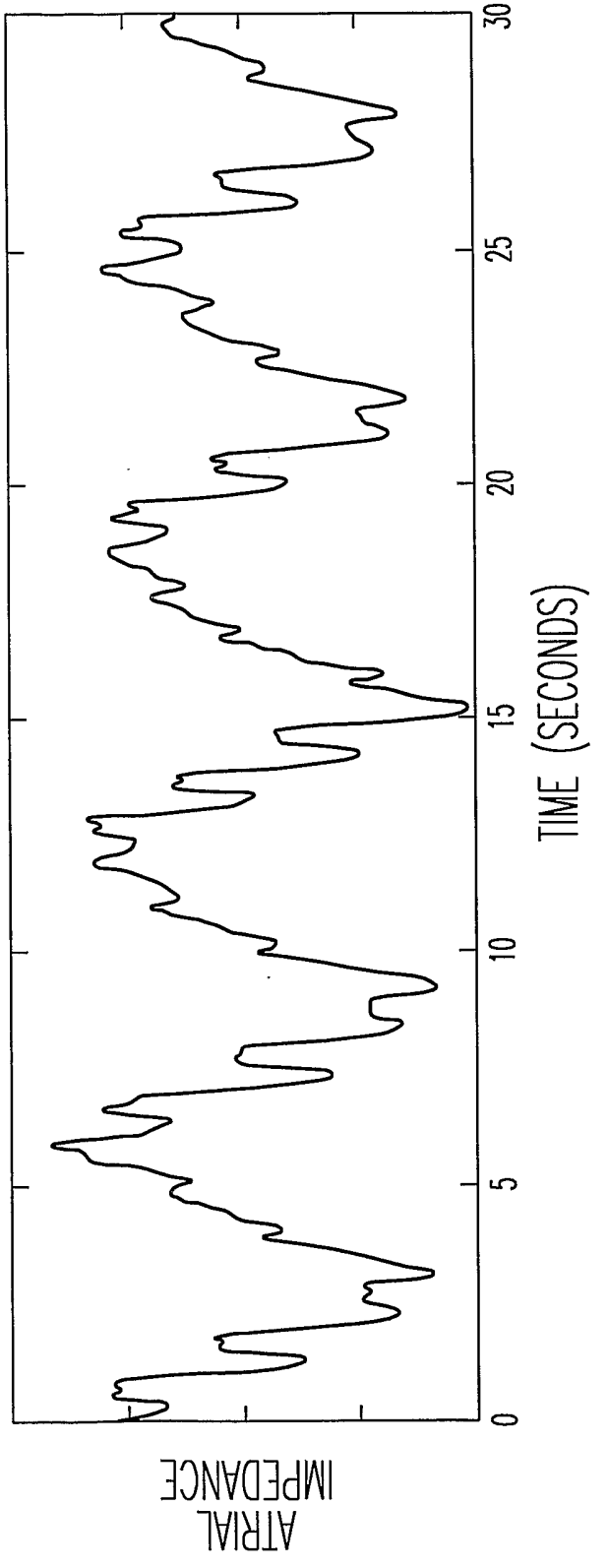

ATRIAL
IMPEDANCE
0
5
10
15
20
25
30
TIME (SECONDS)

Fig. 1

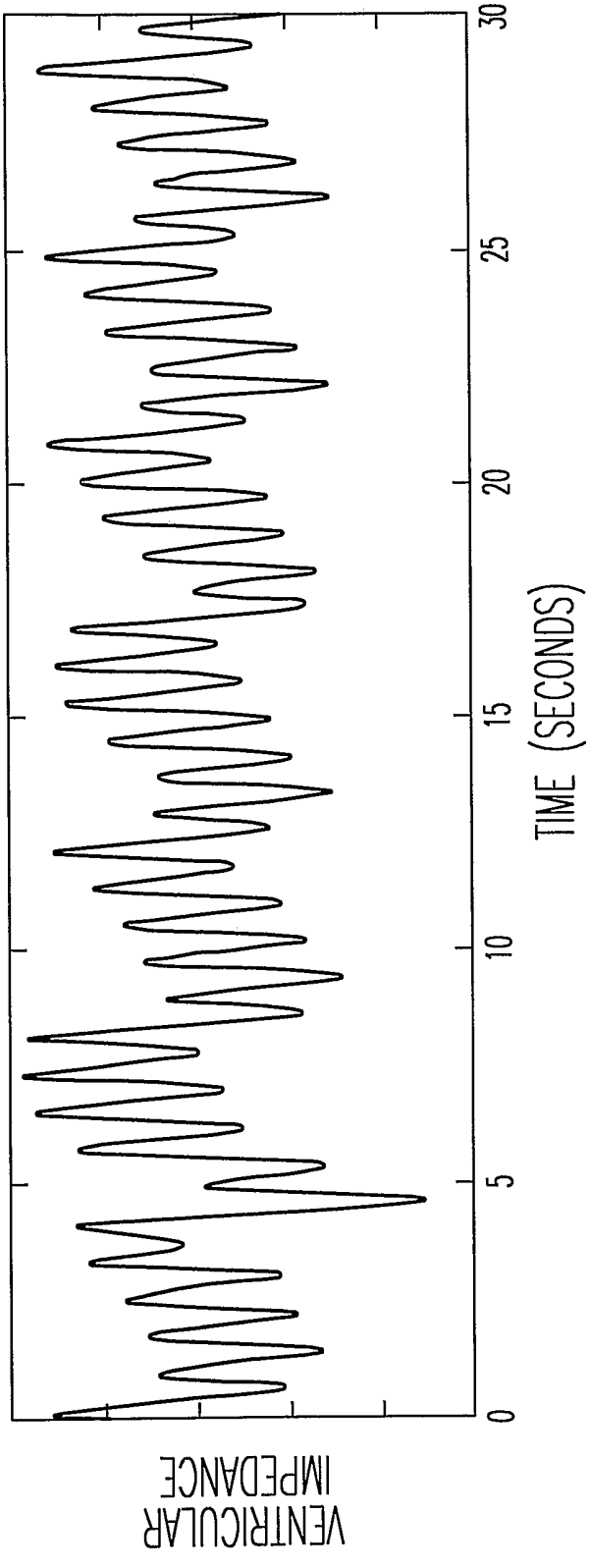

VENTRICULAR
IMPEDANCE
0
5
10
15
20
25
30
TIME (SECONDS)

Fig. 2

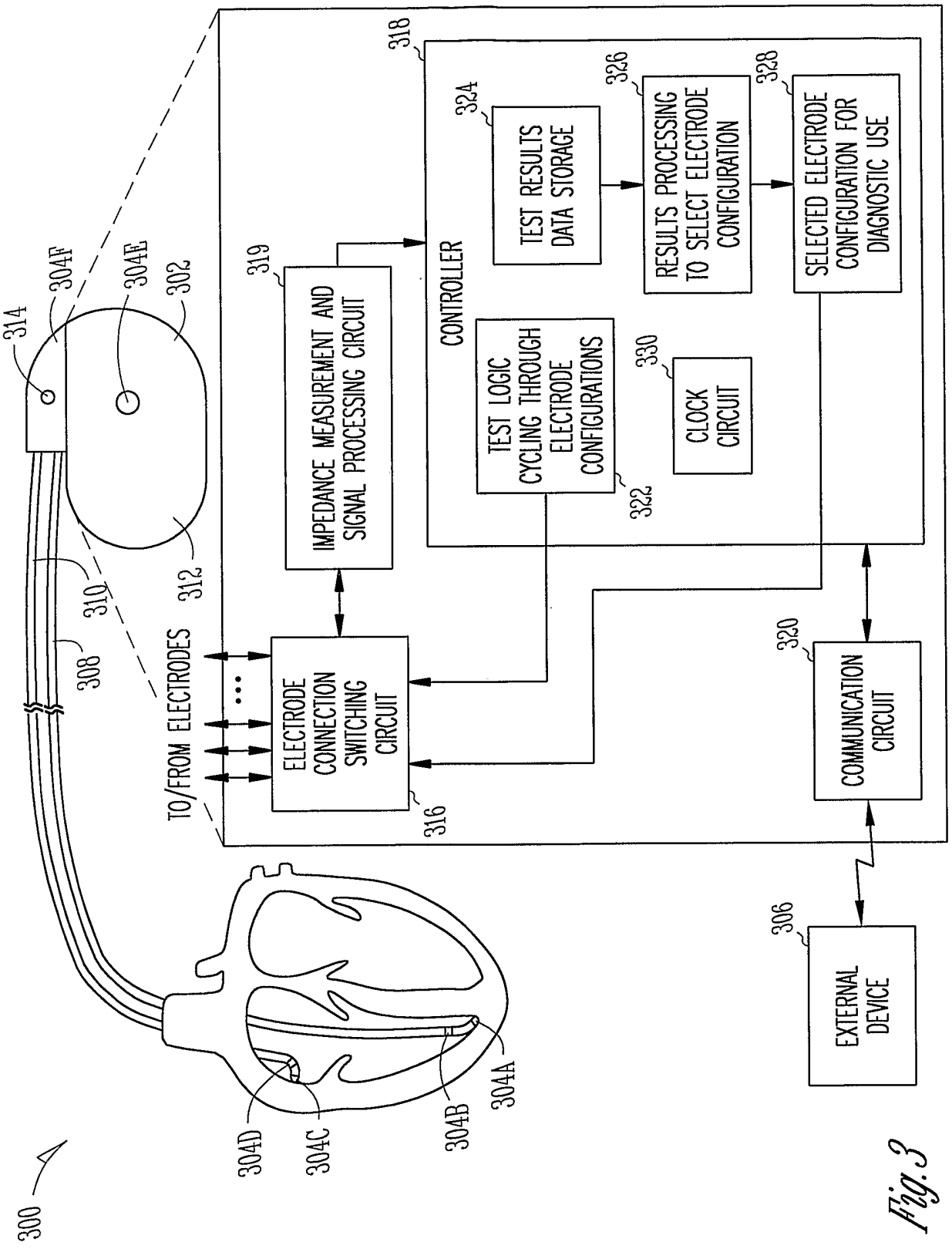

300
304D
304C
304B
304A
314
304F
304E
302
310
312
308
TO/FROM ELECTRODES
ELECTRODE CONNECTION SWITCHING CIRCUIT
316
319
IMPEDANCE MEASUREMENT AND SIGNAL PROCESSING CIRCUIT
318
CONTROLLER
324
TEST RESULTS DATA STORAGE
326
RESULTS PROCESSING TO SELECT ELECTRODE CONFIGURATION
328
SELECTED ELECTRODE CONFIGURATION FOR DIAGNOSTIC USE
322
TEST LOGIC CYCLING THROUGH ELECTRODE CONFIGURATIONS
330
CLOCK CIRCUIT
320
COMMUNICATION CIRCUIT
306
EXTERNAL DEVICE

Fig. 3

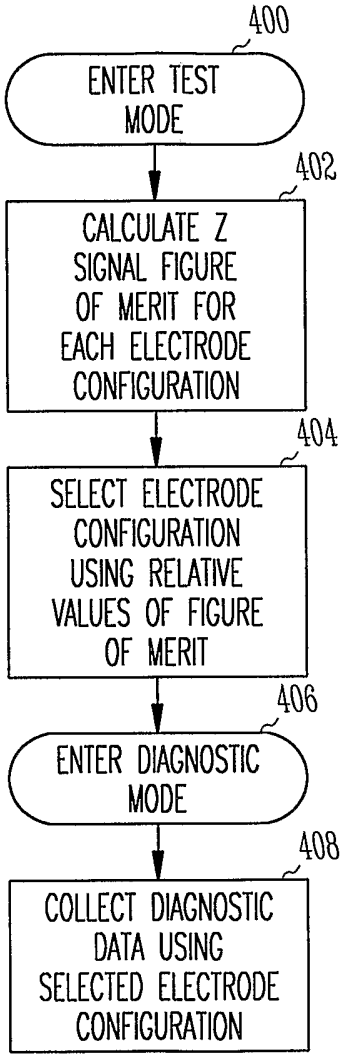

400
ENTER TEST MODE
402
CALCULATE Z SIGNAL FIGURE OF MERIT FOR EACH ELECTRODE CONFIGURATION
404
SELECT ELECTRODE CONFIGURATION USING RELATIVE VALUES OF FIGURE OF MERIT
406
ENTER DIAGNOSTIC MODE
408
COLLECT DIAGNOSTIC DATA USING SELECTED ELECTRODE CONFIGURATION

Fig. 4

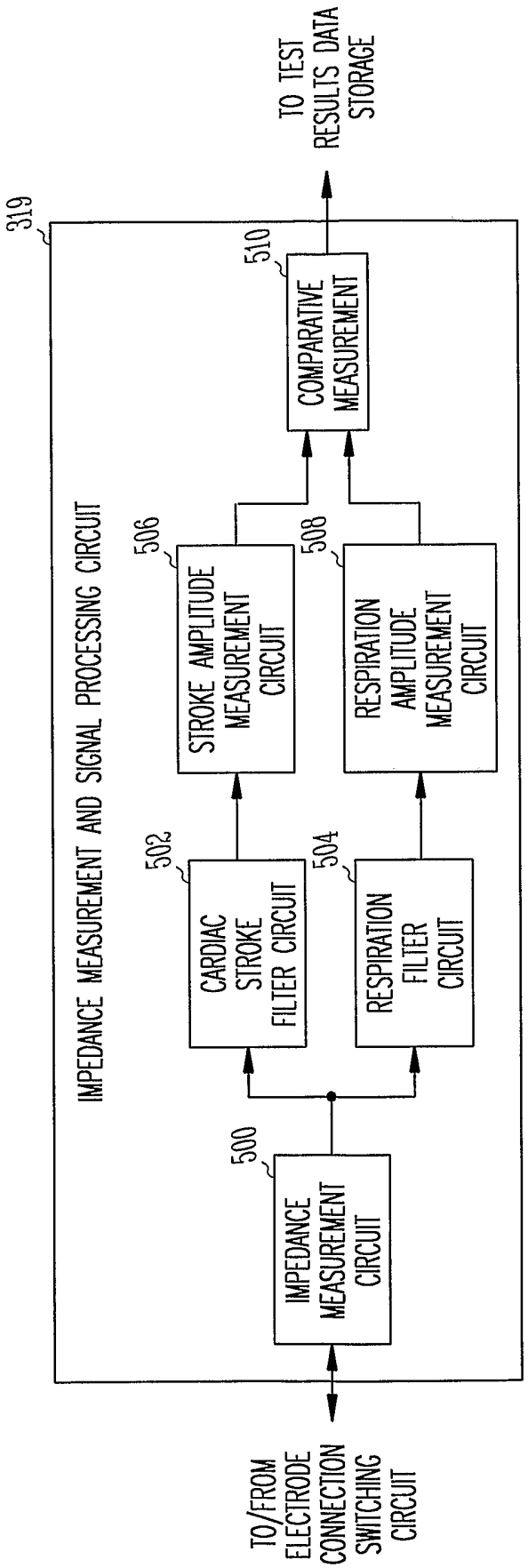
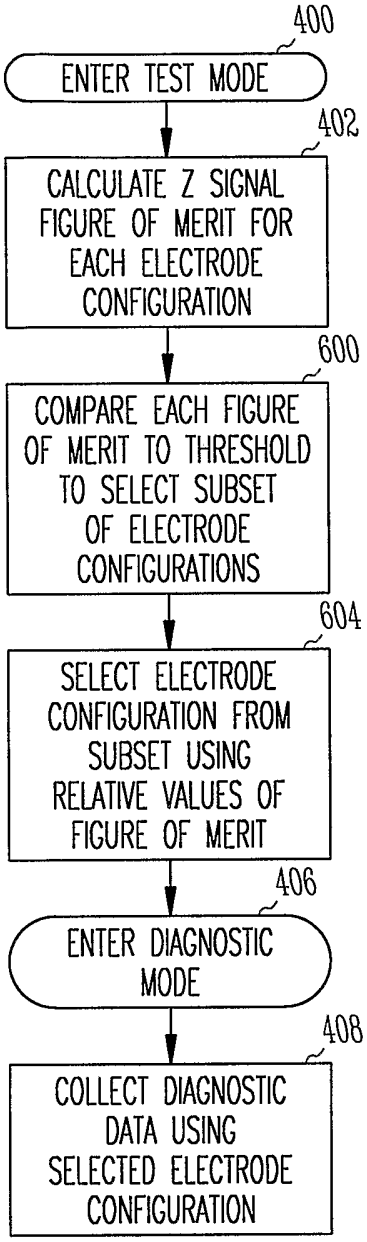

TO TEST RESULTS DATA STORAGE
319
IMPEDANCE MEASUREMENT AND SIGNAL PROCESSING CIRCUIT
510
COMPARATIVE MEASUREMENT
506
STROKE AMPLITUDE MEASUREMENT CIRCUIT
508
RESPIRATION AMPLITUDE MEASUREMENT CIRCUIT
502
CARDIAC STROKE FILTER CIRCUIT
504
RESPIRATION FILTER CIRCUIT
500
IMPEDANCE MEASUREMENT CIRCUIT
TO/FROM ELECTRODE CONNECTION SWITCHING CIRCUIT

Fig. 5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ENTER TEST MODE
402
CALCULATE Z SIGNAL FIGURE OF MERIT FOR EACH ELECTRODE CONFIGURATION
600
COMPARE EACH FIGURE OF MERIT TO THRESHOLD TO SELECT SUBSET OF ELECTRODE CONFIGURATIONS
604
SELECT ELECTRODE CONFIGURATION FROM SUBSET USING RELATIVE VALUES OF FIGURE OF MERIT
406
ENTER DIAGNOSTIC MODE
408
COLLECT DIAGNOSTIC DATA USING SELECTED ELECTRODE CONFIGURATION

Fig. 6

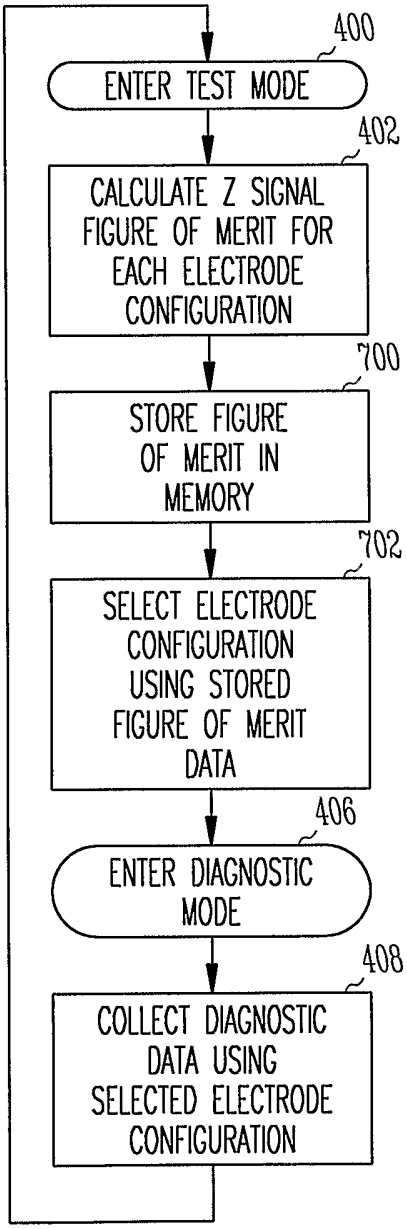
400
ENTER TEST MODE
402
CALCULATE Z SIGNAL FIGURE OF MERIT FOR EACH ELECTRODE CONFIGURATION
700
STORE FIGURE OF MERIT IN MEMORY
702
SELECT ELECTRODE CONFIGURATION USING STORED FIGURE OF MERIT DATA
406
ENTER DIAGNOSTIC MODE
408
COLLECT DIAGNOSTIC DATA USING SELECTED ELECTRODE CONFIGURATION

Fig. 7

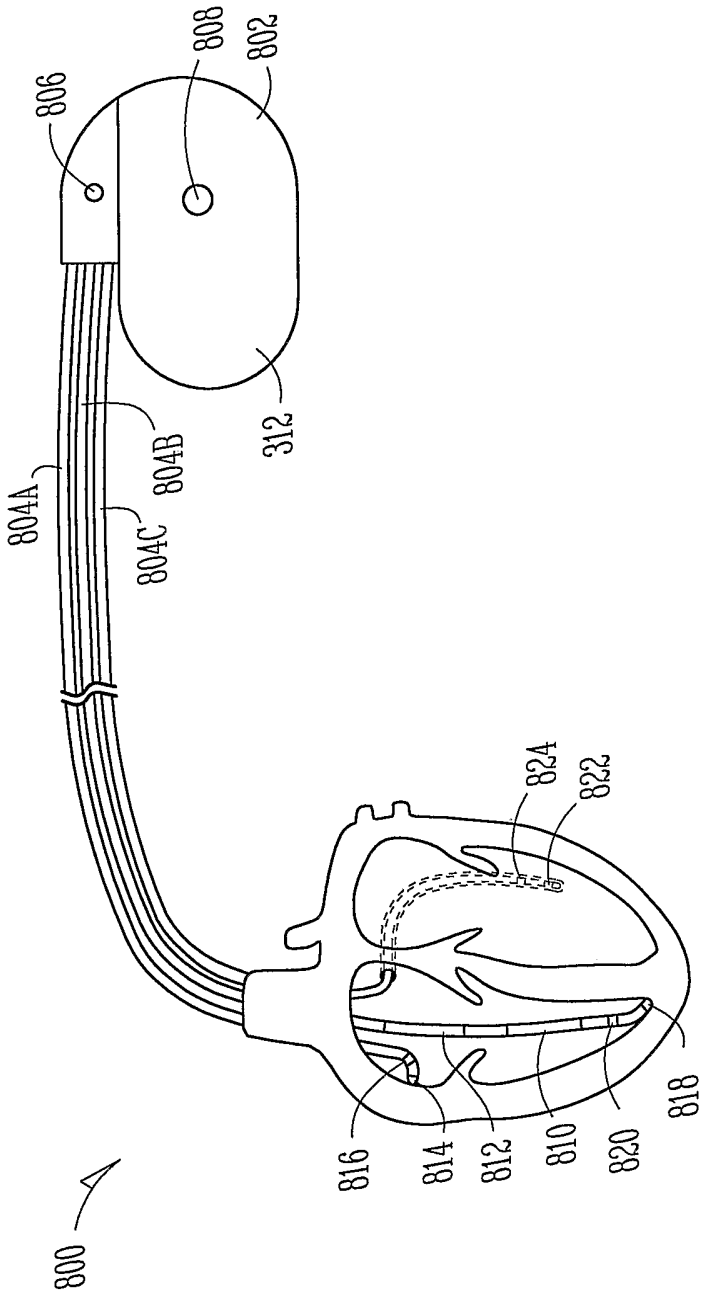
808
802
806
312
804B
804A
804C
824
822
818
816
814
812
810
820
800

Fig.8

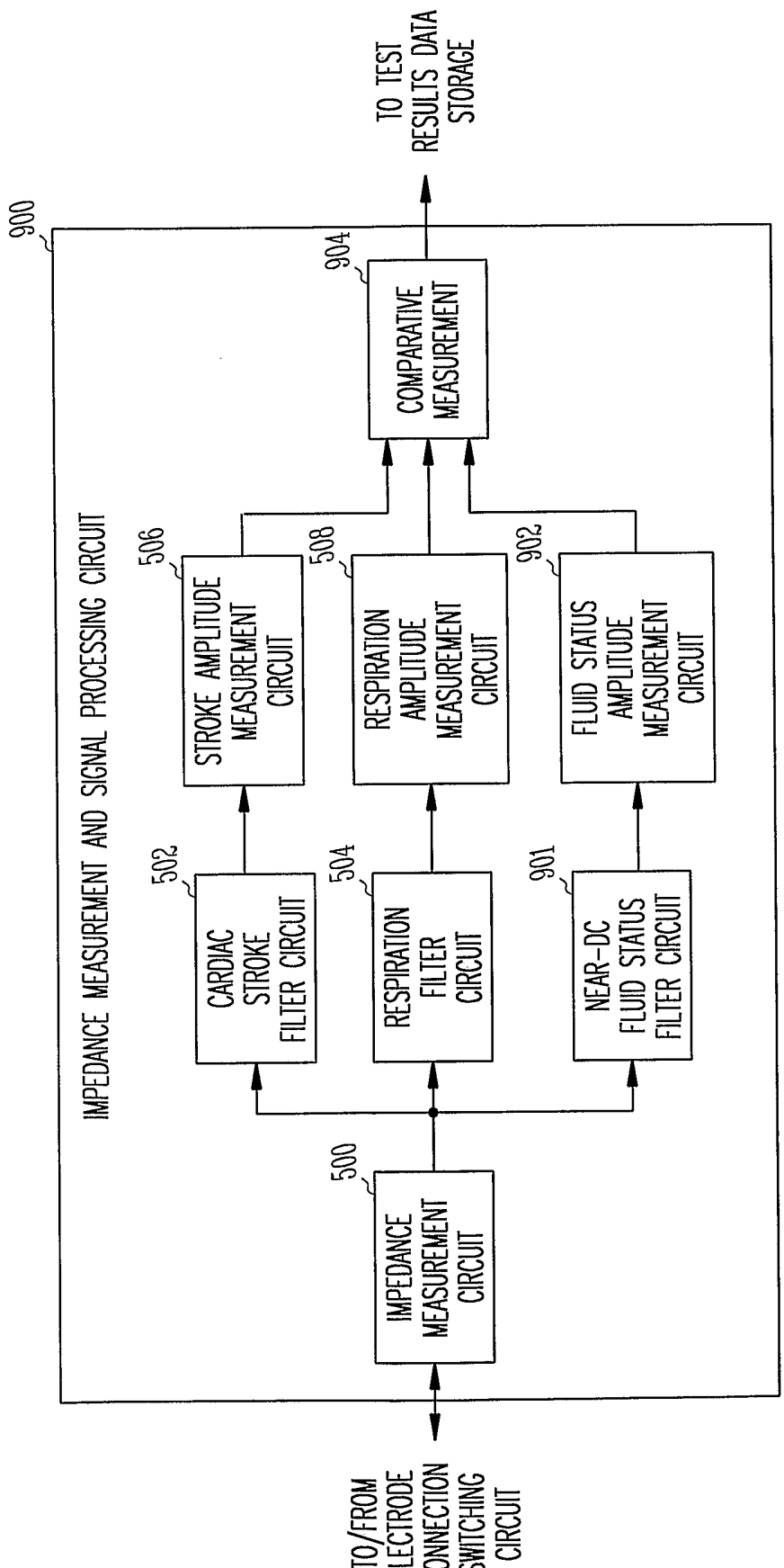
TO TEST RESULTS DATA STORAGE
900
IMPEDANCE MEASUREMENT AND SIGNAL PROCESSING CIRCUIT
904
COMPARATIVE MEASUREMENT
506
STROKE AMPLITUDE MEASUREMENT CIRCUIT
508
RESPIRATION AMPLITUDE MEASUREMENT CIRCUIT
902
FLUID STATUS AMPLITUDE MEASUREMENT CIRCUIT
502
CARDIAC STROKE FILTER CIRCUIT
504
RESPIRATION FILTER CIRCUIT
901
NEAR-DC FLUID STATUS FILTER CIRCUIT
500
IMPEDANCE MEASUREMENT CIRCUIT
TO/FROM ELECTRODE CONNECTION SWITCHING CIRCUIT

Fig. 9

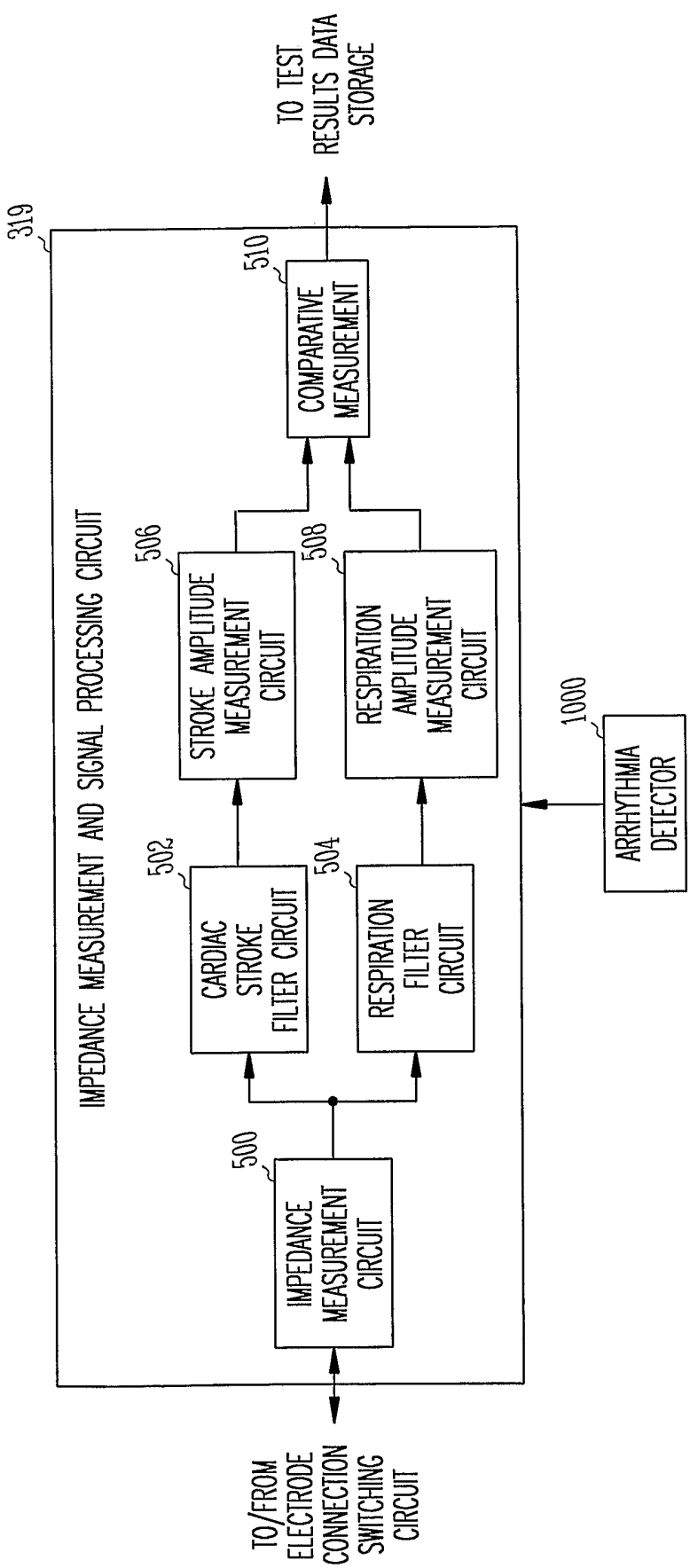
TO TEST RESULTS DATA STORAGE
319
IMPEDANCE MEASUREMENT AND SIGNAL PROCESSING CIRCUIT
510
COMPARATIVE MEASUREMENT
506
STROKE AMPLITUDE MEASUREMENT CIRCUIT
508
RESPIRATION AMPLITUDE MEASUREMENT CIRCUIT
1000
ARRHYTHMIA DETECTOR
502
CARDIAC STROKE FILTER CIRCUIT
504
RESPIRATION FILTER CIRCUIT
500
IMPEDANCE MEASUREMENT CIRCUIT
TO/FROM ELECTRODE CONNECTION SWITCHING CIRCUIT

Fig. 10

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2006/009646

A. CLASSIFICATION OF SUBJECT MATTER
INV. A61N1/365 A61B5/053

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
A61N A61B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP 0 510 456 A (SIEMENS ELEMA AB; SIEMENS AKTIENGESELLSCHAFT; PACESETTER AB) 28 October 1992 (1992-10-28) the whole document	1-14
A	US 6 076 015 A (HARTLEY ET AL) 13 June 2000 (2000-06-13) cited in the application the whole document	1-14
A	EP 0 310 024 A (ALT, ECKHARD, DR) 5 April 1989 (1989-04-05) the whole document	1-14
A	EP 0 576 114 A (TELECTRONICS N.V) 29 December 1993 (1993-12-29) column 6, line 49 - column 13, line 25	1-14

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
7 July 2006	25/07/2006

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31–70) 340–2040, Tx. 31 651 epo nl, Fax: (+31–70) 340–3016	Sopelana Martínez, J

1

Form PCT/ISA/210 (second sheet) (April 2005)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2006/009646

Box II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. [X] Claims Nos.: 15-31
because they relate to subject matter not required to be searched by this Authority, namely:

Rule 39.1(iv) PCT - Method for treatment of the human or animal body by surgery

2. [ ] Claims Nos.:
because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:

3. [ ] Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. [ ] As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.

2. [ ] As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. [ ] As only some of the required additional search fees were timely paid by the applicant, this International Search Report covers only those claims for which fees were paid, specifically claims Nos.:

4. [ ] No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

[ ] The additional search fees were accompanied by the applicant's protest.

[ ] No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/US2006/009646

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 0510456 A	28-10-1992	DE 69205876 D1	14-12-1995
		DE 69205876 T2	19-09-1996
		JP 5137800 A	01-06-1993
		US 5273034 A	28-12-1993
US 6076015 A	13-06-2000	AT 300332 T	15-08-2005
		CA 2322174 A1	02-09-1999
		DE 69926347 D1	01-09-2005
		DE 69926347 T2	24-05-2006
		EP 1061998 A1	27-12-2000
		WO 9943385 A1	02-09-1999
		US 6161042 A	12-12-2000
		US 6463326 B1	08-10-2002
EP 0310024 A	05-04-1989	DE 3732640 C1	18-05-1989
		EP 0310025 A2	05-04-1989
		EP 0310026 A2	05-04-1989
		US 4919136 A	24-04-1990
		US 5003976 A	02-04-1991
		US 4884576 A	05-12-1989
EP 0576114 A	29-12-1993	DE 69330012 D1	19-04-2001
		DE 69330012 T2	09-08-2001
		DE 576114 T1	28-07-1994
		US 5197467 A	30-03-1993