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(54) **SPATIAL CONFIGURATION OF A MOTION SENSOR IN AN IMPLANTABLE MEDICAL DEVICE**

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None
See application file for complete search history.

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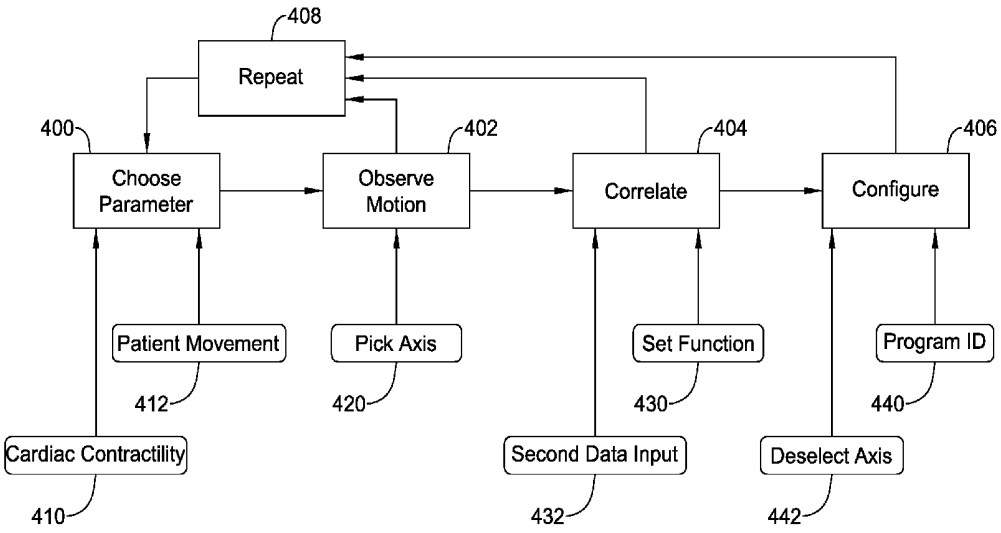
(57) **ABSTRACT**

Implantable devices having motion sensors. In some examples the a configuration is generated for the implantable device to use the motion sensor in an energy preserving mode in which one or more axis of detection of the motion sensor is disabled or ignored. In some examples the motion sensor outputs along multiple axes are analyzed to determine which axes best correspond to certain patient parameters including patient motion/activity and/or cardiac contractility. In other examples the output of the motion sensor is observed across patient movements or postures to develop conversion parameters to determine a patient standard frame of reference relative to outputs of the motion sensor of an implanted device.

19 Claims, 5 Drawing Sheets



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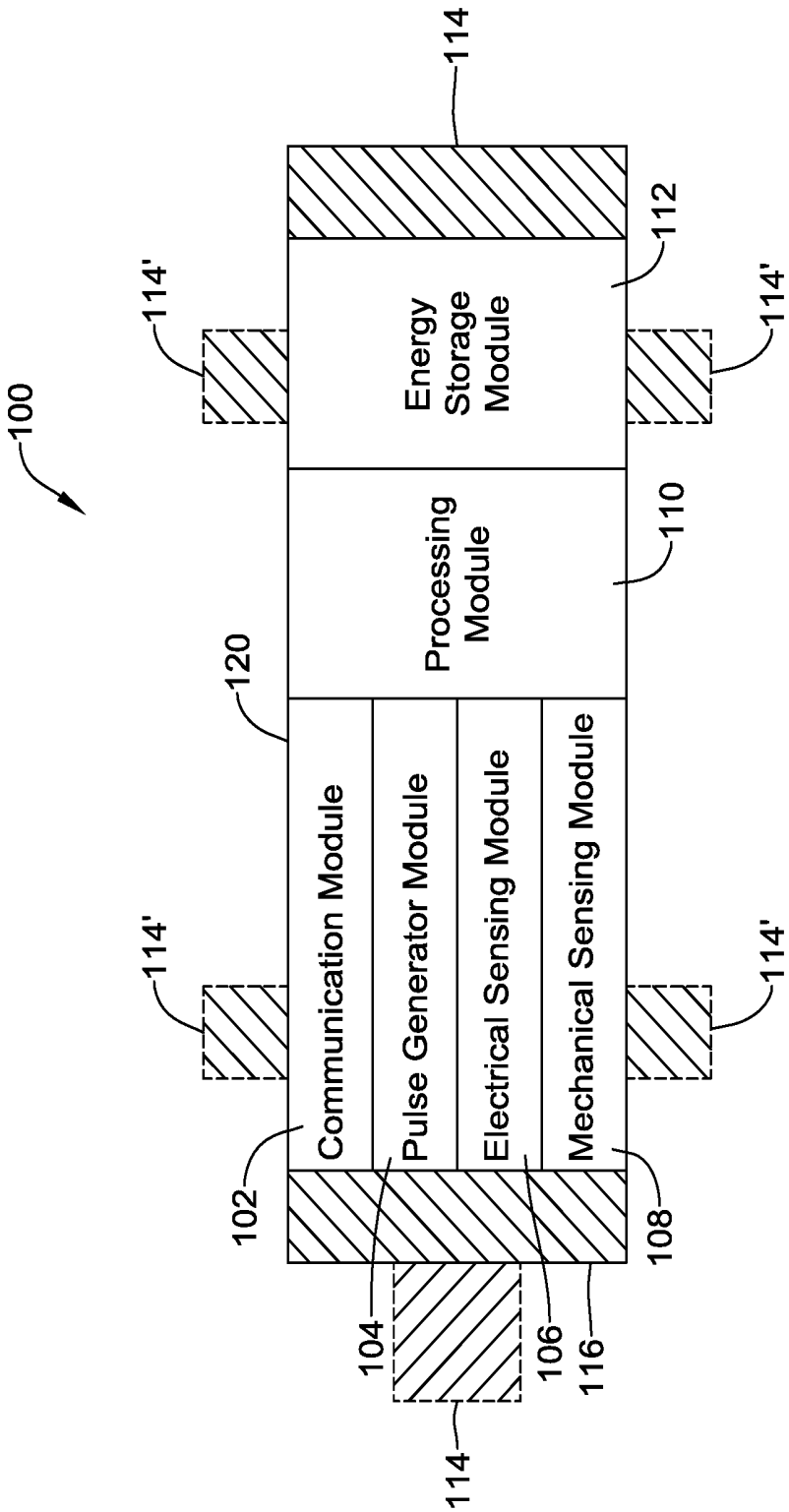
100
114
112
Energy Storage Module
114'
114'
110
Processing Module
120
Communication Module
Pulse Generator Module
Electrical Sensing Module
Mechanical Sensing Module
114'
114'
102
104
106
116
108
114

FIG. 1

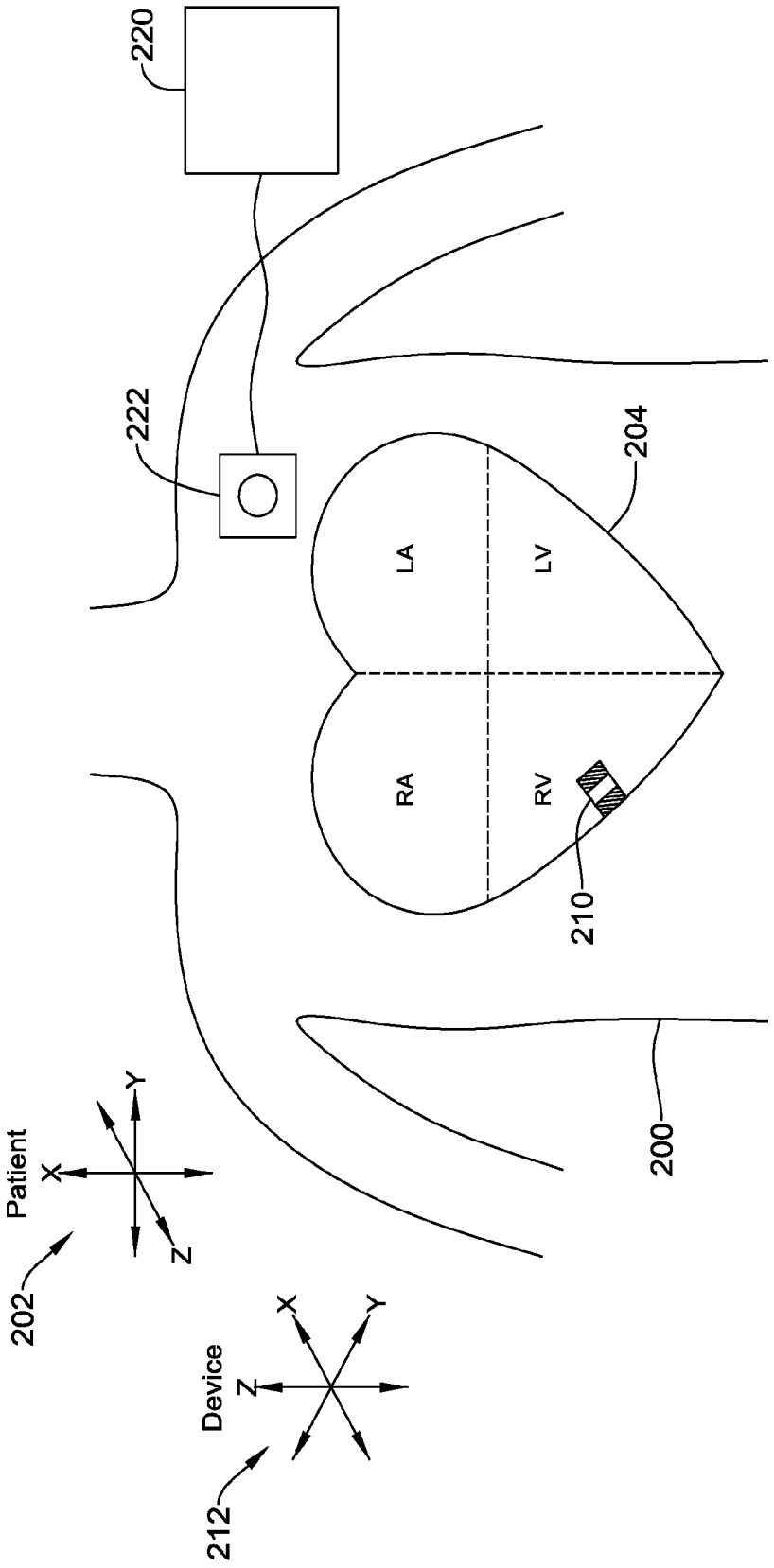

FIG. 2

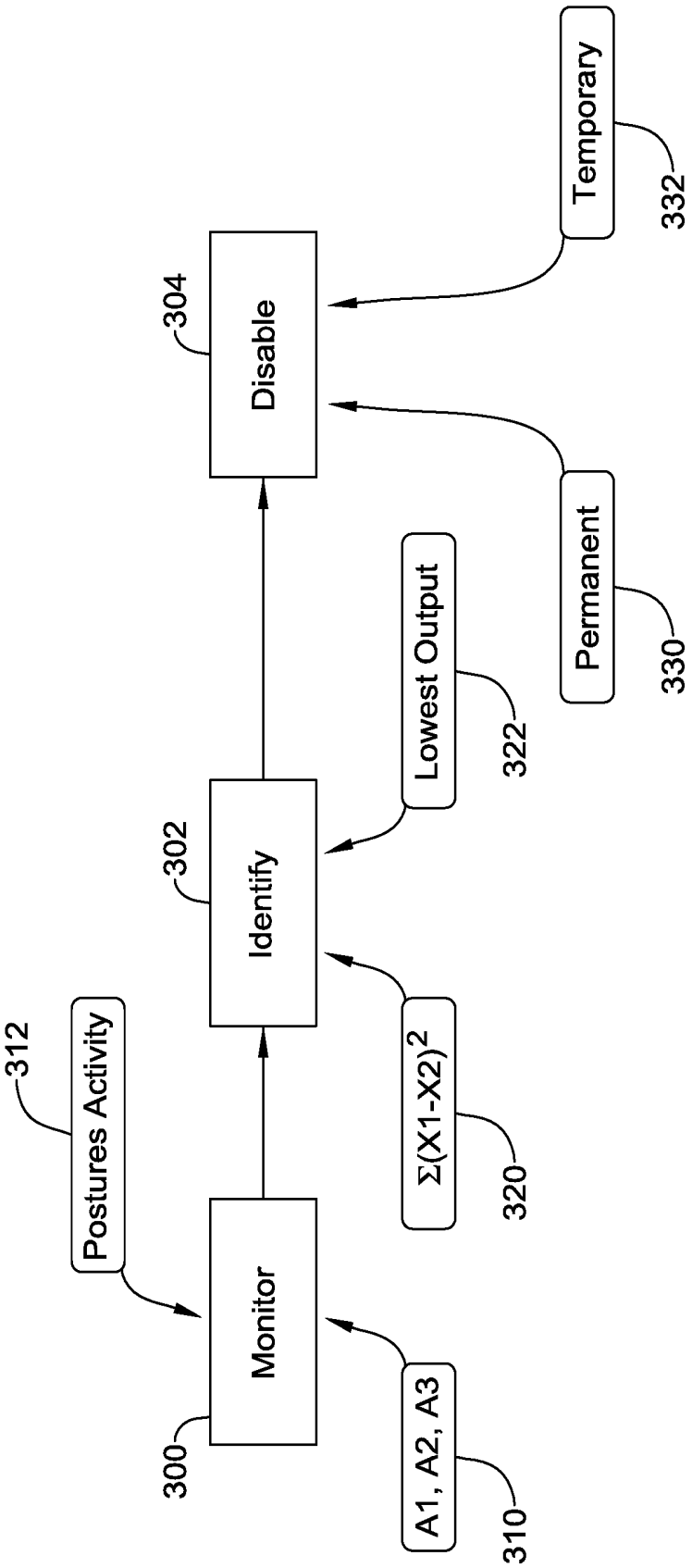
Monitor
300
A1, A2, A3
310
Postures Activity
312
Identify
302
$\Sigma(X1-X2)^2$
320
Lowest Output
322
Disable
304
Permanent
330
Temporary
332

FIG. 3

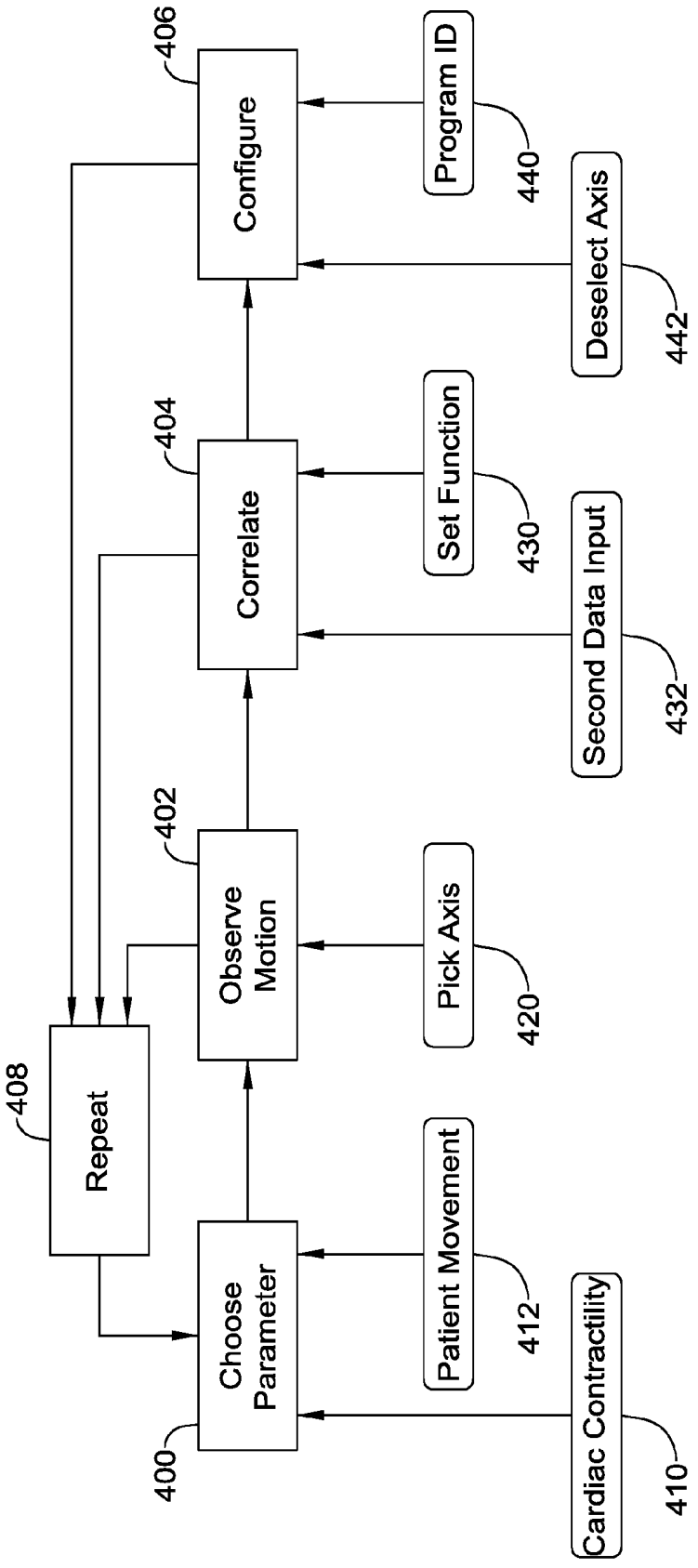
406
Configure
Program ID
440
Deselect Axis
442
404
Correlate
Set Function
430
Second Data Input
432
402
Observe Motion
Pick Axis
420
408
Repeat
Choose Parameter
Patient Movement
412
400
Cardiac Contractility
410

FIG. 4

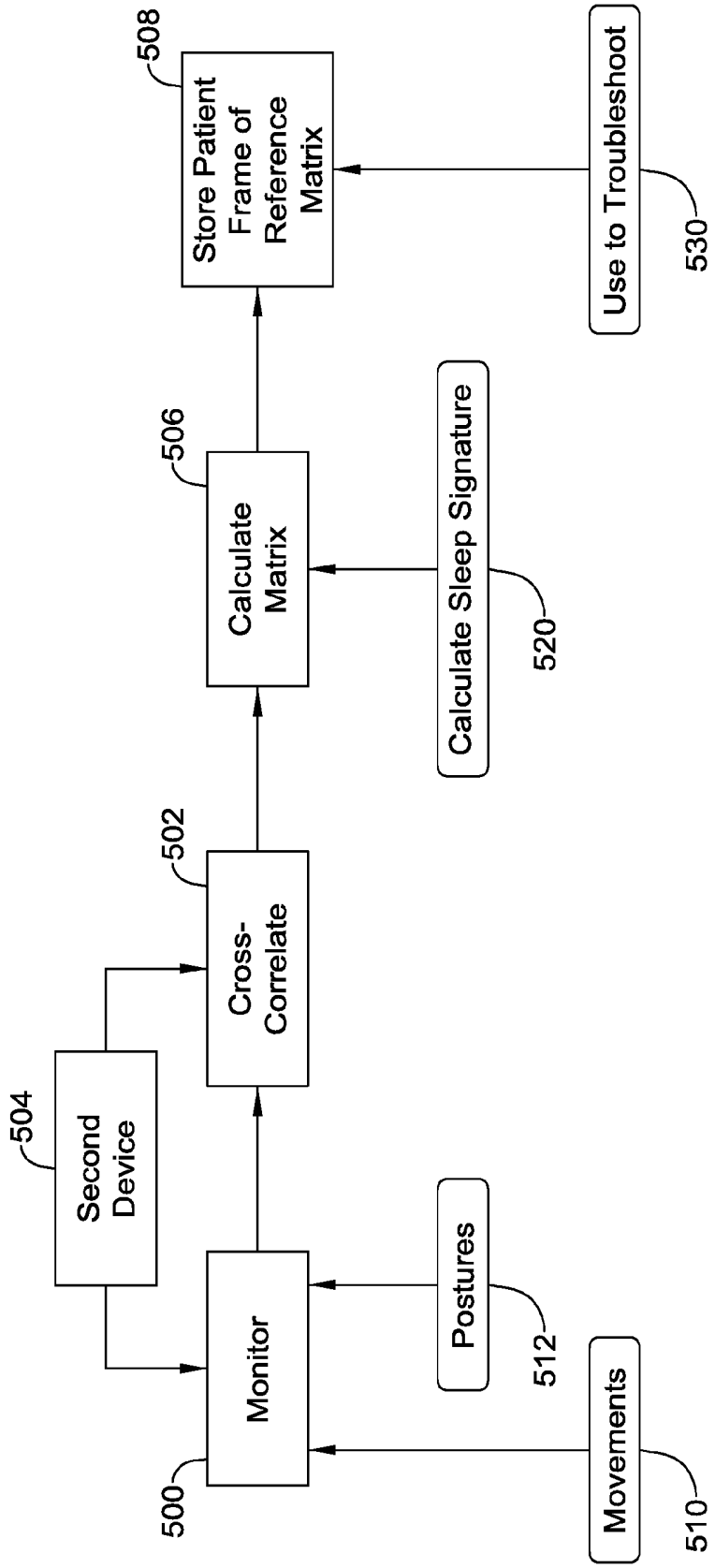
Monitor
500
Second Device
504
Cross-Correlate
502
Calculate Matrix
506
Store Patient Frame of Reference Matrix
508
Movements
510
Postures
512
Calculate Sleep Signature
520
Use to Troubleshoot
530

FIG. 5

SPATIAL CONFIGURATION OF A MOTION SENSOR IN AN IMPLANTABLE MEDICAL DEVICE

CROSS REFERENCE TO RELATED APPLICATIONS

The present application claims the benefit of and priority to U.S. Provisional Patent Application Ser. No. 62/210,887, filed on Aug. 27, 2015, the disclosure of which is incorporated herein by reference.

TECHNICAL FIELD

The present disclosure generally relates to systems, devices, and methods for treating medical conditions using an implantable device, and more particularly, to systems, devices, and methods which include or use a motion sensor to detect a patient's level of activity.

BACKGROUND

Pacing instruments can be used to treat patients suffering from various heart conditions that result in a reduced ability of the heart to deliver sufficient amounts of blood to a patient's body. These heart conditions may lead to rapid, irregular, and/or inefficient heart contractions. To help alleviate some of these conditions, various devices (e.g., pacemakers, defibrillators, etc.) have been implanted in a patient's body. Such devices may monitor and provide electrical stimulation to the heart to help the heart operate in a more normal, efficient and/or safe manner. In some cases, a patient may have multiple implanted devices.

Motion detectors have been used in some pacemakers and other implantable devices to obtain a measure of the activity level of the patient. For example, rate adaptive cardiac pacemakers may adjust the rate at which the patient's heart is paced up or down in response to detected motion of the patient. By so doing, the pacemaker is able to adapt to the activity level of the patient, allowing a more active lifestyle than could be achieved without rate adaptive pacing. New and alternative approaches to the use of motion sensors are desired.

Overview

The present inventors have recognized that a problem to be solved includes the manner in which an implantable device uses a motion sensor having multiple axes. In some examples a configuration is generated for the implantable device to use the motion sensor in an energy preserving mode in which one or more axes of detection of the motion sensor is disabled or ignored. In some examples the motion sensor outputs along multiple axes are analyzed to determine which axes best correspond to certain patient parameters including patient motion/activity and/or cardiac contractility, to simplify and possibly enhance the accuracy of data analysis. In other examples the output of the motion sensor is observed across patient movements or postures to develop conversion parameters to determine a patient standard frame of reference relative to outputs of the motion sensor of an implanted device.

This overview is intended to provide an overview of subject matter of the present patent application. It is not intended to provide an exclusive or exhaustive explanation of the invention. The detailed description is included to provide further information about the present patent application.

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings, which are not necessarily drawn to scale, like numerals may describe similar components in different views. Like numerals having different letter suffixes may represent different instances of 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** is a schematic block diagram of an illustrative implantable device;

FIG. **2** shows an illustrative example of a system implanted in a patient;

FIGS. **3-5** are flow diagrams for illustrative methods.

DETAILED DESCRIPTION

This disclosure describes systems, devices, and methods for delivering electrical stimulation to a heart in a rate adaptive manner. Healthy people's bodies generally adjust the rate at which their hearts beat in response to higher or lower metabolic needs, for example during exercise or in response to various external stimuli. However, some people develop diseases or conditions which affect their bodies' abilities to cause their hearts to contract in an effective manner. Devices in accordance with the present disclosure may be implanted in such people. In some instances, the implanted devices may deliver electrical stimulation on an on-going basis and adjust the rate of delivered electrical stimulation in accordance with sensed physiological parameters indicative of increased metabolic needs.

FIG. **1** is similar to FIG. 1 of commonly assigned and U.S. Provisional Patent Application 62/128,340, the disclosure of which is incorporated herein by reference as showing and describing numerous additional details which may be included in the methods, systems and devices discussed herein.

More specifically, FIG. **1** is a conceptual schematic block diagram of an exemplary leadless cardiac pacemaker (LCP) that may be implanted on the heart or within a chamber of the heart and may operate to sense physiological signals and parameters and deliver one or more types of electrical stimulation therapy to the heart of the patient. Example electrical stimulation therapy may include bradycardia pacing, rate responsive pacing therapy, cardiac resynchronization therapy (CRT), anti-tachycardia pacing (ATP) therapy and/or the like. As can be seen in FIG. **1**, LCP **100** may be a compact device with all components housed within LCP **100** or directly on housing **120**. In some instances, LCP **100** may include communication module **102**, pulse generator module **104**, electrical sensing module **106**, mechanical sensing module **108**, processing module **110**, energy storage module **112**, and electrodes **114**. In some examples (not shown), an optional lead or tether may be attached to an implantable device similar to LCP **100** to provide an additional electrode, extended antenna functionality, to couple to a second such implantable device, or to prevent migration.

As depicted in FIG. **1**, LCP **100** may include electrodes **114**, which can be secured relative to housing **120** and electrically exposed to tissue and/or blood surrounding LCP **100**. Electrodes **114** may generally conduct electrical signals to and from LCP **100** and the surrounding tissue and/or blood. Such electrical signals can include communication

signals, electrical stimulation pulses, and intrinsic cardiac electrical signals, to name a few. Intrinsic cardiac electrical signals may include electrical signals generated by the heart and may be represented by the cardiac electrogram (EGM), if observed on or in the heart, or the electrocardiogram (ECG), if observed at some distance from the heart.

Electrodes **114** may include one or more biocompatible conductive materials such as various metals or alloys that are known to be safe for implantation within a human body. In some instances, electrodes **114** may be generally disposed on either end of LCP **100** and may be in electrical communication with one or more of modules **102**, **104**, **106**, **108**, and **110**. In embodiments where electrodes **114** are secured directly to housing **120**, an insulating material may electrically isolate the electrodes **114** from adjacent electrodes, housing **120**, and/or other parts of LCP **100**. In some instances, some or all of electrodes **114** may be spaced from housing **120** and connected to housing **120** and/or other components of LCP **100** through connecting wires. In such instances, the electrodes **114** may be placed on a tail (not shown) that extends out away from the housing **120**. As shown in FIG. **1**, in some embodiments, LCP **100** may include electrodes **114'**. Electrodes **114'** may be in addition to electrodes **114**, or may replace one or more of electrodes **114**. Electrodes **114'** may be similar to electrodes **114** except that electrodes **114'** are disposed on the sides of LCP **100**. In some cases, electrodes **114'** may increase the number of electrodes by which LCP **100** may deliver communication signals and/or electrical stimulation pulses, and/or may sense intrinsic cardiac electrical signals, communication signals, and/or electrical stimulation pulses.

Electrodes **114** and/or **114'** may assume any of a variety of sizes and/or shapes, and may be spaced at any of a variety of spacings. For example, electrodes **114** may have an outer diameter of two to twenty millimeters (mm). In other embodiments, electrodes **114** and/or **114'** may have a diameter of two, three, five, seven millimeters (mm), or any other suitable diameter, dimension and/or shape. Example lengths for electrodes **114** and/or **114'** may include, for example, one, three, five, ten millimeters (mm), or any other suitable length. As used herein, the length is a dimension of electrodes **114** and/or **114'** that extends away from the outer surface of the housing **120**. In some instances, at least some of electrodes **114** and/or **114'** may be spaced from one another by a distance of twenty, thirty, forty, fifty millimeters (mm), or any other suitable spacing. The electrodes **114** and/or **114'** of a single device may have different sizes with respect to each other, and the spacing and/or lengths of the electrodes on the device may or may not be uniform.

In the embodiment shown, communication module **102** may be electrically coupled to electrodes **114** and/or **114'** and may be configured to deliver communication pulses to tissues of the patient for communicating with other devices such as sensors, programmers, other medical devices, and/or the like. Communication signals, as used herein, may be any modulated signal that conveys information to another device, either by itself or in conjunction with one or more other modulated signals. In some embodiments, communication signals may be limited to sub-threshold signals that do not result in capture of the heart yet still convey information. The communication signals may be delivered to another device that is located either external or internal to the patient's body. In some instances, the communication may take the form of distinct communication pulses separated by various amounts of time. In some of these cases, the timing between successive pulses may convey information. Communication module **102** may additionally be configured to sense for communication signals delivered by other devices, which may be located external or internal to the patient's body.

Communication module **102** may communicate to help accomplish one or more desired functions. Some example functions include delivering sensed data, using communicated data for determining occurrences of events such as arrhythmias, coordinating delivery of electrical stimulation therapy, and/or other functions. In some cases, LCP **100** may use communication signals to communicate raw information, processed information, messages and/or commands, and/or other data. Raw information may include information such as sensed electrical signals (e.g. a sensed EGM), signals gathered from coupled sensors, and the like. In some embodiments, the processed information may include signals that have been filtered using one or more signal processing techniques. Processed information may also include parameters and/or events that are determined by the LCP **100** and/or another device, such as a determined heart rate, timing of determined heartbeats, timing of other determined events, determinations of threshold crossings, expirations of monitored time periods, activity level parameters, blood-oxygen parameters, blood pressure parameters, heart sound parameters, and the like. Messages and/or commands may include instructions or the like directing another device to take action, notifications of imminent actions of the sending device, requests for reading from the receiving device, requests for writing data to the receiving device, information messages, and/or other messages commands.

In at least some embodiments, communication module **102** (or LCP **100**) may further include switching circuitry to selectively connect one or more of electrodes **114** and/or **114'** to communication module **102** in order to select which electrodes **114** and/or **114'** that communication module **102** delivers communication pulses. It is contemplated that communication module **102** may be communicating with other devices via conducted signals, radio frequency (RF) signals, optical signals, acoustic signals, inductive coupling, and/or any other suitable communication methodology. Where communication module **102** generates electrical communication signals, communication module **102** may include one or more capacitor elements and/or other charge storage devices to aid in generating and delivering communication signals. In the embodiment shown, communication module **102** may use energy stored in energy storage module **112** to generate the communication signals. In at least some examples, communication module **102** may include a switching circuit that is connected to energy storage module **112** and, with the switching circuitry, may connect energy storage module **112** to one or more of electrodes **114**/**114'** to generate the communication signals.

As shown in FIG. **1**, a pulse generator module **104** may be electrically connected to one or more of electrodes **114** and/or **114'**. Pulse generator module **104** may be configured to generate electrical stimulation pulses and deliver the electrical stimulation pulses to tissues of a patient via one or more of the electrodes **114** and/or **114'** to provide one or more electrical stimulation therapies such as bradycardia pacing, ATP, CRT, cardioversion, or defibrillation.

The LCP **100** may vary the rate at which pulse generator **104** generates the electrical stimulation pulses, for example in rate adaptive pacing. These are just some examples. When used to treat other ailments, the pulse generator module **104** may generate electrical stimulation pulses suitable for neurostimulation or neuromodulation therapy or the like.

Pulse generator module **104** may include one or more capacitor elements and/or other charge storage devices to aid

in generating and delivering appropriate electrical stimulation pulses. In the embodiment shown, pulse generator module **104** may use energy stored in energy storage module **112** to generate the electrical stimulation pulses. In some examples, pulse generator module **104** may include a switching circuit that is connected to energy storage module **112** and may connect energy storage module **112** to one or more of electrodes **114/114'** to generate electrical stimulation pulses.

Pulse generator module **104** may include the capability to modify the electrical stimulation pulses, such as by adjusting the pulse width and/or amplitude of the electrical stimulation pulses. When pacing the heart, this may help tailor the electrical stimulation pulses to capture the heart a particular patient, sometimes with reduced battery usage. For neurostimulation therapy, adjusting the pulse width and/or amplitude may help tailor the therapy for a particular application and/or help make the therapy more effective for a particular patient.

In some embodiments, LCP **100** may include an electrical sensing module **106** and mechanical sensing module **108**. Electrical sensing module **106** may be configured to sense intrinsic cardiac electrical signals conducted from electrodes **114** and/or **114'** to electrical sensing module **106**. For example, electrical sensing module **106** may be electrically connected to one or more electrodes **114** and/or **114'** and electrical sensing module **106** may be configured to receive cardiac electrical signals conducted through electrodes **114** and/or **114'** via a sensor amplifier or the like. In some embodiments, the cardiac electrical signals may represent local information from the chamber in which LCP **100** is implanted. For instance, if LCP **100** is implanted within a ventricle of the heart, cardiac electrical signals sensed by LCP **100** through electrodes **114** and/or **114'** may represent ventricular cardiac electrical signals.

Mechanical sensing module **108** may include, or be electrically connected to, various sensors, such as accelerometers, blood pressure sensors, heart sound sensors, piezoelectric sensors, blood-oxygen sensors, and/or other sensors which measure one or more physiological parameters of the heart and/or patient. Mechanical sensing module **108** may gather signals from the sensors indicative of the various physiological parameters. Both electrical sensing module **106** and mechanical sensing module **108** may be connected to processing module **110** and may provide signals representative of the sensed cardiac electrical signals and/or physiological signals to processing module **110**. Although described with respect to FIG. **1** as separate sensing modules, in some embodiments, electrical sensing module **106** and mechanical sensing module **108** may be combined into a single module. In at least some examples, LCP **100** may only include one of electrical sensing module **106** and mechanical sensing module **108**. In some cases, any combination of the processing module **110**, electrical sensing module **106**, mechanical sensing module **108**, communication module **102**, pulse generator module **104** and/or energy storage module may be considered a controller of the LCP **100**.

The mechanical sensing module may include, for example, a micro-electro-mechanical system (MEMS) based motion sensor. This may include a 1, 2 or 3 dimensional motion sensor and may take any of numerous forms known in the art. Some examples may include a micromachine size vibrating element that varies an electrical parameter when external motion impacts it. To facilitate sensing, the motion sensor can be turned "on," requiring current drain, and the output can then be sampled to generate an output. Keeping the motion sensor "on" all the time may drain battery sourced current unnecessarily, and so duty cycling is performed to minimize current draw in some embodiments.

Processing module **110** may be configured to direct the operation of LCP **100**. For example, processing module **110** may be configured to receive cardiac electrical signals from electrical sensing module **106** and/or physiological signals from mechanical sensing module **108**. Based on the received signals, processing module **110** may determine, for example, occurrences and types of arrhythmias. Processing module **110** may further receive information from communication module **102**. In some embodiments, processing module **110** may additionally use such received information to determine occurrences and types of arrhythmias. However, in other embodiments, LCP **100** may use the received information instead of the signals received from electrical sensing module **106** and/or mechanical sensing module **108**—for instance if the received information is deemed to be more accurate than the signals received from electrical sensing module **106** and/or mechanical sensing module **108** or if electrical sensing module **106** and/or mechanical sensing module **108** have been disabled or omitted from LCP **100**.

After determining therapy is needed, processing module **110** may control pulse generator module **104** to generate electrical stimulation pulses in accordance with one or more electrical stimulation therapy regimens. For example, processing module **110** may control pulse generator module **104** to generate pacing pulses with varying parameters and in different sequences to effectuate one or more electrical stimulation therapies. As one example, in controlling pulse generator module **104** to deliver bradycardia pacing therapy, processing module **110** may control pulse generator module **104** to deliver pacing pulses designed to capture the heart of the patient at a regular interval to help prevent the heart of a patient from falling below a predetermined threshold.

In some embodiments, processing module **110** may further control communication module **102** to send information to other devices. For example, processing module **110** may control communication module **102** to generate one or more communication signals for communicating with other devices of a system of devices. For instance, processing module **110** may control communication module **102** to generate communication signals in particular pulse sequences, where the specific sequences convey different information. Communication module **102** may also receive communication signals for potential action by processing module **110**.

In some embodiments, processing module **110** may include a pre-programmed chip, such as a very-large-scale integration (VLSI) chip or an application specific integrated circuit (ASIC). In such embodiments, the chip may be pre-programmed with control logic in order to control the operation of LCP **100**. By using a pre-programmed chip, processing module **110** may use less power than other programmable circuits while able to maintain basic functionality, thereby potentially increasing the battery life of LCP **100**. In other instances, processing module **110** may include a programmable microprocessor or the like. Such a programmable microprocessor may allow a user to adjust the control logic of LCP **100** after manufacture, thereby allowing for greater flexibility of LCP **100** than when using a pre-programmed chip.

Processing module **110**, in additional embodiments, may include a memory circuit and processing module **110** may store information on and read information from the memory circuit. In other embodiments, LCP **100** may include a

separate memory circuit (not shown) that is in communication with processing module **110**, such that processing module **110** may read and write information to and from the separate memory circuit. The memory circuit, whether part of processing module **110** or separate from processing module **110**, may be volatile memory, non-volatile memory, or a combination of volatile memory and non-volatile memory.

Energy storage module **112** may provide a power source to LCP **100** for its operations. In some embodiments, energy storage module **112** may be a non-rechargeable lithium-based battery. In other embodiments, the non-rechargeable battery may be made from other suitable materials. In some embodiments, energy storage module **112** may include a rechargeable battery. For embodiments with a rechargeable battery, there may additionally be a recharging circuit using, for example, a coil that receives an electrical or magnetic field to facilitate recharging transcutaneously, as is well known in the art. In other embodiments, biological energy capture devices may be used to take advantage of energy that can be generated using the cardiac or other biological motion. In still other embodiments, energy storage module **112** may include other types of energy storage devices such as super capacitors.

Collectively the processing module **110**, mechanical sensing module **108**, electrical sensing module **106**, pulse generator module **104**, and communication module **102** may be referred to as the operational circuitry of the LCP. In some examples the individual modules **102**, **104**, **106**, **108**, **110** may be subcomponents on a single hybrid or circuit board, or even within a single VSLI or ASIC, or may be spread across several hybrids, circuit boards, VSLI or ASIC components. In some examples, certain elements of processing module **110** are performed in the digital domain—such as determining whether to deliver therapy and operating the communication module when awoken for such a purpose—while others are performed in the analog domain—such as ongoing monitoring of the received electrical and/or motion signal until a significant perturbation of either signal or a timeout occurs, allowing the digital circuitry to stay in a low power state by duty cycling to sleep. On whole, the operational circuitry may be configured to perform the various methods shown herein and below claimed, by reference to memory and/or by operation of application-specific circuitry and/or ASIC chips.

To implant LCP **100** inside a patient's body, an operator (e.g., a physician, clinician, etc.), may fix LCP **100** to the cardiac tissue of the patient's heart. To facilitate fixation, LCP **100** may include one or more anchors **116**. The one or more anchors **116** are shown schematically in FIG. **1**. The one or more anchors **116** may include any number of fixation or anchoring mechanisms. For example, one or more anchors **116** may include one or more pins, staples, threads, screws, helix, tines, and/or the like. In some embodiments, although not shown, one or more anchors **116** may include threads on its external surface that may run along at least a partial length of an anchor member. The threads may provide friction between the cardiac tissue and the anchor to help fix the anchor member within the cardiac tissue. In some cases, the one or more anchors **116** may include an anchor member that has a cork-screw shape that can be screwed into the cardiac tissue. In other embodiments, anchor **116** may include other structures such as barbs, spikes, or the like to facilitate engagement with the surrounding cardiac tissue.

In some examples, LCP **100** may be configured to be implanted on a patient's heart or within a chamber of the patient's heart. For instance, LCP **100** may be implanted within any of a left atrium, right atrium, left ventricle, or right ventricle of a patient's heart. By being implanted within a specific chamber, LCP **100** may be able to sense cardiac electrical signals originating or emanating from the specific chamber that other devices may not be able to sense with such resolution. Where LCP **100** is configured to be implanted on a patient's heart, LCP **100** may be configured to be implanted on or adjacent to one of the chambers of the heart, or on or adjacent to a path along which intrinsically generated cardiac electrical signals generally follow. In these examples, LCP **100** may also have an enhanced ability to sense localized intrinsic cardiac electrical signals and deliver localized electrical stimulation therapy.

In some instances, LCP **100** may be configured to deliver rate-adaptive pacing therapy to a patient's heart. For instance, LCP **100** may be configured to deliver electrical stimulation pulses to the heart of the patient on an on-going basis to help ensure that the patient's heart contracts in a safe and effective manner. LCP **100** may additionally sense one or more signals, for example using electrical sensing module **106** and/or mechanical sensing module **108**, and determine, based on the sensed one or more signals, whether to change the rate of delivery of the electrical stimulation pulses.

For example, based on the sensed one or more signals, LCP **100** may determine that there is less of a need for cardiac output, and may decrease the rate of delivery of the electrical stimulation pulses. In other instances, based on the one or more sensed signals, LCP **100** may determine that there is a need for increased cardiac output, and may increase the rate of delivery of the electrical stimulation pulses. Adjusting the rate of delivery of the electrical stimulation pulses based on the sensed one or more signals may extend the battery life of LCP **100** by only requiring higher rates of delivery of electrical stimulation pulses when the sensed one or more signals indicate there is a need for increased cardiac output. Additionally, adjusting the rate of delivery of the electrical stimulation pulses may increase a comfort level of the patient by more closely matching the rate of delivery of electrical stimulation pulses with the cardiac output need of the patient.

Where LCP **100** adjusts the rate of delivery of electrical stimulation pulses based on the sensed one or more signals, LCP **100** may in some cases determine a respiration rate based on the sensed one or more signals. Respiration rate may be indicative of a relative cardiac output need for the patient. For example, an increased respiration rate may indicate that there is a need for increased cardiac output, and a decreased respiration rate may indicate less of a need for cardiac output. Accordingly, and when so provided, LCP **100** may adjust the rate of delivery of the electrical stimulation pulses based on the determined respiration rate.

In at least some examples, LCP **100** may include a motion sensor (such as an accelerometer) and may determine a measure related to the respiration rate based on the sensed motion sensor signal. Where LCP **100** is implanted on a patient's heart or within the heart, the motion sensor signal may include signals indicative of movement related to a number of different causes. For instance, the motion sensor signal may include movement related to the gross movement of the patient, such as walking, bending, or other gross body movements. Additionally, the motion sensor signal may include movement related to the contraction of the heart, particularly when LCP **100** is implanted on or within the heart. Additionally, the motion sensor signal may include movement related to the inhalation and exhalation of the patient (i.e. respiration). For instance, as a patient breathes

in and out, the lungs apply different pressure to the heart and the intrathoracic pressure changes accordingly. This change in the intrathoracic pressure may cause changes in the shape and size of the various chambers of the heart, as well as the movement of the heart and the heart chambers. After inhalation, the intrathoracic pressure may be relatively higher, which may decrease the volume of blood that flows into one or more of the chambers of the heart during a cardiac cycle. Conversely, after exhalation, the intrathoracic pressure may be relatively lower, which may allow relatively more blood to enter the chambers of the heart during a cardiac cycle. These differences in the amount of blood flowing into and out of the heart and any movement of the heart or heart chambers due to the changes in intrathoracic pressure may be contained in the motion sensor signal.

Although an LCP serves as the platform for much of the below description and above detail, any implantable device having a motion sensor may take advantage of the presently described enhancements. Other devices may include drug or other substance delivery systems, neurostimulator or neuromodulation systems, and implantable cardiac monitoring systems, for example.

FIG. **2** shows an illustrative example of a system implanted in a patient. The patient **200** is shown upright, having a patient frame of reference highlighted at **202**. The patient has an implantable device **210** in the heart **204**. The implantable device is shown as a leadless cardiac pacemaker (LCP), and may take the form generally shown and described above. Alternatively, the implantable device **210** may be provided as an implantable recorder such as an implantable loop recorder or subcutaneous cardiac monitor. The implantable device **210** may instead be a neurostimulation apparatus for implantation in the brain, near the spine or in any other location where therapy may be useful. Although an LCP serves as the platform for much of the below description and above detail, any implantable device having a motion sensor may take advantage of the presently described enhancements.

The implantable system also includes a programmer **220** having (optionally) a programming head **222** for placement on the patient. For an LCP, and some other implantable devices, some configurations may use what is referred to as conducted communication within the patient tissue, which can be read by a programming head **222** placed on the patient. For other configurations, and/or for other devices, inductive or RF telemetry may be performed, with or without the programming head **222** on the patient.

The implantable device **210** is shown in the right ventricle of the heart **204**. As described above, the implantable device **210** includes a motion sensor. Such motion sensors may have several axes along which motion may be detected; typically there are three axes or dimensions. Because the exact position of the device **210** will vary for a given patient **200** based on the cardiac condition and implantation method for such a product, it is entirely likely that the frame of reference for the implanted device **210** will be different from the frame of reference for the patient. Thus, the patient has a frame of reference defined by axes Xp, Yp, and Zp, shown at **202**, while the device has a frame of reference defined by axes Xd, Yd, and Zd.

To facilitate ease of understanding for the physician of patient activity and/or position during a time of interest, the present inventors have recognized it would be useful for the device **210** to store a configuration of the motion sensor output that normalizes every such device for later interrogation. Thus a conversion matrix can be calculated for a particular patient **200** having a particular device, and the conversion matrix would be stored by the implant device **210** for later use during a programming session. Thus the output of a three dimensional motion sensor can be converted from the frame of reference **212** of the implantable device to the frame of reference **202** of the patient by storing the matrix:

a_{11}	a_{12}	a_{13}
a_{21}	a_{22}	a_{23}
a_{31}	a_{32}	a_{33}

The conversion from device axes Xd, Yd, and Zd to standardized or patient axes Xp, Yp, and Zp can occur according to these formulas:

$$Xp=a11*Xd+a12*Yd+a13*Zd$$

$$Yp=a21*Xd+a22*Yd+a23*Zd$$

$$Zp=a31*Xd+a32*Yd+a33*Zd$$

The matrix can be calculated by observing the output of the motion sensor as the patient assumes a variety of different postures; preferably at least two postures would be used to eliminate ambiguity; three or more postures may be used. To generate the matrix, it may be helpful to capture and average samples across a relatively long period of time—possibly several samples equally spaced across several cardiac cycles—to reduce the impact of the motion of the heart during the cardiac cycle, since such additional movement would show up as noise in the calculation. Such issues may arise more in a device residing entirely in the heart as opposed to devices, such as implantable loop recorders or patient monitors, or traditional pacemakers, that do not place the accelerometer in contact with the myocardium itself.

Storing the conversion matrix in the implantable device for later recall would allow any programmer, possessed by any physician, to determine what sort of activity or posture the patient had ongoing at the time of an event of interest. For example, if the patient suffers a syncopal episode, knowing the patient posture just before the episode may be helpful in determining what exactly happened. In another example, if a patient having an implantable device receives an inappropriate therapy, understanding the patient posture may aid in troubleshooting any difficulties with sensing that result from changing postures.

In another example, a patient does not receive inappropriate therapy, but an implantable device determines that malsensing occurred. Malsensing may be determined by, for example, determining that double detection, or other over-detection, or noise, has been identified. Troubleshooting such an event can be very difficult because the patient would be unaware of malsensing if no therapy is delivered. If malsensing is identified, however, the implantable device can call a function which records the output of the motion sensor at the time of malsensing. Using a normalized frame of reference, the physician may better be able to determine a root cause for malsensing. In one example, a subcutaneous implantable defibrillator, such as the S-ICD System™, from Cameron Health, Inc. and Boston Scientific Corporation, is used in conjunction with a leadless cardiac pacemaker as in FIGS. **1-2**, and if malsensing is identified by the subcutaneous implantable defibrillator (due to oversensing or noise), the subcutaneous implantable defibrillator requests that the leadless cardiac pacemaker record and/or transmit to the subcutaneous implantable defibrillator patient position or motion data at the time of the malsensing.

FIGS. **3-5** are flow diagrams for illustrative methods. FIG. **3** illustrates a method for reducing power consumption in an implantable device. At block **300**, the output of a motion sensor is monitored. The motion sensor may have multiple axes and separate outputs for each axis. Next, a least used or useful output of the motion sensor is identified at **302**. That least useful output is disabled at **304**. The monitoring, as noted, may include multiple axes such as axis A**1**, A**2** and A**3**, as noted at **310**. Monitoring **300** may occur in a controlled or ambulatory setting, and may include monitoring for multiple postures or activity, as indicated at **312**.

In a controlled setting, for example, the patient may be asked in clinic to assume a plurality of postures or perform selected activities. Illustrative postures may include sitting, standing, prone, lying on the back, recumbent, lying on the side (left/right), or any particular posture of interest for a given patient such as the posture the patient usually sleeps in. Illustrative physical activities that may be requested include walking, standing up or sitting down, rolling over, jogging or running, or an activity that the person engages in frequently such as a favorite exercise (elliptical machine, swimming, golf swing), or a work activity that is performed often (a mechanic emulating the movement to get under a vehicle, or a desk worker sitting at a desk and typing).

The identification of a least useful vector at **302** may be performed by monitoring for the lowest output axis of those enabled by the motion sensor. More complex analysis may be done by observing the change over time, for example, summing the sample-to-sample differences (or squares thereof) as noted at **320**. Sum of differences may be performed by observing outputs while in different postures or during active movement, rather than on a sample to sample basis. For example, an axis that show significant motion from sample to sample, but which does not provide a significant difference from one posture to another, or between outputs while the patient is at rest and active, may not be helpful in identifying patient movement or activity. The aim is to identify any axis which fails to provide useful data. Sometimes this will be indicated by an axis that provides only small signals.

After activities and/or postures are assessed, a temporary **332** or (semi) permanent **330** disabling of one or more axes may be performed. For "permanent" **330** disabling of an axis in the controlled or clinical setting, the analysis may be performed again in a subsequent programming session at a subsequent clinic visit. In some examples, if a malsensing or dangerous condition is identified by an implantable device, all axes of the implantable device motion sensor may be re-enabled to allow data capture associated with the malsensing or dangerous condition.

In an ambulatory setting, it may be useful to perform this process periodically or as changes are identified. For example, monitoring may be performed for 2 to 10 seconds and identification **302** and temporary disabling **304**/**332** may be performed. In this context, if the heart rate changes, or the remaining, selected axes show significant changes, the temporary disabling of one or more axes may be undone. Alternatively, if temporary **332** disabling of an axis is done, then after a set period of time, for example, one to thirty minutes (or more or less), the process restarts at block **300**.

In one example, data from one or more axis of an accelerometer may be ignored or turned off by the implantable system. As noted above, in use when an accelerometer output is taken, this may yield a plurality of outputs that can be run through a matrix of coefficients to obtain a measure of patient movement. To normalize the output of the accelerometer the corresponding matrix coefficients for those axes which are not deselected may be updated.

FIG. **4** shows another illustrative example. Here, the particular axes of a motion sensor are to be correlated with particular physiological parameters. In an example, a parameter is selected for analysis at **400**. Motion sensor output is observed at **402**, and the parameter and the motion sensor outputs are correlated at **404**. Once one or more axes are correlated to—or shown to be uncorrelated to—the selected parameter, a configuration is stored at **406**. The process may be repeated at **408** for multiple parameters or to analyze individual axes or combinations of axis within block **402**.

For example, a parameter such as cardiac contractility **410** can be selected at block **400**. Motion sensor outputs are observed at **402**, including selecting single or multiple axes at **420**. The correlation of the parameter to the selected axes may be performed by comparing the observed motion **402** to a second data input **432**. The second data input **432** for correlation **404** with cardiac contractility may be, for example, a cardiac electrogram or surface electrocardiogram, an imaging system, or a blood pressure monitor output, any of which will indicate when the cardiac muscle is in motion as myocardial contractions occur or blood pressure/flow rises and drops during the cardiac cycle. This correlation **404** can be used to show that one or more axes are not useful in monitoring the selected parameter, leading to deselection of an axis **442** as part of the configuration **406**. Correlation **404** may include setting a function **420** and relevant thresholds for storage during configuration step **406**. The configuration step **406** may also include programming the implantable device to deselect an axis and/or to store the function calculated at **430**.

In another example, the chosen parameter may be patient movement **412**. Again the motion sensor outputs may be monitored at **402** by selecting and deselecting combinations of the axes of the motion sensor. Correlation is again performed at **404**. Here the second data input for patient motion monitoring may come from an associated programmer, which would be used in a clinical setting to allow the user to indicate to the implanted device whether the patient is moving or not. Again the correlation **404** facilitates identification of the function **430** for analysis of the output (for example, setting threshold to determine whether the patient is active). The correlation **404** may also allow identification of one or more axes of the motion sensor that do not provide useful information for the function **430**. Again, the configuring step **406** may store data indicating which axis to deselect **442**, if any, and to program the implantable device **440** to accurately use the motion sensor output.

FIG. **5** shows another illustrative example. Here monitoring is performed at block **500** and cross correlation is performed at **502** against the outputs or other information provided by a second device **504**. Next a matrix is calculated at **506**, and a patient frame of reference matrix is stored in the implantable device at **508**. Monitoring **500** may be performed while the patient is moving **510** or in various postures **512**.

The second device **504** may be a programmer used to indicate which movements **510** or postures **512** the patient is engaged in or has assumed. The second device **504** may instead be a wearable accelerometer or motion sensor for the patient. In another example, the second device **504** may be a second implantable medical device such as a pacemaker, defibrillator, neuromodulation device, etc.

In a specific example, a sleep signature for the patient may be calculated, as noted at **520**. This may be performed as part

of a sleep study for the patient, where the device engages in a specific mode of repeated monitoring **500** over the course of a night to gather data allowing the motion sensor output to be repeatedly visited. Once a patient sleep signature **520** is generated, the implantable device may be able to positively determine that the patient is likely asleep. Such a determination can be used to disable rate adaptive pacing during the night for the patient, to reduce power consumed by analytics directed at rate adaptive pacing.

As discussed briefly above, the patient frame of reference matrix may be used in troubleshooting **530**. For example, sometimes events are detected by an implantable device such as a long pause, an arrhythmia such as a tachycardia, or excess noise. Any of these conditions, when identified by an implantable device, may be used to trigger data capture with the motion sensor to determine whether there is a postural or activity-related element to the anomaly.

In several of the above examples, significant data calculations are performed. To simplify implant device programming and electronics, or to reduce power usage in making complex calculations, data analysis may be performed by the external programmer after motion sensor outputs are telemetered out to the programmer. Alternatively, the implant device may perform its own data analysis.

A first non-limiting example takes the form of an implantable medical device comprising: a power source; a plurality of electrodes for use in one or more of biological signal monitoring or providing a electrical therapy; a motion sensor having at least first and second axes of sensitivity; and operational circuitry configured to control the use of the electrodes and motion sensor for one or more of capturing biological signal data and patient motion and providing electrical therapy; wherein the operational circuitry is configured to perform the following: monitoring an output from a motion sensor along at least first and second axes; identifying one of the first and second axes as providing less information than one or more other axes; and at least temporarily disabling the identified axis of the motion sensor.

A second non-limiting example takes the form of a device as in the first non-limiting example, wherein the operational circuitry is further configured such that the at least temporarily disabling step comprises disabling the identified axis for a predetermined period of time, and the operational circuitry is further configured to perform the following: re-enabling the temporarily disabled axis; and repeating the steps of monitoring, identifying and at least temporarily disabling steps.

A third non-limiting example takes the form of a device as in either of the first or second non-limiting examples, wherein the operational circuitry is further configured to perform the following: while the identified axis is disabled, monitoring the output of the motion sensor on one or more remaining axes; observing a change in output of the one or more remaining axes; and re-enabling the identified axis. A fourth non-limiting example takes the form of a device as in any of the first to third non-limiting examples, wherein the operational circuitry is further configured to use an output of the motion sensor from at least one axis which is not at least temporarily disabled to monitor activity of the patient. A fifth non-limiting example takes the form of a device as in any of the first four non-limiting examples, wherein the implantable medical device is configured as a leadless cardiac pacemaker for placement entirely inside the heart of a patient, wherein the operational circuitry is further configured to apply an algorithm for rate responsive pacing to determine a pacing rate for delivery of pacing pulses, and to deliver rate responsive pacing therapy to the patient using at least an output from the motion sensor.

A sixth non-limiting example takes the form of a device as in any of the first to fifth non-limiting examples, wherein the operational circuitry is configured to determine and store a conversion matrix for normalizing an output of the motion sensor to a patient frame of reference. A seventh non-limiting example takes the form of a device as in any of the first to sixth non-limiting examples, wherein the motion sensor has three axes.

An eighth non-limiting example takes the form of a method of initializing a device as in any of the first to seventh non-limiting examples, the method comprising: instructing a patient to perform a first activity with the implantable device implanted; instructing the implantable device to assess motion sensor outputs; instructing the patient to perform a second activity with the implantable device implanted; and instructing the implantable device to further assess motion sensor outputs. A ninth non-limiting example takes the form of a method as in the eighth non-limiting example, wherein the first activity and second activities are each one of: assuming a posture selected from the group consisting of sitting, standing, supine, prone, or a sleep position; or engaging in physical activity.

A tenth non-limiting example takes the form of an implantable medical device comprising: a power source; a plurality of electrodes for use in one or more of biological signal monitoring or providing a electrical therapy; a motion sensor having at least first and second axes of sensitivity; and operational circuitry configured to control the use of the electrodes and motion sensor for one or more of capturing biological signal data and patient motion and providing electrical therapy; wherein the operational circuitry is configured to perform the following: capturing a plurality of outputs of the motion sensor for at least first and second axes of the motion sensor; establishing a standard frame of reference for the patient using the outputs of the motion sensor.

An eleventh non-limiting example takes the form of an implantable device system comprising: the implantable medical device of the tenth non-limiting example, and an external programmer configured to communicate with the implantable medical device, wherein the programmer and implantable medical device are configured to cooperate in the capturing step by the programmer instructing a patient to assume a series of postures.

A twelfth non-limiting example takes the form of a system as in the eleventh non-limiting example, further comprising a second medical device having a motion sensor, wherein the programmer is configured to receive motion sensor data from each of the implantable medical device and the second medical device to establish a conversion matrix for converting an output of the implantable medical device to a patient standard frame of reference.

A thirteenth non-limiting example takes the form of a device as in the tenth non-limiting example, wherein the motion sensor has three axes. A fourteenth non-limiting example takes the form of a device as in either of the tenth or thirteenth non-limiting examples, wherein the implantable medical device is an implantable leadless cardiac pacemaker. A fifteenth non-limiting example takes the form of a device as in any of the tenth, thirteenth, or fourteenth non-limiting examples, wherein the operational circuitry is configured to determine that malsensing has occurred and record an output of the motion sensor in response to the malsensing.

A sixteenth non-limiting example takes the form of a method of operation in an implantable device, the implantable device comprising a motion sensor, the method comprising: monitoring an output from a motion sensor along at least first and second axes; identifying one of the first and second axes as providing less information than one or more other axes; and at least temporarily disabling the identified axis of the motion sensor.

A seventeenth non-limiting example takes the form of a method as in the sixteenth non-limiting example, wherein the implantable device is a leadless pacemaker configured for implantation within the heart of a patient. An eighteenth non-limiting example takes the form of a method as in either of the sixteenth or seventeenth non-limiting examples, wherein the motion sensor has three axes. A nineteenth non-limiting example takes the form of a method as in any of the sixteenth to eighteenth non-limiting examples, wherein the at least temporarily disabling step comprises disabling the identified axis for a predetermined period of time and the method comprises: re-enabling the temporarily disabled axis; and repeating the steps of monitoring, identifying and at least temporarily disabling steps.

A twentieth non-limiting example takes the form of a method as in any of the sixteenth to nineteenth non-limiting examples, further comprising: while the identified axis is disabled, monitoring the output of the motion sensor on one or more remaining axes; observing a change in output of the one or more remaining axes; and re-enabling the identified axis. A twenty-first non-limiting example takes the form of a method as in any of the sixteenth to twentieth non-limiting examples, further comprising using an output of the motion sensor from at least one axis which is not at least temporarily disabled to monitor activity of the patient. A twenty-second non-limiting example takes the form of a method as in the twenty-first non-limiting example further comprising applying an algorithm for rate responsive pacing to determine a pacing rate for delivery of pacing pulses to the patient using at least an output from the motion sensor, and delivering the rate responsive pacing to the patient. A twenty-third non-limiting example takes the form of a method as in the twenty-first non-limiting example, further comprising normalizing an output of the motion sensor to a patient frame of reference.

A twenty-fourth non-limiting example takes the form of a method of initializing an implantable device having a motion sensor comprising: instructing a patient to perform a first activity; performing the method of claim **16** to assess motion sensor outputs; instructing a patient to perform a second activity; and repeating the method of claim **16** to further assess motion sensor outputs. A twenty-fifth non-limiting example takes the form of a method as in the twenty-fourth non-limiting example, wherein the first activity and second activities are each one of: assuming a posture selected from the group consisting of sitting, standing, supine, prone, or a sleep position; or engaging in physical activity.

A twenty-sixth non-limiting example takes the form of a method of operation in an implantable device configured for placement inside the heart of a patient, the implantable device comprising a motion sensor, the method comprising: selecting a first parameter; observing at least first and second outputs of the motion sensor, the first and second outputs relating to respective first and second axes of measurement for the motion sensor; correlating at least one of the at least first and second outputs, or a combination thereof, to the first parameter; storing a first configuration of the at least first and second outputs of the motion detector corresponding to the first parameter; applying the first configuration to outputs of the motion sensor to monitor characteristics of the first parameter.

A twenty-seventh non-limiting example takes the form of a method as in the twenty-sixth non-limiting example, further comprising selecting a second parameter and repeating the observing, and correlating steps, and then: storing a second configuration of the at least first and second outputs of the motion detector corresponding to the second parameter; applying the second configuration to outputs of the motion sensor to monitor characteristics of the second parameter. A twenty-eighth non-limiting example takes the form of a method as in the twenty-seventh non-limiting example, wherein the first parameter is cardiac contractility, and the second parameter is patient motion; further comprising: using the first configuration to monitor the cardiac contractility of the patient and generate diagnostic data therefrom for use by a physician; and using the second configuration to monitor the activity level of the patient and facilitate a rate responsive pacing output regimen for the patient. A twenty-ninth non-limiting example takes the form of a method as in the twenty-eighth non-limiting example, further comprising the implantable device delivering the rate responsive pacing output regimen to the patient.

A thirtieth non-limiting example takes the form of a method as in the twenty-sixth non-limiting example, wherein the first parameter is patient motion and the method further comprises: delivering pacing therapy to the patient via the implantable medical device; and using the first configuration to facilitate a rate responsive pacing output regimen for the patient in which the rate at which pacing therapy is delivered adjusts in view of patient activity. A thirty-first non-limiting example takes the form of a method as in the twenty-sixth non-limiting example, wherein the implantable device includes a sensing circuit for sensing cardiac electrical signals of the patient, and the method further comprises: using a sensed cardiac electrical signal, determining that a cardiac event took place; using the stored configuration, analyzing one or more outputs from the motion sensor to determine a state of the parameter during the cardiac event.

A thirty-second non-limiting example takes the form of a method of operation in an implantable device configured for placement inside the heart of a patient, the implantable device comprising a motion sensor, the method comprising: capturing a plurality of outputs of the motion sensor for at least first and second axes of the motion sensor; establishing a standard frame of reference for the patient using the outputs of the motion sensor.

A thirty-third non-limiting example takes the form of a method as in the thirty-second non-limiting example, wherein the capturing step is performed by having the patient assume a series of postures. A thirty-fourth non-limiting example takes the form of a method as in the thirty-third non-limiting example, further comprising capturing an output of a second device while the patient assumes the series of postures, wherein the step of establishing a standard frame of reference is performed by comparing an output from the second device to the captured plurality of outputs of the motion sensor. A thirty-fifth non-limiting example takes the form of a method as in either of the thirty-third or thirty-fourth non-limiting example, wherein the step of having the patient assume a series of postures is performed by having a programmer provide an instruction for the patient and await an indication that the patient has complied.

Each of these non-limiting examples can stand on its own, or can be combined in various permutations or combinations with one or more of the other examples.

The above 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 can be practiced. These embodiments are also referred to herein as "examples." Such examples can include elements in addition to those shown or described. However, the present inventors also contemplate examples in which only those elements shown or described are provided. Moreover, the present inventors also contemplate examples using any combination or permutation of those elements shown or described (or one or more aspects thereof), either with respect to a particular example (or one or more aspects thereof), or with respect to other examples (or one or more aspects thereof) shown or described herein.

In the event of inconsistent usages between this document and any documents so incorporated by reference, the usage in this document controls.

In this document, the terms "a" or "an" are used, as is common in patent documents, to include one or more than one, independent of any other instances or usages of "at least one" or "one or more." Moreover, 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.

Method examples described herein can be machine or computer-implemented at least in part. Some examples can include a computer-readable medium or machine-readable medium encoded with instructions operable to configure an electronic device to perform methods as described in the above examples. An implementation of such methods can include code, such as microcode, assembly language code, a higher-level language code, or the like. Such code can include computer readable instructions for performing various methods. The code may form portions of computer program products. Further, in an example, the code can be tangibly stored on one or more volatile, non-transitory, or non-volatile tangible computer-readable media, such as during execution or at other times. Examples of these tangible computer-readable media can include, but are not limited to, hard disks, removable magnetic or optical disks, magnetic cassettes, memory cards or sticks, random access memories (RAMs), read only memories (ROMs), and the like.

The above description is intended to be illustrative, and not restrictive. For example, the above-described examples (or one or more aspects thereof) may be used in combination with each other. Other embodiments can be used, such as by one of ordinary skill in the art upon reviewing the above description.

The Abstract is provided to comply with 37 C.F.R. § 1.72(b), to allow the reader to quickly ascertain the nature of the technical disclosure. It is submitted with the understanding that it will not be used to interpret or limit the scope or meaning of the claims.

Also, in the above Detailed Description, various features may be grouped together to streamline the disclosure. This should not be interpreted as intending that an unclaimed disclosed feature is essential to any claim. Rather, inventive subject matter may lie in less than all features of a particular disclosed embodiment. Thus, the following claims are hereby incorporated into the Detailed Description as examples or embodiments, with each claim standing on its own as a separate embodiment, and it is contemplated that such embodiments can be combined with each other in various combinations or permutations. The scope of the invention should be determined with reference to the appended claims, along with the full scope of equivalents to which such claims are entitled.

What is claimed is:

1. A method of operation in an implantable device configured for placement inside the heart of a patient, the implantable device comprising a motion sensor, the method comprising:

selecting a first parameter;

observing at least first and second outputs of the motion sensor, the first and second outputs relating to respective first and second axes of measurement for the motion sensor;

correlating at least one of the at least first and second outputs, or a combination thereof, to the first parameter;

storing a first configuration of the at least first and second outputs of the motion detector for measuring the first parameter;

applying the first configuration to outputs of the motion sensor to monitor characteristics of the first parameter.

2. The method of claim **1** further comprising selecting a second parameter and repeating the observing, and correlating steps, and then:

storing a second configuration of the at least first and second outputs of the motion detector corresponding to the second parameter;

applying the second configuration to outputs of the motion sensor to monitor characteristics of the second parameter.

3. The method of claim **2** wherein the first parameter is cardiac contractility, and the second parameter is patient motion; further comprising:

using the first configuration to monitor the cardiac contractility of the patient and generate diagnostic data therefrom for use by a physician; and

using the second configuration to monitor the activity level of the patient and facilitate a rate responsive pacing output regimen for the patient.

4. The method of claim **3** further comprising the implantable device delivering the rate responsive pacing output regimen to the patient.

5. The method of claim **1** wherein the first parameter is patient motion and the method further comprises:

delivering pacing therapy to the patient via the implantable medical device; and

using the first configuration to facilitate a rate responsive pacing output regimen for the patient in which the rate at which pacing therapy is delivered adjusts in view of patient activity.

6. The method of claim **1** wherein the implantable device includes a sensing circuit for sensing cardiac electrical signals of the patient, and the method further comprises:

using a sensed cardiac electrical signal, determining that a cardiac event took place;

using the stored configuration, analyzing one or more outputs from the motion sensor to determine a state of the parameter during the cardiac event.

7. The implantable medical device of claim **1** wherein:

the operational circuitry is configured to select a second parameter, observe the at least first and second outputs of the motion sensor, and correlate at least one of the at least first and second outputs, or a combination thereof, to the second parameter, and then:

store a second configuration of the at least first and second outputs of the motion detector corresponding to the second parameter, and apply the second configuration

to outputs of the motion sensor to monitor characteristics of the second parameter.

8. The implantable medical device of claim **7** wherein:

the first parameter is cardiac contractility, and the second parameter is patient motion;

the operational circuitry is configured to use the first configuration to monitor the cardiac contractility of the patient and generate diagnostic data therefrom for use by a physician; and

the operational circuitry is configured to use the second configuration to monitor the activity level of the patient and facilitate a rate responsive pacing output regimen for the patient.

9. The implantable medical device of claim **8** wherein the operational circuitry is configured to deliver the rate responsive pacing output regimen to the patient using the electrodes.

10. The method of claim **1** further comprising obtaining a data input from a source other than the motion sensor in order to establish the correlation, and the first configuration defines a relationship, established using the second data input, between the outputs of the motion sensor and the first parameter, wherein the first parameter is cardiac contractility and the data input comprises information from one of a cardiac electrogram, a surface electrocardiogram, an imaging system, or a blood pressure monitor.

11. The method of claim **1** further comprising obtaining a data input from a source other than the motion sensor in order to establish the correlation, and the first configuration defines a relationship, established using the second data input, between the outputs of the motion sensor and the first parameter, wherein the first parameter is patient movement, and the data input is obtained from a programmer adapted to communicate with the implantable medical device, wherein the data input is an indication from the programmer whether the patient is moving or not.

12. An implantable medical device comprising:

a power source;

a plurality of electrodes for use in one or more of biological signal monitoring or providing an electrical therapy;

a motion sensor having at least first and second axes of sensitivity; and

operational circuitry configured to control the use of the electrodes and motion sensor for one or more of: capturing biological signal data, capturing patient motion data, and/or providing electrical therapy;

wherein:

the operational circuitry is configured to select a first parameter;

the operational circuitry is configured to observe at least first and second outputs of the motion sensor, the first and second outputs relating to respective first and second axes of measurement for the motion sensor;

the operational circuitry is configured to correlate at least one of the at least first and second outputs, or a combination thereof, to the first parameter;

the operational circuitry is configured to store a first configuration of the at least first and second outputs of the motion detector for measuring the first parameter; and

the operational circuitry is configured to apply the first configuration to outputs of the motion sensor to monitor characteristics of the first parameter.

13. The implantable medical device of claim **12** wherein:

the first parameter is patient motion;

the operational circuitry is configured to deliver pacing therapy to the patient using the electrodes; and

the operational circuitry is configured to use the first configuration to facilitate a rate responsive pacing output regimen for the patient in which the rate at which pacing therapy is delivered adjusts in view of patient activity.

14. The implantable medical device of claim **12** wherein:

the operational circuitry is configured to use signals from the electrodes for sensing cardiac electrical signals of the patient;

the operational circuitry is configured to use a sensed cardiac electrical signal to determine that a cardiac event took place; and

the operational circuitry is configured to use the stored configuration to analyze one or more outputs from the motion sensor to determine a state of the parameter during the cardiac event.

15. An implantable leadless cardiac pacemaker taking the form of an implantable medical device as in claim **12**.

16. An implantable cardiac monitor taking the form of an implantable medical device as in claim **12**.

17. An implantable neuromodulation device taking the form of an implantable medical device as in claim **12**.

18. The implantable medical device of claim **12** wherein the operational circuitry is configured to obtain a data input from a source other than the motion sensor in order to establish the correlation, and the first configuration defines a relationship, established using the data input, between the outputs of the motion sensor and the first parameter, wherein the first parameter is cardiac contractility and the data input comprises information from one of a cardiac electrogram, a surface electrocardiogram, an imaging system, or a blood pressure monitor.

19. The implantable medical device of claim **12** wherein the operational circuitry is configured to obtain a data input from a source other than the motion sensor in order to establish the correlation, and the first configuration defines a relationship, established using the data input, between the outputs of the motion sensor and the first parameter, wherein the first parameter is patient movement, and the data input is obtained from a programmer adapted to communicate with the implantable medical device, wherein the data input is an indication from the programmer whether the patient is moving or not.

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专利名称(译)	可植入医疗设备中运动传感器的空间配置		
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摘要(译)

具有运动传感器的可植入设备。在一些示例中，为可植入设备生成配置，以在能量保持模式下使用运动传感器，其中运动传感器的一个或多个检测轴被禁用或忽略。在一些示例中，分析沿着多个轴的运动传感器输出以确定哪些轴最佳地对应于某些患者参数，包括患者运动/活动和/或心脏收缩性。在其他示例中，在患者移动或姿势上观察运动传感器的输出，以产生转换参数以相对于植入设备的运动传感器的输出确定患者标准参照系。