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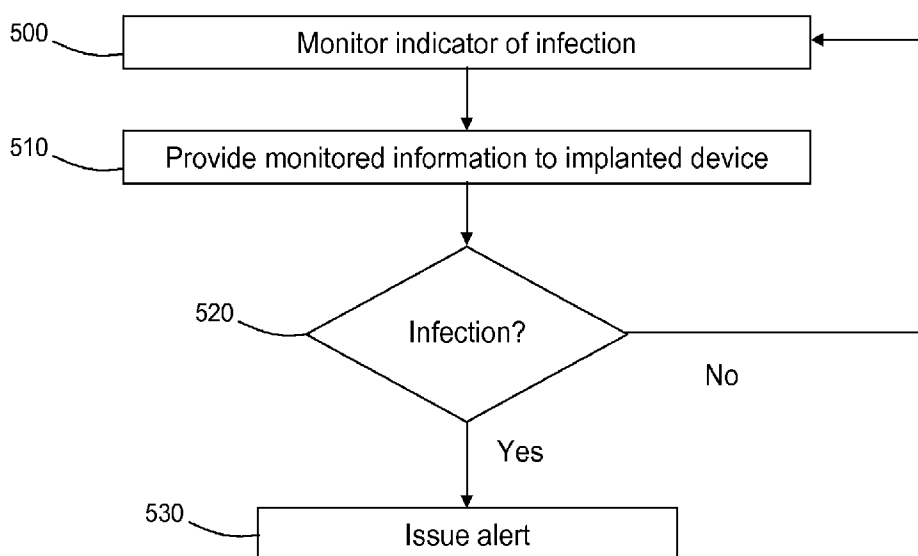


FIG. 7

(57) Abstract: A method includes monitoring an indicator of infection in proximity to an implanted active therapy delivering medical device and providing information regarding the monitored indicator to the implanted medical device. The method further includes determining whether the information regarding the monitored indicator is indicative of infection in proximity to the implanted medical device.

WO 2008/130406 A1

## INFECTION MONITORING

### FIELD

- [01] This disclosure relates, *inter alia*, to implantable medical devices. More particularly, it relates to systems, devices and methods for monitoring infection in proximity to medical devices implanted in patients.

### BACKGROUND

- [02] Infection associated with implantation of medical devices is a serious health and economic concern. Today, infections associated with implanted medical devices are not very common due to care and precautions taken during surgical implantation of the devices. However, when infection associated with an implanted medical device (IMD) does occur, explanting the device is often the only appropriate course of action.
- [03] For IMDs having a battery powered component, such as implantable cardiac pacemakers, cardioverter/defibrillators having pacing capabilities, other electrical stimulators including spinal cord, deep brain, nerve, and muscle stimulators, infusion devices, cardiac and other physiologic monitors, cochlear implants, etc., the battery powered component is typically enclosed in a housing that is implanted subcutaneously at a surgically prepared site, referred to as a "pocket". Associated devices, such as elongated medical electrical leads or drug delivery catheters, extend from the pocket to other subcutaneous sites or deeper into the body to organs or other implantation sites.
- [04] Surgical preparation and implantation are conducted in a sterile field, and the IMD components are packaged in sterile containers or sterilized prior to introduction into the sterile field. However, despite these precautions, there always is a risk of introduction of microbes into the pocket. Surgeons therefore typically apply

disinfectant or antiseptic agents to the skin at the surgical site prior to surgery, directly to the site before the incision is closed, and prescribe oral antibiotics for the patient to ingest during recovery.

- [05] Despite these precautions, infections do occur. In addition, once the pocket becomes infected, the infection can migrate along the lead or catheter to the heart, brain, spinal canal or other location in which the lead or catheter is implanted. Such a migrating infection can become intractable and life-threatening, requiring removal of the IMD in the pocket and associated devices, such as leads and catheters. Removal of a chronically implanted lead or catheter can be difficult and dangerous. Accordingly, aggressive systemic drug treatment is prescribed to treat such infections. However, early detection of infection associated with implanted medical devices may allow for earlier intervention, resulting in fewer device explants.

#### SUMMARY

- [06] The present disclosure describes, *inter alia*, systems, devices and methods that can be used to monitor an infection in proximity to an implantable medical device, such as an active therapy delivering medical device.
- [07] In an embodiment, a method for monitoring an indicator of infection is described. The method includes monitoring an indicator of infection in proximity to an implanted active therapy delivering medical device and providing information regarding the monitored indicator to the implanted medical device. The method further includes determining whether the information regarding the monitored indicator is indicative of infection in proximity to the implanted medical device.
- [08] By providing devices, systems and methods that allow for monitoring of infection in proximity to an implanted active therapy delivering medical device, early intervention and treatment may be administered, which may result in fewer device explants. Such methods, systems and devices, not only can serve to reduce costly

medical explant surgery but also can provide implant patients with added peace of mind. These and other advantages will be readily understood from the following detailed descriptions when read in conjunction with the accompanying drawings.

#### BRIEF DESCRIPTION OF THE DRAWINGS

- [09] **FIG. 1** is a diagrammatic representation of a perspective view of an environment of an infusion system implanted in a patient.
- [10] **FIG. 2** is a diagrammatic representation of a perspective view of an environment of an electrical signal generator system implanted in a patient
- [11] **FIGs. 3A-D** are a diagrammatic representations of a perspective views of environments of medical devices implanted in patients.
- [12] **FIG. 4** is a diagrammatic representation of an external device in wireless communication with an implantable medical device.
- [13] **FIGs. 5A-B** is a diagrammatic representation of a side view (**5A**) and back view (**B**) of an implantable medical device system having sensor(s) in proximity to the implantable device.
- [14] **FIG. 6** is a schematic block diagram of representative components of a representative implantable medical device.
- [15] **FIG. 7** is a flow diagram of a representative method.
- [16] **FIGs. 8A-C** are schematic block diagrams of a representative implantable medical devices or systems.
- [17] The drawings are not necessarily to scale. Like numbers used in the figures refer to like components, steps and the like. However, it will be understood that the use of a

number to refer to a component in a given figure is not intended to limit the component in another figure labeled with the same number.

#### DETAILED DESCRIPTION

- [18] In the following detailed description, reference is made to the accompanying drawings that form a part hereof, and in which are shown by way of illustration several specific embodiments of devices, systems and methods. It is to be understood that other embodiments are contemplated and may be made without departing from the scope or spirit of the present invention. The following detailed description, therefore, is not to be taken in a limiting sense.
- [19] All scientific and technical terms used herein have meanings commonly used in the art unless otherwise specified. The definitions provided herein are to facilitate understanding of certain terms used frequently herein and are not meant to limit the scope of the present disclosure.
- [20] As used in this specification and the appended claims, the singular forms “a”, “an”, and “the” encompass embodiments having plural referents, unless the content clearly dictates otherwise. As used in this specification and the appended claims, the term “or” is generally employed in its sense including “and/or” unless the content clearly dictates otherwise.
- [21] As used herein, “active therapy delivering implantable medical device” or the like means an implantable medical device that includes a power source and electronics operably coupled to the power source to control delivery of therapy to a patient. Non-limiting examples of active therapy delivering implantable medical devices include implantable infusion devices and implantable electrical signal generators, such as cardiac defibrillators, pacemakers, neurostimulators, gastric stimulators, and cochlear implants. Active implantable medical devices typically are used in conjunction with associated implantable medical devices, such as catheters or leads.

- [22] Unless otherwise indicated, all numbers expressing feature sizes, amounts, and physical properties used in the specification and claims are to be understood as being modified in all instances by the term “about.” Accordingly, unless indicated to the contrary, the numerical parameters set forth in the foregoing specification and attached claims are approximations that can vary depending upon the desired properties sought to be obtained by those skilled in the art utilizing the teachings disclosed herein.
- [23] The recitation of numerical ranges by endpoints includes all numbers subsumed within that range (*e.g.* 1 to 5 includes 1, 1.5, 2, 2.75, 3, 3.80, 4, and 5) and any range within that range.
- [24] The present disclosure describes, *inter alia*, systems, devices and methods that may be used to monitor infection in proximity to an implanted active therapy delivering medical device. Referring to **FIGs. 1** and **2**, general representative environments for implanted active therapy delivering medical devices **1** and associated devices **20** are shown. Active medical device **1** is subcutaneously implanted in an abdominal region of a patient. A distal portion of associated device **20** is intrathecally inserted into the patient’s spinal canal through a lumbar puncture and advanced rostrally to a desired location (**FIG. 1**) or epidurally placed along a suitable location of spinal cord (**FIG. 2**). Proximal end of associated device **20** is tunneled subcutaneously to location of active device **1**, where it may be connected to active device **1**. While distal portion of associated device **20** is shown in **FIGs. 1** and **2** as being located in or on spinal cord, it will be understood that associated device **20** may be placed at any location in patient for which it is desirable to administer therapy generated or delivered by active medical device **1**.
- [25] In the embodiment shown in **FIG. 1**, active implantable device **1** is an infusion device, and associated device **20** is a catheter. Catheter **20** is typically a flexible tube with a lumen running from the proximal end of catheter **20** to one or more delivery regions that are typically located at the distal portion of catheter **20**. Proximal portion of catheter **20** is connected to infusion device **20**. Distal portion of catheter

**20** is positioned at a target location in the patient to deliver fluid containing therapeutic agent from infusion device **1** to patient through a delivery region of catheter **20**. Infusion device **1**, such as Medtronic Inc.'s SynchroMed™ II implantable programmable pump system, includes a reservoir (not shown) for housing a therapeutic substance and a refill port **45** in fluid communication with reservoir. The reservoir may be refilled by percutaneously inserting a needle (not shown) into patient such that needle enters refill port **45**, and fluid containing therapeutic substance may be delivered into reservoir from needle via refill port **45**. Infusion device **1** shown in **FIG. 1** also includes a catheter access port **30** that is in fluid communication with the catheter **20**. Fluid may be injected into or withdrawn from patient through catheter **20** via catheter access port **30** by percutaneously inserting a needle into access port **30**. Each entry of needle across patient's skin to gain access refill port **45** or access port **30** results in the possibility of infection in proximity to the active medical device **1**.

- [26] In the embodiment shown in **FIG. 2**, active implantable device **1** is an electrical signal generator, such as Medtronic Inc.'s Restore™ Advanced implantable neurostimulator, and associated devices **20**, **20'** are a lead extension **20** and lead **20'**. Lead **20'** includes one or more electrical contacts (not shown) on its proximal end portion and one or more electrodes on its distal end portion **26**. The contacts and electrodes are electrically coupled via wires running through lead **20'**. Electrical signals generated by the signal generator **1** may be delivered to lead **20** through the contacts and then to the patient through the electrodes. As shown in **FIG. 2**, lead **20'** may be connected to signal generator **1** through a lead extension **20**. Extension **20** includes one or more contacts at the proximal and distal end portions that are electrically coupled through wires running through extension **20**. Of course it will be understood that with some systems lead **20'** may be directly connected to electrical signal generator **1** without use of a lead extension **20**. It will be further understood that more than one lead **20'** or lead extension **20** may be employed per signal generator **1**.

- [27] While **FIGs. 1** and **2** depict systems infusion devices and electrical signal generators, it will be understood that the teachings described herein may be applicable to virtually any known or future developed active implantable therapy delivering medical device.
- [28] Referring to **FIG. 3**, alternative locations for implanting a medical device **1** are shown. As depicted in **FIG. 3A**, device **1** may be implanted in the pectoral region **7** of a patient. Alternatively, device **1** may be implanted in the head of a patient, more specifically behind the patient's ear (**FIG. 3B**), in the patient's abdomen (**FIG. 3C**) or in the patient's lower back or buttocks (**FIG. 3D**). Of course, device **1** may be placed in any medically acceptable location in patient.
- [29] Referring to **FIG. 4**, an external device **40** in wireless communication with implantable device **1** is shown. External device **40** may communicate with implantable device **1** through patient's skin, which is represented by the dashed line in **FIG. 4**. In various embodiments implantable device **1** carries out the various infection monitoring methods, or portions thereof, described herein. In some other embodiments the combination of implantable device **1** and external device **40** carry out the various infection monitoring methods, or portions thereof, described herein. In various embodiments, where implantable device **1** is a programmable device, external device **40** may be a programmer device, such as Medtronic Inc.'s N'Vision™ clinician programmer. Of course external device may be any device capable of wirelessly communicating with implantable device **1**, such as a patient programmer, a computer, a personal data assistant, or the like. As shown in **FIG. 4**, implantable device **1** contains a wireless transmitter or receiver **18**, and external device **40** contains a wireless transmitter or receiver **18** to allow implantable device **1** and external device **40** to communicate. External device **40** and implantable device **1** may be capable of one-way (external device **40** to implantable device **1** or implantable device **1** to external device **40**) or two-way communication.
- [30] Referring to **FIG. 5**, sensor(s) **50**, **50'** associated with implantable active medical device **1** is shown. **FIG. 5A** is a side view of a representative active device **1** and

associated device 20. FIG. 5B is a back view of a representative active device 1. One or more sensor 50, 50' may be located in proximity to device 1; *e.g.*, disposed on, in, or near housing 60 of device 1. Sensor 50, 50' may be any device capable of detecting and transmitting information regarding an indicator of infection to device 1. If housing 60 is hermetically sealed, feedthroughs (not shown) may be used to provide electrical connectivity through housing 60 while maintaining the hermetic seal. While not shown, it will be understood that one or more sensor capable of detecting an indicator of infection may be located on, in, or about accessory device 20. Examples of physical or chemical stimuli that may serve as indicators of infection are temperature, impedance, pH, and biological markers of infection.

- [31] Changes in temperature in proximity to implanted device 1 may be used as an indicator of infection in proximity to device 1. The temperature of body tissue at a site of infection is generally greater than that of body tissue at a location removed from the site of infection. Accordingly, an increase in temperature in proximity to an implanted medical device 1 may serve as an indicator of infection. Any suitable sensor 50, 50' capable of detecting temperature or changes in temperature may be employed. For example, temperature sensor 50, 50' may include a thermocouple, a thermistor, a junction-based thermal sensor, a thermopile, a fiber optic detector, an acoustic temperature sensor, a quartz or other resonant temperature sensor, a thermo-mechanical temperature sensor, a thin film resistive element, or the like.
- [32] Changes in impedance of tissue in proximity to implanted device 1 may be used as an indicator of infection in proximity to device 1. For example, an increase in fluid in tissue is often observed at a site of an infection. Accordingly, a decrease in impedance of tissue in proximity may serve as an indicator of infection. In the case of impedance measurement, detection or monitoring, sensors 50, 50' are electrodes. Impedance may be measured between two electrodes. Current or voltage is applied between the electrodes with one electrode at any given time serving as a source and the other serving as a sink. In various embodiments, electrodes will be positioned at opposing surfaces of housing 60 of device 1. In other embodiments, one electrode may be located on accessory device 20, *e.g.* on a lead, and one may be located on

housing of device **1**. Alternatively, one electrode may be located on accessory device **20** and housing **60** of device **1** may serve as a return electrode, in a manner similar to unipolar signal generators. Further, it will be understood that more than one electrode pair may be employed to monitor impedance.

- [33] In instances where device **1** is an electrical signal generator, the electrical components used for generating therapeutic electrical signals may also be used for generating signals for impedance monitoring. In instances where device **1** is not an electrical signal generator, *e.g.* device **1** is an infusion pump, components capable of generating appropriate electrical signals for testing impedance of body tissue may be incorporated into device **1**. Any impedance detection components or circuitry may be employed. For example, an ohm meter or a wheatstone bridge design may be used to measure or detect changes in impedance or resistance. Examples of additional suitable components or circuitry are described in, for example, the following patents and applications assigned to Medtronic, Inc.: US 2006/0259079; US 2006/0036186; US 2004/0162591; US 2003/0176807; US 5,876,353; US 5,824,029; and US 5,282,840.
- [34] Changes in pH in proximity to implanted device **1** may be used as an indicator of infection in proximity to device **1**. As pH may serve as a general indicator of the state of a tissue, a change in pH may be indicative of infection. Accordingly, a sudden or gradual change in pH in proximity to an implanted medical device **1** may serve as an indicator of infection. Any suitable sensor **50**, **50'** capable of detecting pH or changes in pH may be employed.
- [35] Any biological markers of infection may be detected in accordance with the teachings presented herein. Non-limiting examples of biological markers of infection include viral, fungal, or bacterial proteins or nucleic acids or fragments thereof. As most infections associated with implantable medical devices appear to be due to infection due to *Staphylococcus aureus*, *Staphylococcus epidermis*, *Pseudomonas aeruginosa* and *Candidia* Sp., detection of proteins, nucleic acids, or fragments thereof of such microorganisms may be beneficial. Alternatively,

detection of indicators of an immune response may be detected. For example, an increase in a pro-inflammatory cytokine. Non-limiting examples of proinflammatory cytokines include tumor necrosis factor (TNF; also known as TNF $\alpha$  or cachectin), interleukin (IL)-1 $\alpha$ , IL-1 $\beta$ , IL-2, IL-5, IL-6, IL-8, IL-15, IL-18, interferon  $\gamma$  (IFN- $\gamma$ ); platelet-activating factor (PAF), thromboxane; soluble adhesion molecules; vasoactive neuropeptides; phospholipase A2; plasminogen activator inhibitor (PAI-1); free radical generation; neopterin; CD14; prostacyclin; neutrophil elastase; protein kinase; monocyte chemotactic proteins 1 and 2 (MCP-1, MCP-2); macrophage migration inhibitory factor (MIF), high mobility group box protein 1 (HMGB-1), and other known factors. Indication of an immune response may also be detected by an decrease in an anti-inflammatory cytokine in proximity to device 1. Non-limiting examples of anti-inflammatory cytokines include IL-4, IL-10, IL-17, IL-13, IL-1 $\alpha$ , and TNF $\alpha$  receptor. It will be recognized that some of proinflammatory cytokines may act as anti-inflammatory cytokines in certain circumstances, and vice-versa. Such cytokines are typically referred to as pleiotropic cytokines. An immune response may also be detected by measuring changes (baseline versus after device implant or other event, a first point after device implant or other event versus a second point after device implant or other event, etc.) in the presence of other factors involved in an immune response. Non-limiting examples of such other factors include TGF, PDGF, VEGF, EGF, FGF, I-CAM, and nitric oxide. In addition, an immune response may be detected by changes in chemokines, such as 6cKine and MIP3beta, and chemokine receptors, including CCR7 receptor. Further, an immune response may be measured by changes in immune cell population (upregulated Langerhans cells, dendritic cells, lymphocytes), or immune cell surface co-stimulatory molecules (Major Histocompatibility, CD80, CD86, CD28, CD40). An immune response may also be detected by measuring changes in other factors involved in the inflammatory cascade, for example in the signal transduction cascades including factors such as NF $\kappa$ -B, Egr-1, Smads, toll-like receptors, and MAP kinases. In addition, an immune response may be detected by a change in the presence of an exogenous antigen believed to have caused an inflammatory response, such as, *e.g.*, a bacteria, a virus, or a fungus.

- [36] Any sensor capable of detecting such biological markers indicative of infection may be used. In various embodiments, a biosensor is used to detect the presence of a molecule in proximity to implanted device **1**. Any known or future developed biosensor may be used. The biosensor may have, *e.g.*, an enzyme, an antibody, a receptor, or the like operably coupled to, *e.g.*, a suitable physical transducer capable of converting the biological signal into an electrical signal. In some situations, receptors or enzymes that reversibly bind the molecule being detected may be preferred. In various embodiments, sensor **50**, **50'** includes an electrode with an ion selective coating that is capable of directly transducing the amount of a particular substance. An example of this type of transducer is described in the paper "Multichannel semiconductor-based electrodes for in vivo electrochemical and electrophysiological studies in rat CNS" by Craig G. van Home, Spencer Bement, Barry J. Hoffer, and Greg A. Gerhardt, published in Neuroscience Letters, 120 (1990) 249-252. In various embodiments, sensor **50**, **50'** may be a sensor as described in, *e.g.*, U.S. Pat. No. 5,978,702, entitled TECHNIQUES OF TREATING EPILEPSY BY BRAIN STIMULATION AND DRUG INFUSION or U.S. 2005/0209513, entitled COLLECTING SLEEP QUALITY INFORMATION VIA A MEDICAL DEVICE, filed Apr. 15, 2004, and published September 22, 2005. Modifications of the teachings presented in the above-cited references may be made to account for one or more biological marker of infection.
- [37] For certain biological markers, *e.g.* proteins or nucleic acids or fragments thereof of microorganisms responsible for infection, merely the presence of such markers may be indicative of an infection. For other markers that may be present in a patient lacking an infection, *e.g.* cytokines and chemokines, increases or decreases in the levels of such markers may be indicative of an infection.
- [38] For the above-discussed indicators of infection or other indicator of infection, a determination of the presence of infection in proximity to implanted device **1** may be made in any suitable fashion. For example, a determination of infection may be made if a given indicator is detected at, above or below a predetermined threshold value. For example, if a temperature of 101°F (38.3 C) is detected, a determination

may be made that an infection is present in proximity to implanted device **1**. Alternatively or in addition, a determination of infection may be made if a given indicator is detected at, above or below a predetermined value for a predetermined period of time. For example, if a temperature of 100°F (37.8 C) or greater is detected for two hours or more is detected for two hours or more, a determination may be made that an infection is present in proximity to implanted device **1**. Of course other types of trends in information regarding indicators of infection may be used advantageously to improve the accuracy of determinations of infections in proximity to an implanted medical device. Additional information regarding use of thresholds determining infection in proximity to an implantable medical device is provided in US Patent Application Serial No. 11/737,180, entitled “Indicator Metrics For Infection Monitoring”, filed on even date herewith, naming Martin Gerber and John Rondoni as inventors, and having P0028530.00 as an attorney docket number, which application is hereby incorporated herein by reference in its entirety to the extent it does not conflict with the disclosure presented herein.

- [39] For the above-discussed indicators of infection or other indicator of infection, it may be desirable to compare levels of the indicators at a location in proximity to device **1** and at a location removed from device. Such comparisons may allow for a reduction in false positive detections. For example, elevation in temperature in proximity to device **1** may be due to localized infection or may be due to increased activity of the patient; increases in inflammatory cytokines in proximity to the device may be due to localized infection or a more general immune response; etc. By comparing the level of an indicator of infection in proximity to an implanted device to the level at a location removed from the device, a more accurate determination of whether an infection is present in proximity to the device may be made. Additional information regarding monitoring an indicator of infection at two locations is provided in US Patent Application Serial No. 11/737,171, entitled “Implantable Therapy Delivery System Having Multiple Temperature Sensors”, filed on even date herewith, naming Martin Gerber and John Rondoni as inventors, and having P0028539.00 as an attorney docket number, which application is hereby incorporated herein by

reference in its entirety to the extent it does not conflict with the disclosure presented herein.

- [40] Information regarding a first indicator of infection may be used to determine whether an infection is present in proximity to the implanted device **1**. In addition, one or more second indicators of infection may be used to determine whether the indication based on the first indicator is accurate. Additional information regarding infection monitoring using two or more indicators of infection is provided in US Patent Application Serial No. 11/737,181, entitled “Multi-Parameter Infection Monitoring”, filed on even date herewith, naming Martin Gerber and John Rondoni as inventors, and having P0028531.00 as an attorney docket number, which application is hereby incorporated herein by reference in its entirety to the extent it does not conflict with the disclosure presented herein.
- [41] Referring to **FIG. 6**, some representative electronic components of an implantable medical device **1** according to various embodiments are shown in block form. Active implantable medical device **1** as depicted in the embodiment shown in **FIG. 6** includes a clock **100**, a processor **110**, a memory **120**, a therapy output or delivery component **130**, a telemetry component **140**, a sensor **150**, a power management module **160**, a power source **170**, an alert module **185**, and a system reset module **190**. Other components of active implantable medical device **1** can include, e.g., a diagnostics module (not shown). All components except the power source **170** can be configured on one or more Application Specific Integrated Circuits (ASICs) or may be one or more discrete components, or a combination of both. Also, all components, except the clock and power source are connected to bi-directional data bus **180** that is non-multiplexed with separate address and data lines.
- [42] Processor **110** may be synchronous and typically operates on low power, such as Motorola 68HC11 synthesized core operating with a compatible instruction set. Clock **100** counts the number of seconds since a fixed date for date/time stamping of events and may be used for therapy control. Memory **120** includes memory sufficient for operation of device **1**, such as volatile Random Access Memory (RAM)

for example static RAM, nonvolatile Read Only Memory (ROM), Electrically Erasable Programmable Read Only Memory (EEPROM) for example Flash EEPROM, and register arrays configured on ASICs. Direct Memory Access (DMA) is available to selected modules such as telemetry module **140** or sensor module **150**, so that the selected modules can request control of data bus **180** and write data directly to memory **120** bypassing processor **110**. System Reset **190** controls operation of ASICs and modules during power-up of device **1**, so ASICs and modules registers can be loaded and brought on-line in a stable condition.

- [43] Telemetry **140** module or other wireless module provides for communication between implantable device **1** and external device **40** such as a programmer. Communication may be bi-directional. Telemetry module **140** generally includes a telemetry antenna, a receiver **18** (see, *e.g.*, **FIG. 4**), a transmitter **48** (see, *e.g.*, **FIG. 4**), and a telemetry processor. Telemetry modules are generally known in the art and are further detailed in U.S. Patent No. 5,752,977, entitled “Efficient High Data Rate Telemetry Format For Implanted Medical Device” issued to Grevious et al. (May 19, 1998). While module **140** is referred to herein as “telemetry” module, it will be understood that other forms of wireless communication may readily be substituted where appropriate for telemetry. Examples of forms of wireless communication include Bluetooth®, 802.11, and Medical Implant Communication Service (MICS) frequency band communication.
- [44] Therapy module **130** refers to components for carrying out the delivery or generation of therapeutic output to be delivered to a patient from active device **1**. One of skill in the art will appreciate that the components may vary on a device-by-device basis and a therapy-by-therapy basis. For example, therapy module **130** may contain an oscillator if device **1** is an electrical signal generator and may contain a pumping mechanism if device **1** is an infusion device.
- [45] Sensor module **150** includes circuitry associated with one or more sensors **50**, **50'** and may include other components for transmitting sensed information from sensor **50**, **50'** to, *e.g.*, processor **110** or memory **120**. Sensor module **150** or other

components of device **1** may include one or more analog to digital converters to convert analog signals generated by sensor **50** into digital signals usable by processor **110**, as well as suitable filter and amplifier circuitry.

- [46] Alert module **185** may issue an alert, e.g. an audible alert or tactile alert, such as a vibration. An alert may be issued if information indicative of an infection is detected. The alert will serve to prompt the patient to seek medical attention.
- [47] While not shown, device **1** may be rechargeable and include a recharge module. Additional information regarding rechargeable implantable medical devices and infection monitoring is provided in U.S. Patent Application Serial No. 11/737,179, entitled "CONTROLLING TEMPERATURE DURING RECHARGE FOR TREATMENT OF A CONDITION", filed on even date herewith, naming Martin Gerber and John Rondoni as inventors, and having attorney docket number P0028540.00, which application is hereby incorporated herein by reference in its entirety to the extent that it does not conflict with the disclosure presented herein.
- [48] It will be understood that the components described in **FIGs. 1-6** are but examples of components that an implantable device **1** may have and that many other device or system configurations may be employed to carry out the methods described below. However, for the sake of convenience, the discussion that follows with regard to the method illustrated in the flow diagram of **FIG. 7** will refer to components as described with regard to **FIGs. 1-6**.
- [49] Referring to **FIG. 7**, a flow diagram of a representative method is shown. According to various embodiments, a method includes monitoring an indicator of infection in proximity to an implantable medical device **1** (**500**) and providing the monitored information to the implanted device **1** (**510**). For example a sensor **50**, **50'** located in proximity to the device **1** may be operably coupled to electronics of the device **1** so that information detected by sensor **50**, **50'** is transmitted to electronics. The information may be used by processor **110**, stored in memory **120**, or the like. The method further includes determining whether the information regarding the indicator of infection is indicative of infection in proximity to device **1** (**520**). The

determination (520) may be made within device 1, *e.g.* by processor 110 or detection circuit (not shown), or may be made by external device 40. Monitored information may be provided to external device 40 via telemetry module 140. If it is determined that the monitored indicator is not indicative of an infection, the indicator may continued to be monitored (500). If the monitored information is indicative of an infection, an alert may be provided to the patient (530). The alert may include a sensory indication, such as an audible indication or a tactile indication, such as a vibration, or visual indication. A visual indication may include, for example, text or an image. The alert may be issued by implanted device 1, *e.g.* by activation of an alarm, or an external device 40, such as a programmer. If the indication is visual, the alert will be presented to the patient or clinician by an external device. While not shown, it will be understood that monitoring of the indicator of infection (500) may continue following an alert being issued (530).

[50] **FIGs. 8A-C** are block diagrams of representative devices or systems. It will be understood that one or more components described with regard to **FIGs. 1-6** may be included or carry out a function of one or more modules described in **FIGs. 8A-C**. As shown in **FIGs. 8A-C**, a system or device suitable for carrying out methods as discussed with regard to **FIG. 7** may include a sensor module 630, a determination module 640, and an alert module 650. Determination module 640 may make a determination as to whether information from sensor module 630 is indicative of an infection (520). If the sensed information is indicative of infection, alert module 650 may provide an alert (530). As shown in **FIG. 8A**, all of the components may be included within an implantable medical device 1. Alternatively, some of the components may be included in an external device 40 as shown in **FIGs. 8B-C**. Thus, as shown in **FIG. 8B**, alert module 650 may be included in an external device 40. In the embodiment shown in **FIG. 8C**, determination module 640 and alert module 650 may be included in an external device 40. Of course, a variety of other distributions of modules between an implantable medical device and an external device are possible.

- [51] One of skill in the art will understand that components or steps described herein regarding a given embodiment or set of embodiments may readily be omitted, substituted, or added from, with, or to components or steps of other embodiments or sets of embodiments, as appropriate or desirable.
- [52] It will be further understood that a computer readable medium containing instructions that when implemented cause an implantable medical device (or system including an implantable medical device) to perform the methods described herein are contemplated. In an embodiment, the computer readable medium contains instructions that when implemented cause an implantable medical device to (i) monitor an indicator of infection in proximity to the implanted active therapy delivering medical device; and (ii) determine whether the information regarding the monitored indicator is indicative of infection in proximity to the implanted medical device.
- [53] Devices including computer readable medium are also contemplated. In an embodiment, an active implantable therapy delivering medical device includes a hermetically sealed housing, a power source disposed in the housing, and electronics disposed in the housing. The electronics are operably coupled to the power source and are capable of controlling therapeutic output from the device. The device further includes a sensor located in proximity to the housing. The sensor is operably coupled to the electronics and is capable of detecting information regarding an indicator of infection and transmitting the information to the electronics. The device also includes a computer readable medium containing instructions that when implemented by the electronics cause the device to determine whether the information is indicative of infection.
- [54] Systems including computer readable medium are also contemplated. In an embodiment, a system includes an active implantable therapy delivering medical device and a second device. The active implantable therapy delivering medical device includes a hermetically sealed housing, a power source disposed in the housing, and first electronics disposed in the housing. The first electronics are

operably coupled to the power source and are capable of controlling therapeutic output from the active implantable therapy delivering device. The active implantable therapy delivering medical device further includes a sensor located in proximity to the housing. The sensor is being operably coupled to the electronics and capable of detecting information regarding an indicator of infection and transmitting the information to the electronics. The device also includes a wireless transmitter operably coupled to the electronics. The wireless transmitter is capable of transmitting the information regarding the indicator of infection. The second device includes second electronics, and a wireless receiver operably coupled to the electronics. The wireless receiver is capable of receiving the information regarding the indicator of infection from the active implantable medical device. The second device further includes a computer readable medium containing instructions that when implemented by the second electronics cause the second device to determine whether the information is indicative of infection in proximity to the active implantable therapy delivering medical device.

- [55] In addition, the principles of the methods, systems and devices described herein may be used for detecting various other potential adverse health issues associated with an implantable medical device. For example, temperature, pH, impedance, and various indicators of infection may also be used to determine whether a hematoma, edema, or seroma is present in proximity to an implanted device. Accordingly, monitoring of such other potential adverse health issues is within the scope of the present disclosure.
- [56] Patent applications directed to infection monitoring that may provide additional insight into the teachings provided herein include the following patent applications filed on even date herewith: (i) US Patent Application Serial No. 11/737,170, entitled "Infection Monitoring", naming Martin Gerber and John Rondoni as inventors, and having P0028529.00 as an attorney docket number; (ii) US Patent Application Serial No. 11/737,176, entitled "Refined Infection Monitoring", naming Martin Gerber and John Rondoni as inventors, and having P0028541.00 as an attorney docket number; and (iii) US Patent Application Serial No. 11/737,169, entitled "Event Triggered

Infection Monitoring”, naming Martin Gerber and John Rondoni as inventors, and having P0028528.00 as an attorney docket number. Each of the above-referenced patent applications is hereby incorporated herein by reference in their respective entireties to the extent that they do not conflict with the disclosure presented herein.

[57] Thus, embodiments of the INFECTION MONITORING are disclosed. One skilled in the art will appreciate that the present invention can be practiced with embodiments other than those disclosed. The disclosed embodiments are presented for purposes of illustration and not limitation, and the present invention is limited only by the claims that follow.

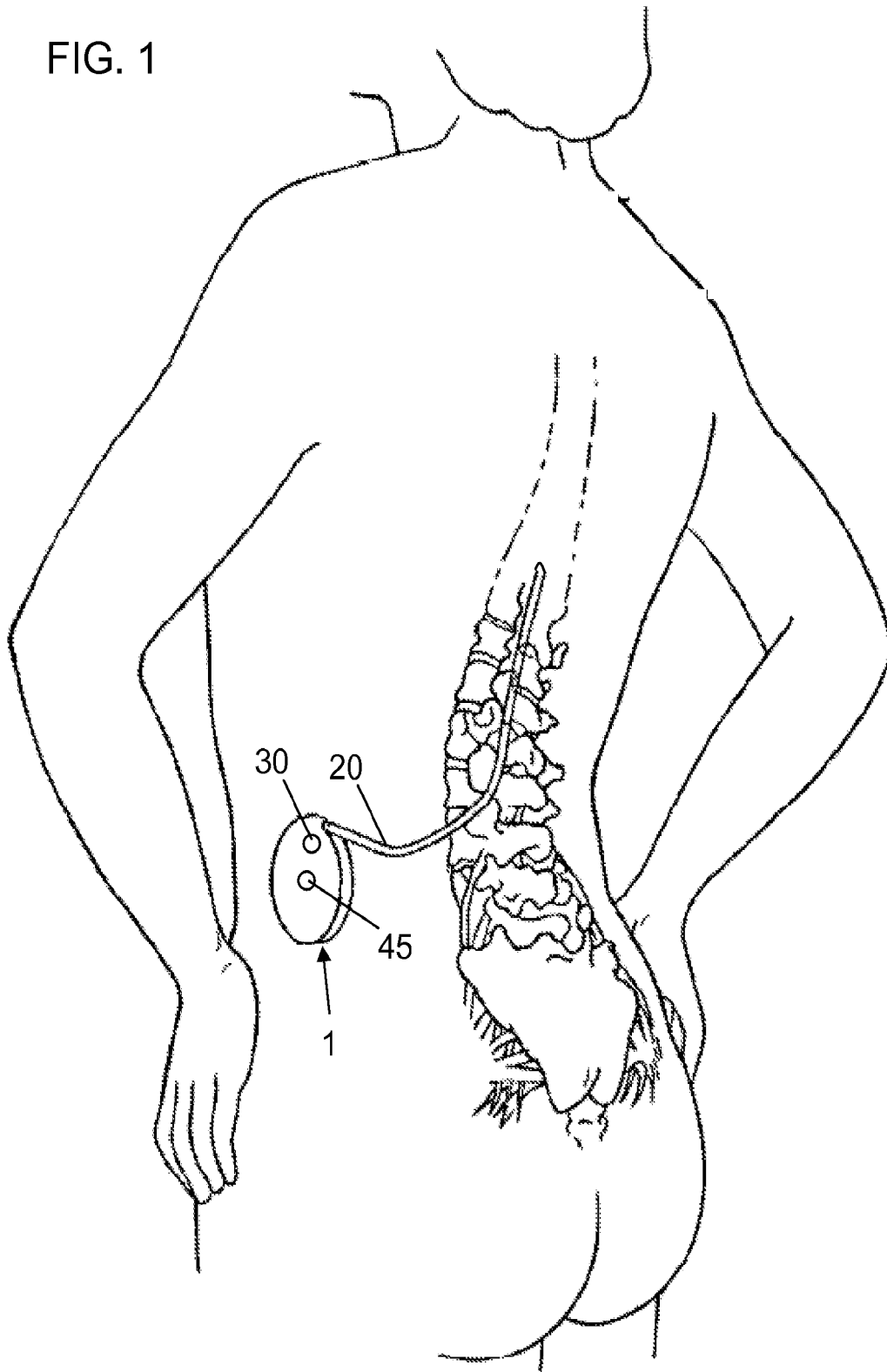
What is claimed is:

1. An active implantable therapy delivering medical device comprising:  
a hermetically sealed housing;  
a power source disposed in the housing;  
electronics disposed in the housing and operably coupled to the power source, the electronics capable of controlling therapeutic output from the device; and  
a sensor located in proximity to the housing and being operably coupled to the electronics, the sensor capable of detecting information regarding an indicator of infection and transmitting the information to the electronics,  
wherein the electronics are capable of determining whether the information is indicative of infection.
2. A device according to claim 1, further comprising an alarm operably coupled to the electronics, wherein the electronics are further capable of activating the alarm if a determination is made that the information is indicative of infection.
3. A device according to claim 1 or claim 2, wherein the active implantable therapy delivering medical device is an infusion device.
4. A device according to claim 1 or claim 2, wherein the active implantable therapy delivering medical device is an electrical signal generator.
5. A device according to any of claims 1 to 4, wherein the sensor is a temperature sensor.
6. A device according to any of claims 1 to 4, wherein the sensor is a pH sensor.

7. A device according to any of claims 1 to 4, wherein the sensor is capable of detecting impedance.
8. A device according to any of claims 1 to 4, wherein the sensor is capable of detecting a biological indicator of infection.

1/8

FIG. 1



2/8

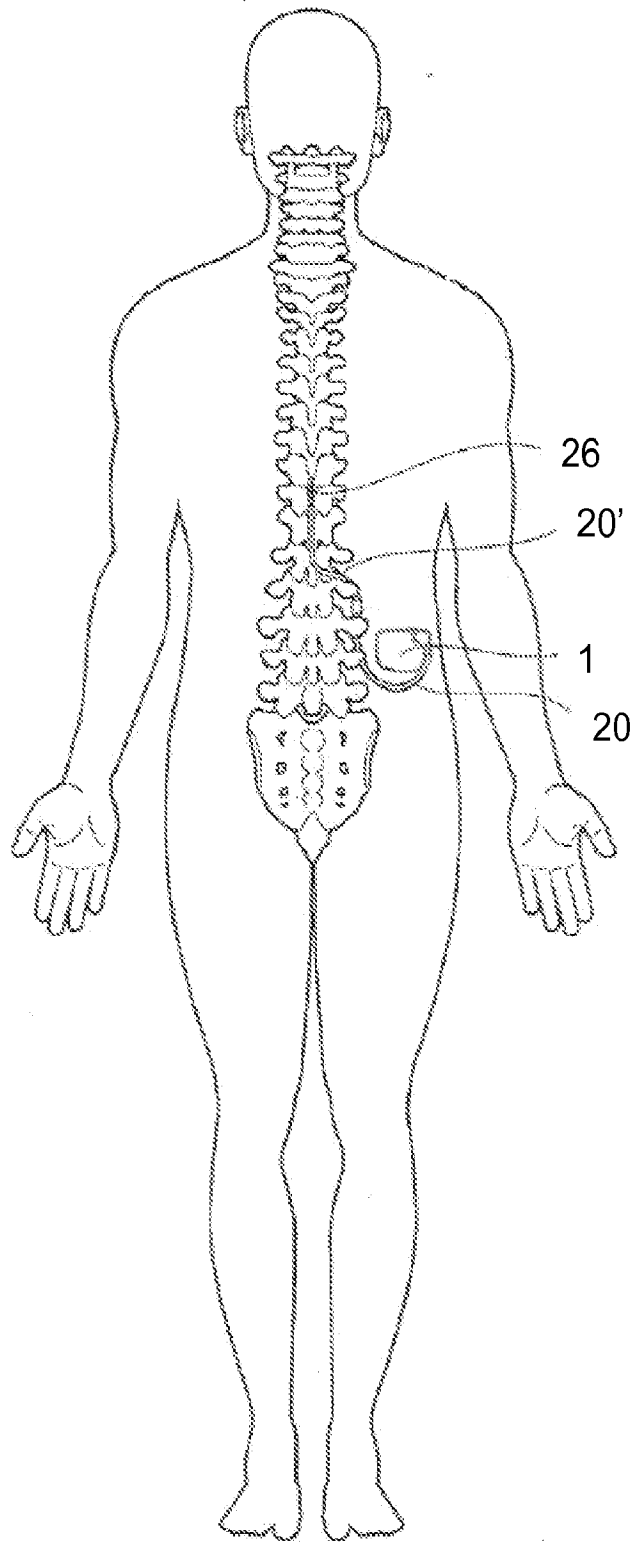


FIG. 2

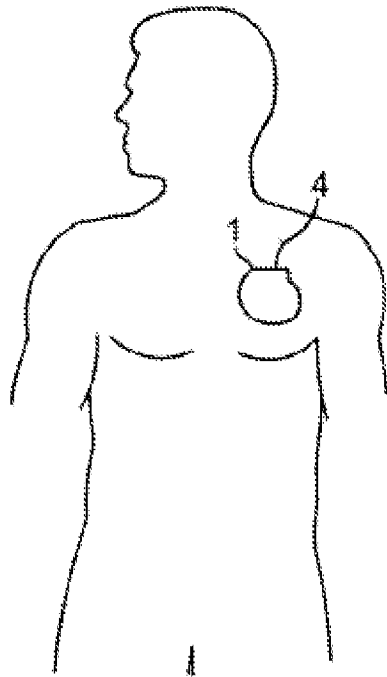


FIG. 3A

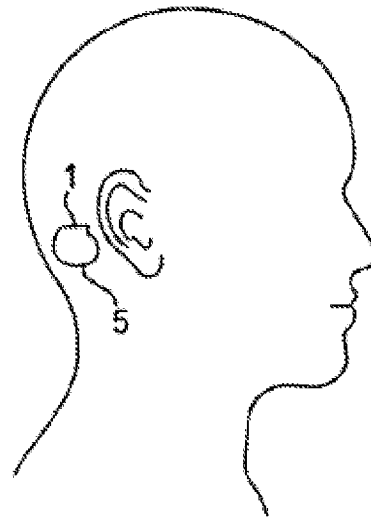


FIG. 3B

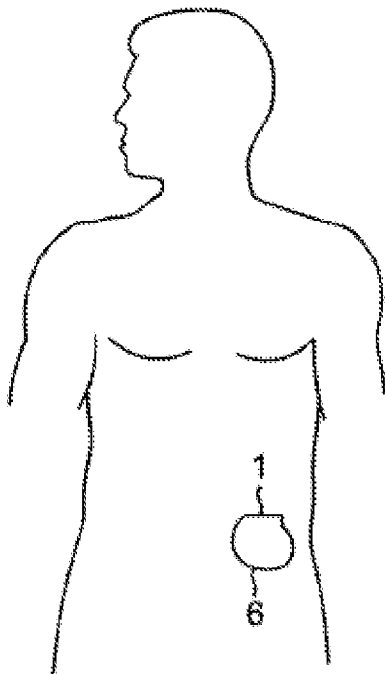


FIG. 3C

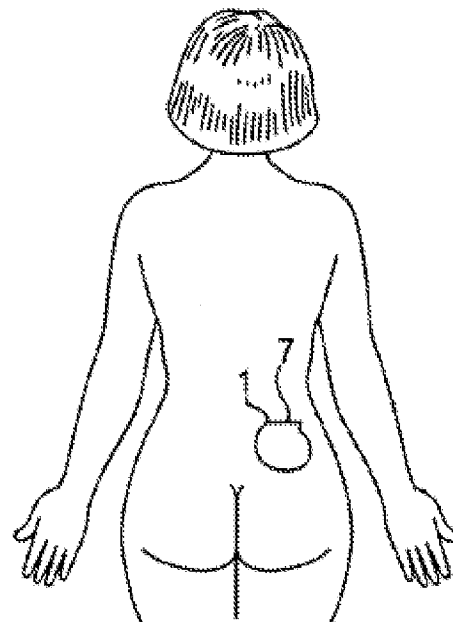


FIG. 3D

4/8

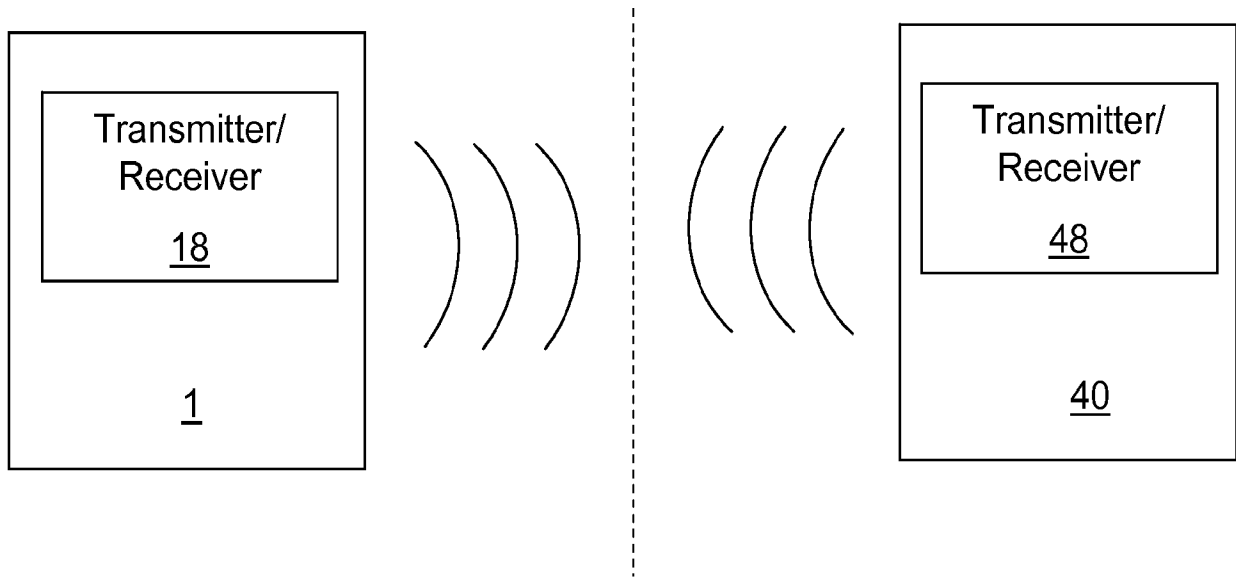


FIG. 4

5/8

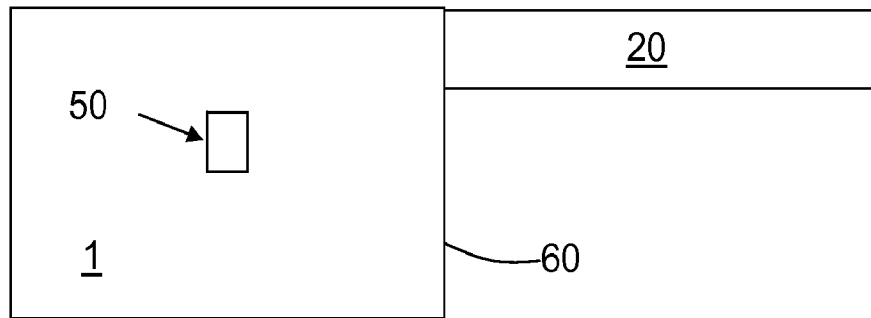


FIG. 5A

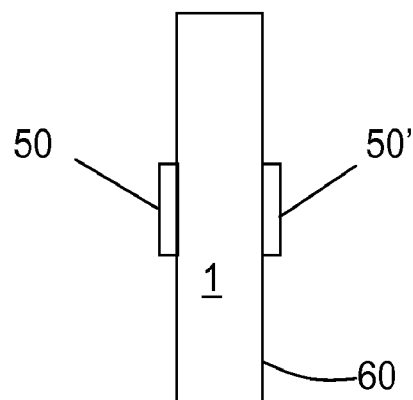


FIG. 5B

## Implantable Device 1

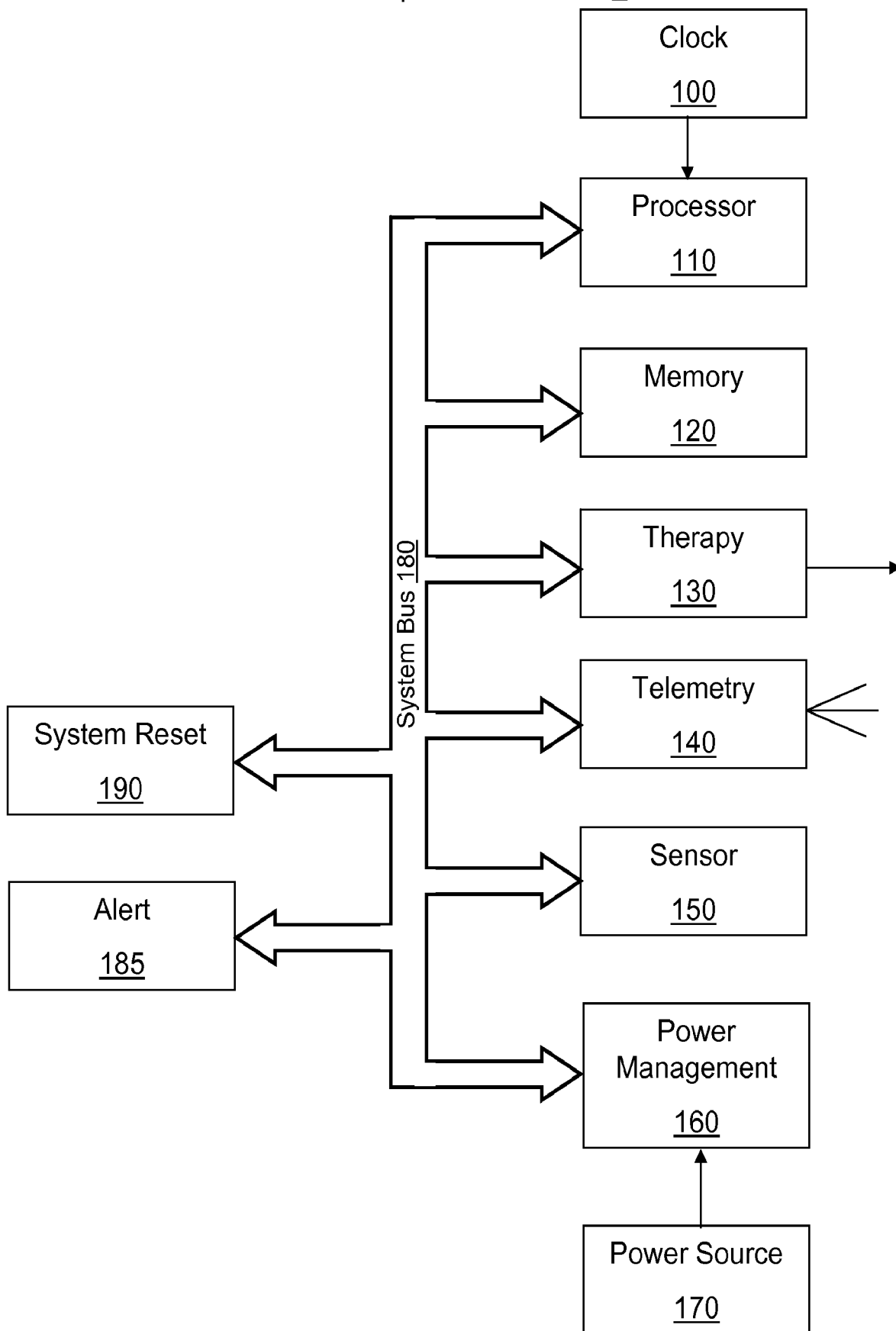


FIG. 6

7/8

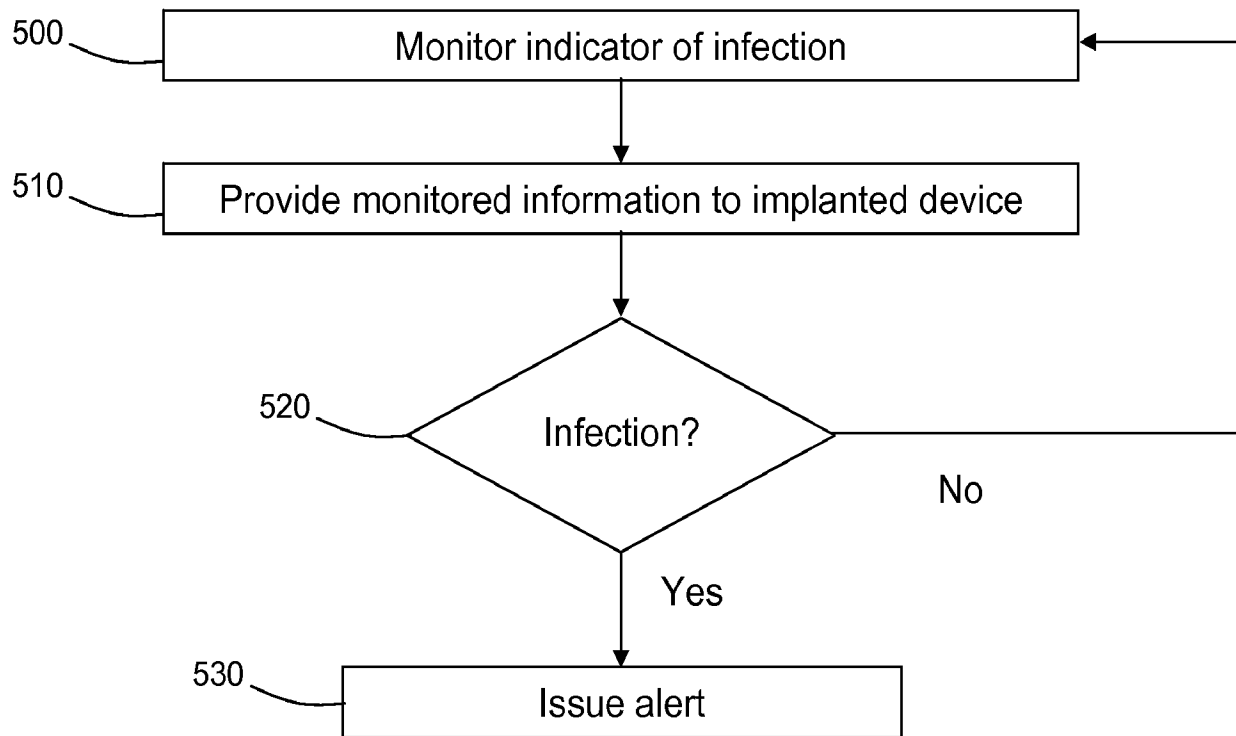


FIG. 7

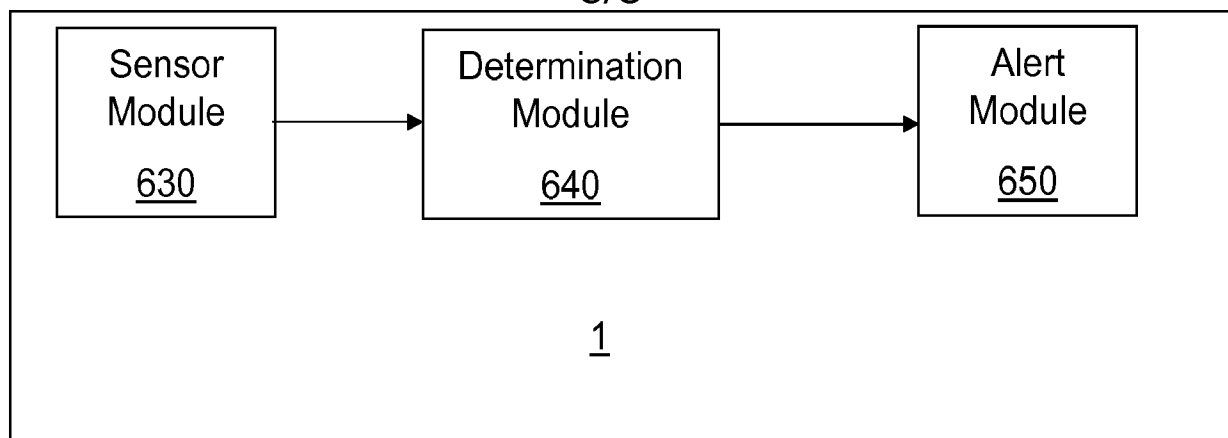


FIG. 8A

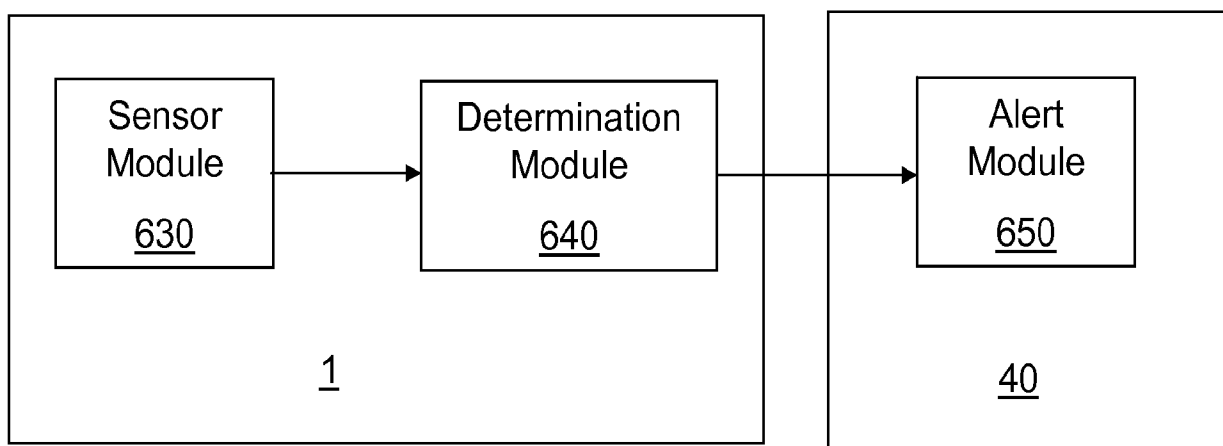


FIG. 8B

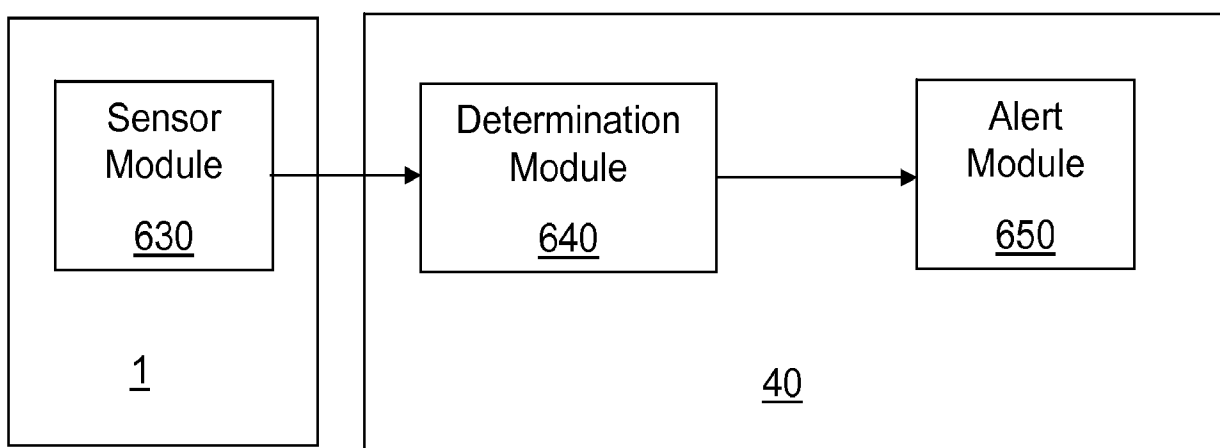


FIG. 8C

# INTERNATIONAL SEARCH REPORT

International application No  
PCT/US2007/067033

**A. CLASSIFICATION OF SUBJECT MATTER**  
INV. A61B5/00 A61B5/07

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)

A61B A61M A61N

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.
X	US 6 970 741 B1 (WHITEHURST TODD K [US] ET AL) 29 November 2005 (2005-11-29) abstract figure 3d column 5, line 8 - line 26 column 10, line 27 - line 57 column 15, line 15 - line 32 column 18, line 59 - column 19, line 26	1,3,4,6, 7
X	WO 2007/028035 A (PROTEUS BIOMEDICAL INC [US]; ZDEBLICK MARK [US]; ROBERTSON TIMOTHY [US]) 8 March 2007 (2007-03-08) page 1, line 18 - page 2, line 12 page 6, line 13 - page 7, line 2 page 12, line 6 - line 15 page 14, line 6 - line 26 page 55, line 28 - page 56, line 12 page 67, line 6 - line 18 ----- -/--	1-5,8

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

☒ See patent family annex.

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\*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.

\*G\* document member of the same patent family

Date of the actual completion of the international search

7 November 2007

Date of mailing of the international search report

19/11/2007

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## INTERNATIONAL SEARCH REPORT

International application No

PCT/US2007/067033

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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X	US 2005/096584 A1 (FEREK-PETRIC BOZIDAR [HR]) 5 May 2005 (2005-05-05) paragraphs [0001], [0015], [0039], [0058] - [0060], [0062], [0072], [0073], [0081], [0082], [0120] figures 2,3 -----	1,3,4,6, 7

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Information on patent family members

International application No

PCT/US2007/067033

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			EP	1696997 A1	06-09-2006
			WO	2005044371 A1	19-05-2005