(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) **EP 2 477 692 B1**

(12) **EUROPEAN PATENT SPECIFICATION**

(45) Date of publication and mention of the grant of the patent:
21.10.2015 Bulletin 2015/43

(21) Application number: **10816789.1**

(22) Date of filing: **20.09.2010**

(51) Int Cl.:
A61N 1/36 *(2006.01)* ***H03M 1/10*** *(2006.01)*
A61B 5/00 *(2006.01)* ***G01R 35/00*** *(2006.01)*
A61N 1/372 *(2006.01)* ***A61N 1/02*** *(2006.01)*

(86) International application number:
PCT/IB2010/054246

(87) International publication number:
WO 2011/033489 (24.03.2011 Gazette 2011/12)

(54) **CALIBRATION OF CURRENT SOURCES AND SINKS IN A STIMULATING MEDICAL DEVICE**

KALIBRIERUNG VON STROMQUELLEN UND -SENKEN IN EINER MEDIZINISCHEN STIMULATIONSVORRICHTUNG

ÉTALONNAGE DE SOURCES ET DE RÉCEPTEURS DE COURANT DANS UN DISPOSITIF MÉDICAL DE STIMULATION

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO SE SI SK SM TR

(30) Priority: **18.09.2009 AU 2009217394**

(43) Date of publication of application:
25.07.2012 Bulletin 2012/30

(73) Proprietor: **Cochlear Limited**
Macquarie University, NSW 2109 (AU)

(72) Inventors:
- **MARKEY, Mathew**
  Lane Cove 2066 (AU)
- **MOGHE, Yoshodhan**
  Lane Cove, New South Wales 2066 (AU)

(74) Representative: **Grünecker Patent- und Rechtsanwälte**
PartG mbB
Leopoldstraße 4
80802 München (DE)

(56) References cited:
GB-A- 2 449 546
US-A- 4 706 674
US-A- 4 917 093
US-A- 6 035 237
US-A1- 2007 100 399
US-A1- 2007 135 868
US-B2- 7 539 538

EP 2 477 692 B1

Description

BACKGROUND

Field of the Invention

[0001] The present invention relates generally to stimulating medical devices, and more particularly, to calibration of current sources and sinks in a stimulating medical device.

Related Art

[0002] The delivery of electrical stimulation has become an established part of medical therapy. Numerous types of medical devices have components positioned on, or implantable in, a recipient's body in order to stimulate a recipient's tissue. Such devices are sometimes referred to herein as stimulating medical devices. Stimulating medical devices commonly include a plurality of electrodes that function as the interface between electronics of the device and the recipient's body tissue. In general terms, current is delivered to the recipient's tissue via the electrodes in order to evoke a response, such as a perception (e.g. for sound perception) or a function (e.g. for limb movement), in the recipient.

[0003] FIG. 1 is a schematic diagram illustrating the delivery of current to tissue. In this illustration, an implantable stimulating medical device 110 comprises an implantable component 112, and a multi-electrode system in the form of two platinum electrodes 101. Each of the electrodes are connected to component 112 by insulated wires 104. Component 112 comprises a stimulating current source 102 that provides current to electrode 101A. The current passes through the recipient's tissue 100, including nerve cell 107, and returns to ground 114 within implantable component 112. The return of this current is shown schematically by arrow 103.

[0004] At the surface of platinum electrodes 101, chemical reactions take place, changing the electron current from the current source to an ion current 105 in the tissue. A charge 106 remains on the electrode surface, causing an increase in voltage in the tissue. Under normal conditions, these chemical reactions are reversible by a change in the direction of current. That is, a reversal in the direction of current will neutralize the increase in voltage. As such, it is common for the stimulation current to be delivered as biphasic pulses, in such a way that there is no net charge delivered to the tissue. A biphasic pulse includes a positive charge pulse followed by an equal negative charge pulse. In certain circumstances, the current level (amplitude) and periods of both the positive and negative pulses are substantially the same. In other circumstances, one of the pulses is applied over a longer or shorter period, but has lower or greater amplitude, respectively. However, in both circumstances, the total charge remaining in the tissue after delivery of both the positive and negative pulses is substantially zero.

[0005] In circumstances using biphasic pulses, if current is allowed to flow in one direction for too long, toxic products can escape and damage or destroy the surrounding tissue. Likewise, if the voltage between two electrodes is allowed to remain elevated for too long, toxic species are irreversibly generated. To ensure that stimulation remains safe, and that no toxic species escape, it is known that the DC and low-frequency (LF) states of the electrodes, sometimes referred to as the DC/LF voltages and the DC/LF currents, must remain within certain bounds. For a typical cochlear implant electrode having an area of about 0.25mm^2, these values are generally a few hundred milli-volts (mV), or tens of nanoamperes (nA). Additionally, the United States Federal Drug Administration (FDA) requires that the magnitude of the current through an electrode, during a 1 ms period, be below 100nA. The use of charge neutralizing biphasic pulses helps ensure that these requirements are met, but charge errors occur in practice.

[0006] In certain stimulating medical devices, separate current source circuits and current sink circuits, referred to simply as current sources and current sinks, respectively, are configured to deliver or receive stimulating current. The sources and sinks each use a Digital-to-Analog Converter (DAC) to control the flow of current.

[0007] GB 2449546A relates to a stimulator device with sequenced pulses across multiple pairs of electrodes and discloses all of the features in the preamble of claims 1 and 9.

[0008] US 2007/0135868A1 relates to techniques for sensing and adjusting a compliance voltage in an implantable stimulator device. Disclosed therein are methods and circuitry for monitoring and adjusting a compliance voltage in implantable stimulator device to an optimal value that is sufficiently high to allow for proper circuit performance. This document discloses PDAC current sources and NDAC current sinks.

SUMMARY

[0009] In one aspect of the present invention, a stimulating medical device according to claim 1 is provided.

[0010] In another aspect of the present invention, a method of calibrating current sources and current sinks in a stimulating medical device according to claim 9.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] Embodiments of the present invention are described below with reference to the attached drawings, in which:

FIG. 1 is a schematic diagram illustrating electrical stimulation of a recipient's tissue via two electrodes;

FIG. 2 is a schematic circuit diagram of a multi-electrode system in which one electrode is connected to a current source and two electrodes are connected

to current sinks;

FIG. 3 is a circuit diagram of the multi-electrode system of FIG. 2 including a calibration arrangement, in accordance with embodiments of the present invention; and

FIG. 4 is a circuit diagram of the multi-electrode system of FIG. 2 including an alternative calibration arrangement, in accordance with embodiments of the present invention.

DETAILED DESCRIPTION

[0012] As is known in the art, certain stimulating medical devices are configured to implement current focusing strategies in which particular groups of nerve or tissue cells are stimulated at selected times or stimulated independently of adjacent cells. Additionally, complex stimulation strategies have been developed for certain medical devices that require control of the current delivered and/or the current sunk by electrodes. That is, there is a level of current matching required between current sources and sinks in stimulating medical devices that facilitates effective current focusing and other stimulation strategies. As used herein, current matching refers to matching of the current delivered by a current source to the current sunk by a current sink. Current sources and sinks are referred to as being matched when the current delivered by the source substantially match the current sunk by the sink.

[0013] Typically, the current sources and sinks comprise Digital-to-Analog Converter (DACs), and the desired level of current matching is set during manufacture by trimming the DACs. However, setting accuracy during manufacture does not account for the possibility that DACs operational parameters may drift over time. For example, typical silicon IC manufacturing technologies may result in the value of each stimulation current source and sink being susceptible to drift, by different and unpredictable amounts, after implantation into a recipient (potentially tens of years). IC manufacturers generally do not guarantee the drift of crucial parameters beyond a 10-20 year timeframe. Unfortunately, a period of 10-20 years is much less than the typical intended lifetime of a stimulating medical device.

[0014] Aspects of the present invention are generally directed to providing the desired level of current matching through in situ calibration of current sources and sinks in a stimulating medical device. More particularly, a stimulating medical device in accordance with aspects of the present invention comprises a plurality of electrodes each connected to a current source and a current sink. Each current source comprises a p-type Digital-to-Analog Converter (PDAC) that sources current from a supply, while each current sink comprises an n-type Digital-to-Analog Converter (NDAC) that sinks current to a ground. The calibration arrangement is configured to compare the current provided by a current source to the current sunk through a current sink. Based on the comparison, the calibration arrangement adjusts the parameters of either the PDAC and NDAC until the sourced and sunk currents are substantially the same.

[0015] The in situ calibration of current sources (i.e. subsequent to the manufacturing process) that ensures sufficient current matching between the sources and sinks to facilitate effectiveness of current focusing and other stimulation strategies. The calibration of current sources also helps maintain the safety of the device by reducing the potential for accumulation of harmful toxic products as a result of the mismatching of stimulation currents. The current source and sink calibration of the present invention may reduce, but will likely not eliminate, all toxic products resulting from mismatched current.

[0016] Embodiments of the present invention will be described with reference to a particular stimulating medical device, namely an intra-cochlear electrical stimulation system, (commonly referred to as a cochlear prosthetic device, cochlear implant, cochlear device, and the like; simply "cochlear implant" herein.) However, it would be appreciated that embodiments of the present invention may be implemented in any stimulating medical device, including, but not limited to, hybrid electrical and acoustic stimulation systems, brain stem implants, muscle stimulators or other neural stimulation systems. Additionally, it would be appreciated that embodiments of the present invention may be implemented in systems having both implanted and external components, as well as a totally or fully implanted system.

[0017] As noted, embodiments of the present invention generally relate to the electrical stimulating components of a cochlear implant. As would be appreciated, cochlear implants also include a variety of signal processors, power supplies, RF links, *etc.* All of these elements are well known in the art and will not be described in detail herein.

[0018] FIG. 2 is a schematic diagram of an exemplary cochlear implant 290. As shown, cochlear implant 290 comprises a plurality of electrodes 201 configured to interface with a recipient's tissue 200. As shown, electrode 210A is switchably connected to a current source 220 provided by a p-type digital-to-analog converter (PDAC) connected to a stimulating supply rail V_{stim}. The current sourced through PDAC 220 is sunk by current sinks 222A, 222B associated with electrodes 201B, 201C, respectively. Each of the current sinks 222 comprise a n-type digital-to-analog converter (NDAC) connected to ground.

[0019] FIG. 2 illustrates cochlear implant 290 having three electrodes. However, it would be appreciated that cochlear implant 290 may include larger numbers of electrodes. For example, in one specific implementation, cochlear implant 290 includes 24 stimulating electrodes. In such an arrangement, each electrode may have a respective PDAC and a NDAC connected thereto. Accordingly, such an arrangement would include a total 48 DACs. Implementations are also envisioned in which

fewer DACs are required. For example, implementations may use one or more DACs which are not associated with particular electrodes, but that are selectively connected using suitable switches. The present invention is not limited in application to any one of the above or other DAC configuration.

[0020] During normal operation, any number of electrodes may operate to sink or source current at the same time, referred to as asynchronous stimulation. In the specific example of FIG. 2, sourcing current of 1.0 units is provided at electrode 210A. Sinking current of 0.5 units is provided by each of electrode 201B and 201C, thereby reducing the net current (and hence charge) to approximately zero. As previously noted, this current matching is a key issue in maintaining the effectiveness of current focusing and other stimulation strategies.

[0021] In certain embodiments, each DAC is individually programmable, under the control of, for example, the system controller or processor, to apply a required stimulation current for the respective electrode. Accordingly, all current DACs should be accurately matched for a given programmable value so that the total current entering and leaving all the electrodes can be programmed as close to zero as possible. In specific implementations, an accuracy of approximately 0.1% between sourced and sunk current is desirable.

[0022] As previously noted, embodiments of the present invention seek to calibrate all current sources and sinks to ensure they are able to obtain the desired accuracy. FIG. 3 is a schematic diagram illustrating one system for calibrating the sources and sinks of one electrode 201A of cochlear implant 290 of FIG. 2. It would be appreciated that arrangements similar to that shown in FIG. 3 may be provided for each electrode or DAC.

[0023] As shown in FIG. 3, electrode 201A is electrically connectable, via switch 344A, to a current source 332 comprising a PDAC connected to a supply voltage (V_{stim}). Similarly, electrode 201A is connectable, via switch 344B, to a current sink comprising a NDAC connected to ground. In operation, switches 344 are selectively actuated depending on whether electrode 210A is sinking or sourcing current.

[0024] Additionally, cochlear implant 290 of FIG. 3A comprises a calibration arrangement 380. Calibration arrangement 380 comprises, in this embodiment, a comparator 330 connectable to each of PDAC 332 and NDAC 334 via switches 342 and line 350. To perform calibration of either PDAC 332 or NDAC 334, the respective switch 342 is closed to provide a path between the DAC and comparator 330. At the same time, a PDAC or NDAC is also connected to comparator 330 and the resulting current values are evaluated by the comparator.

[0025] For example, in one specific implementation, cochlear implant 290 comprises a processor 382 that sets PDAC 332 and an NDAC from electrode 201B each to a high value. That is, assigning bit values to the digital output of each of PDAC 332 and the NDAC, the most significant bit (MSB) of each would be set to a '1' and all other bits would be set to '0'. Additionally, the processor closes the necessary switches to connect each of PDAC 332 and the NDAC to comparator 330. At this time, switches to electrodes 201A, 201B are set open so that no current flows to the electrodes. The currents provided to comparator 330 will result in the voltage at node 352 being pulled towards one of either the supply rail or ground, depending on its sign. More particularly, if the current of PDAC 332 is higher, then the node 352 will pull up to V_{stim}, and if the current of NDAC of electrode 201B is higher, then node 352 will pull down to ground. Comparator 330 senses this and transmits a representative signal back to processor 382. As would be appreciated, processor 382 may comprise any combination of hardware or software and may be part of calibration arrangement 380 or may be positioned in a separate implantable or external component. For ease of illustration, processor 382 is shown schematically using a simple block element.

[0026] As a result of the comparison, processor 382 will vary either the programmable value of the output of the NDAC of electrode 201B or the output value of PDAC 332 by 1LSB in the appropriate direction that would cause comparator 330 to change state. For example, if node 352 was high (that is, pulled toward the supply rail), then processor 382 would increase the programmable value of the NDAC of electrode 201B by 1 LSB. Processor 382 continues with the incremental change of the next LSB until the state of comparator 330 changes. DAC operational parameters or settings may be adjusted by altering their trimmed values as well as applying a gain correction factor to their digital programmable values.

[0027] Once the state of comparator 330 changes, the amount by which the programmable value of the NDAC of electrode differs from the value of PDAC 332 is stored. This value may be stored in non-volatile memory (NVM) within the implanted device, in an external component, or in a separate device such as a remote control. This value may then be used by elements of the device that control stimulation to correct for the gain error between the two evaluated DACs.

[0028] The steps discussed above for PDAC 332 and the NDAC of electrode 201B may be repeated for the NDACs in comparison to PDAC 332 (including the NDAC of electrode 201A). Processor 382 may then repeat the steps for all of the PDACs of the other electrodes versus the NDACs. In these subsequent tests, the calibration value for the NDAC of electrode 201B is used.

[0029] In certain implementations, processor 382 will compare the current for NDAC 334 of electrode 201A to an arbitrarily chosen PDAC of the same or different electrode. This comparison uses the (calibration value for the arbitrarily selected PDAC). Similarly, processor 382 will compare the current for a PDAC of another electrode to that of any arbitrarily chosen NDAC of another electrode. Again this comparison uses calibration value for the arbitrarily selected NDAC. The result of these two additional steps is that a correction value is generated. This cor-

rection value may be stored in memory for all DACs, except for PDAC 332, and may be used to control the stimulation currents as a gain error correction value that should be applied to the programmable value for each DAC.

[0030] In the above exemplary implementation, all DACs are calibrated for the purpose of matching relative to a single selected DAC. As would be appreciated, the selected reference DAC may itself be subject to drift from the initial value set at manufacture. As such, the above method does not address a recalibration of absolute values of the DACs, but rather provides a relative calibration between the DACs. However, it is noted that this relative matching suitably satisfies the aspect of stimulation current matching for current focusing and other stimulation strategies.

[0031] As would be appreciated, the arrangement and method described above with reference to FIG. 3 is merely illustrative, and other arrangements/methods for calibrating current sources and sinks are within the scope of the present invention as defined in the claims. For example, in one alternative implementation, the method commences, as above, with an NDAC and PDAC being compared to one another. In this variation, the digital current values for each of the NDAC and PDAC are set such that the most significant bits (MSB) are high, while the other bits are set low (e.g. 10000). In these embodiments, if, for example, the PDAC value is higher, the value of the NDAC may remain fixed, and the MSB, rather than the LSB as described above, of the PDAC bit value may be adjusted based on the comparison to the predetermined value. More particularly, if PDAC is higher, then the MSB of the PDAC is set to 0. The next MSB is then set to 1 to provide a bit value (starting with the illustrative digital value of 10000) of PDAC = 010000. A comparison between the currents is then made (i.e. NDAC=10000 and PDAC= 01000). If, as a result of the comparison, the PDAC is still higher, the second MSB is also set to 0. However, if the NDAC is lower, (i.e. the comparator changed state), then the second MSB remains at 1. This process is continued for all bit values assigning either a 1 or 0 to the next MSB of the PDAC. This process, referred to as a successive approximation algorithm, allows the correct value to be determined with no more steps than there are bits (i.e. 11 bits requires 11 iterations).

[0032] The arrangement illustrated above with reference to FIG. 3 utilizes an independent comparator shared with all of the DACS. In another exemplary implementation, a comparator associated with, provided as part of a DAC, or otherwise within the stimulation circuitry may be used to perform the comparison. FIG. 4 is a schematic diagram of one alternative system for calibrating the sources and sinks of an electrode 201A of cochlear implant 290 of FIG. 2. In contrast to the embodiments of FIG. 3, the arrangement of FIG. 4 does not use the same comparator for all comparisons.

[0033] Similar to the embodiments of FIG. 3, electrode 201A is electrically connected to PDAC 332 and switch 344A. Similarly, electrode 201A is connected to NDAC 334 and switch 344B. In operation, switches 344 are selectively actuated depending on whether electrode 210A is sinking or sourcing current.

[0034] PDAC 332 is connected to a PDAC compliance comparator 460A , while NDAC 334 is connected to NDAC compliance comparator 460B. Additionally, switch 464A is configured to selectively connect PDAC 332 and PDAC compliance comparator 460A to a line 450, while switch 464B is configured to connect NDAC 334 and NDAC compliance comparator 460B to line 450. Line 450 extends to other electrodes 201 B and 201C.

[0035] To perform an exemplary calibration, switches 344A, 344B and 464B are set open, while switch 464A is closed to connect PDAC 332 and PDAC compliance comparator 460A to, for example, an NDAC in electrode 201B. The difference in the currents provided to comparator 460A from PDAC 332 and the NDAC in electrode 201B results in the voltage at node 452 being pulled towards one of either the supply rail or ground, depending on its sign. For example, if the current of PDAC 332 is higher, then node 452 will pull up to V_{stim}, and if the current of NDAC of electrode 201B is higher, then node 452 will pull down to ground. Comparator 460A senses this and transmits a representative signal back to a processor 482.

[0036] As a result of the comparison, processor 482 will vary either the programmable value of the NDAC of electrode 201B or the value of PDAC 332 by 1 LSB in the appropriate direction that would cause comparator 460A to change state. For example, if node 452 was high (that is, pulled toward the supply rail), then processor 482 would increase the programmable value of the NDAC of electrode 201B by 1 LSB. Processor 482 continues with the incremental change until the state of comparator 460A changes.

[0037] Once the state of comparator 460A changes, the amount by which the programmable value of the NDAC of electrode differs from the value of PDAC 332 is stored. This value may be stored in non-volatile memory (NVM) within the implanted device, in an external component, or in a separate device such as a remote control. This value may then be used by the elements that control stimulation to correct for the gain error between the two evaluated DACs.

[0038] The steps discussed above for PDAC 332 and the NDAC of electrode 201B may be repeated for the NDACs in comparison to PDAC 332 (including the NDAC of electrode 201A). Processor 482 may then repeat the steps for all of the PDACs of the other electrodes versus the NDACs. In these subsequent tests, the calibration value for the NDAC of electrode 201B is used.

[0039] In certain implementations, processor 482 will compare the current for NDAC 334 of electrode 201A to an arbitrarily chosen PDAC in substantially the same manner as described above. This comparison uses the calibration value for the arbitrarily selected PDAC. Similarly, processor 482 will compare the current for a PDAC

of another electrode to that of any arbitrarily chosen NDAC of another electrode. Again this comparison uses calibration value for the arbitrarily selected NDAC. The result of these two additional steps is a correction value is generated. This correction value may be stored in memory for all DACs, except for PDAC 332 and may be used to control the stimulation currents as a gain error correction value that should be applied to the programmable value for each DAC.

[0040] In specific implementations of FIG. 3 and 4, it is possible to implement comparisons of DACS within different zones or areas of the electrode array. That is, the system may perform localized calibrations in which DACS of certain area of the electrode array are compared only to DACS within that same area, rather than to all the DACS within the electrode array. Depending on the hardware configuration of the system, these localized calibrations may be performed sequentially (i.e. calibrate the DACS of one area after one another) or simultaneously (performance of multiple localized calibrations at the same time). Sequential comparisons may use a single common comparator, or multiple comparators, depending on the desired configuration, while simultaneous comparisons use multiple comparators.

[0041] Additionally, FIGS. 3 and 4 have been described with reference to a comparator to evaluate the currents of a current source and sink. In one alternative embodiment, the current comparator may be replaced by a resistor and analog-to-digital converter (ADC). In such an embodiment, instead of diverting two currents to the line connecting the comparator, PDAC and NDAC (lines 350 and 450 in FIGS. 3 and 4) currents could be sequentially diverted to the resistor and the voltage on the line measured by the ADC. The sequentially recorded ADC values could be compared to determine the difference in current.

[0042] In the above embodiments, the calibration path is generally independent of the electrode current path. Accordingly, the calibration does not depend upon, for example, the peculiarities of location, orientation or connection of the electrode, or on any electrical effects from such peculiarities.

[0043] In another variation, a single PDAC could be calibrated against a single NDAC and the determined calibration values are assumed to apply to all the rest of the PDACs. Such an implementation would simplify both the processing and circuitry. In specific embodiments, the processor is an intelligent controller controls the system and the calibration procedure. The intelligent controller may comprise any combination of hardware/software and may be embedded in an implanted component, such as a stimulator unit, in an external component or other device, such as remote control, fitting system, etc. Additionally, as noted above, a memory allows the calibration data to be stored and accessed when needed.

[0044] As previously noted, each DAC includes a digital value comprised of a plurality of bits. It would be appreciated that the least significant bit (LSB) should have a value that is smaller that desired current matching accuracy. If the LSB of the DACs are not smaller than the desired accuracy, then it may be difficult or even impossible to achieve a desired accuracy. Specifically, if the desired current matching accuracy is 1%, then the LSB of the DACs should have a value equal to approximately 0.5% of the desired accuracy.

[0045] It will be appreciated that the above calibration procedures may be adjusted for the specific device or recipient. For example, it is not uncommon that one or more electrodes in a cochlear implant are non-functional or are not required for stimulation. As such, any DAC specifically associated with such an electrode need not be calibrated.

[0046] As noted above, there area number of different methods for managing the comparison process other than those described above. For example, the number that is recorded in the memory for each DAC pair could be the ratio of the two digital values at the moment when the current comparator changes in sign.

[0047] It is noted that it is anticipated that this calibration process will only be carried out infrequently, for example at periodic appointments for maintenance, in response to a fault condition, or the like. Accordingly, the calibration can be performed at a time when it is not required that the stimulating device is operating, and so the user need not be inconvenienced. It is expected that the rate of drift will be relatively slow.

[0048] The invention described and claimed herein is not to be limited in scope by the specific preferred embodiments herein disclosed, since these embodiments are intended as illustrations, and not limitations, of several aspects of the invention. Indeed, various modifications of the invention in addition to those shown and described herein will become apparent to those skilled in the art from the foregoing description. Such modifications are also intended to fall within the scope of the appended claims.

Claims

1. A stimulating medical device (290), comprising:

a plurality of electrodes (201A, 201 B, 201 C); and

a current source (332) and a current sink (334) electrically connectable to each one of the electrodes (201A, 201 B, 201 C) via electric switches;

characterized by

a calibration arrangement (380) configured to compare the current provided by a selected one of the current sources (332) to the current sunk by a selected one of the current sinks (334) when said switches are set open so that no current flows to the electrodes, and configured to adjust an operational parameter of at least one of the

source (332) and sink (334) based on said comparison such that the current provided by the selected current source (332) is substantially the same as the current sunk by the current sink (334).

2. The medical device (290) of claim 1, further comprising:

memory, wherein the operational parameters of one or more of the selected current source (332) and the selected current sink (334) are stored in the memory for subsequent use.

3. The medical device (290) of claim 2, wherein the electrodes (201A, 201 B, 201 C) are configured to deliver electrical stimulation current to a recipient of the medical device (290), and wherein the medical device (290) is configured to utilize the stored operational parameters to generate the electrical stimulation current.

4. The medical device (290) of claim 1, wherein each current source (332) comprises a p-type Digital-to-Analog Converter (PDAC), and wherein each current sink (334) comprises a n-type Digital-to-Analog Converter (NDAC).

5. The medical device (290) of claim 1, wherein the calibration arrangement (380) further comprises:

a comparator (330) configured to compare the current provided from a current source (332) to the current sunk (334) by a NDAC; and
a processor (382) configured to adjust the operational parameters of at least one of the PDAC and the NDAC based on the comparison.

6. The medical device (290) of claim 5, wherein the calibration arrangement (380) comprises a plurality of comparators each configured to perform comparisons of the current provided from a current source (332) to the current sunk by a current sink (334); and wherein the calibration arrangement (380) comprises at least one comparator (330) for each electrode (201 A, 201B, 201 C).

7. The medical device (290) of claim 1, wherein the adjustable operational parameter of a DAC is the digitally controlled output of the DAC having a multi-bit value, and wherein the compared are matched to within the least significant bit of that DAC value.

8. The medical device (290) of claim 1, wherein the calibration arrangement (380) further comprises:

a resistor and analog-to-digital converter (ADC) configured to compare the current provided from a current source (332) to the current sunk by a current sink (334); and
a processor (382) configured to adjust the operational parameters of at least one of the current source (332) and current sink (334) based on the comparison.

9. A method of calibrating current sources (332) and current sinks (334) in a stimulating medical device (290), according to anyone of claims 1 to 8 the method comprising:

selecting a current source (332) and a current sink (334);
characterized by
comparing the current provided by the selected current source (332) and the current sunk by the selected current sink (334) when said switches are set open so that no current flows to the electrodes; and
adjusting an operational parameter of at least one of the source (332) and sink (334) based on the evaluation such that the current provided by the selected current source (332) is substantially the same as the current sunk by the current sink (334).

10. The method of claim 9, further comprising:

storing the operational parameters of one or more of the selected current source (332) and the selected current sink (334) for subsequent use.

11. The method of claim 9, wherein each of the current sources (332) comprises a p-type Digital-to-Analog Converter (PDAC), and wherein each of the current sinks (334) comprises a n-type Digital-to-Analog Converter (NDAC).

12. The method of claim 9, wherein the device (290) comprises a plurality of comparators (330), and wherein the method further comprises:

evaluating the current provided by the selected current source (332) and the current sunk by the selected current sink (334) with a first comparator (330);
selecting a second current source and a second current sink; and
evaluating the current provided by the second selected current source and the current sunk by the second selected current sink with a second comparator.

13. The method of claim 9, wherein the adjustable operational parameter of a DAC is the digitally controlled output of the DAC having a multi-bit value, and

wherein adjusting an operational parameter of at least one of the source (332) and sink (334) comprises:

adjusting the least significant bit of that output value of at least one of the current source (332) or sink (334) so that the current provided by the selected source (332) and the current sunk by the selected current sink (334) are substantially the same.

14. The method of claim 9, the medical device (290) comprises a resistor and analog-to-digital converter (ADC), and wherein evaluating the current provided by the selected current source (332) and the current sunk by selected current sink (334) comprises:

sequentially diverting the current provided by the current source (332) and the current sunk by the current sink (334) to the resistor;
measuring the voltage with the ADC during each sequential diversion; and
comparing the measured voltages to determine the difference in currents.

15. The method of claim 9, further comprising:

selecting a second current source and second current sink;
evaluating the current provided by the second selected current source and the current sunk by the second selected current sink with a second comparator;
repeating the selection of current sources and sinks and the comparison of currents until a desired number of current sources and sinks have been compared.

Patentansprüche

1. Stimulierendes medizinisches Gerät (290), das umfasst:

eine Vielzahl von Elektroden (201 a, 201 b, 201 c); und
eine Stromquelle (332) und eine Stromsenke (334), die elektrisch mit jeder der Elektroden (201 a, 201 b, 201 c) über elektrische Schalter verbindbar sind;
gekennzeichnet durch
eine Kalibrieranordnung (380), die konfiguriert ist, den Strom, der von einer ausgewählten der Stromquellen (332) bereitgestellt wird, mit dem Strom, der von einer ausgewählten der Stromsenken (334) aufgenommen wurde, zu vergleichen, wenn die Schalter geöffnet sind, so dass kein Strom zwischen den Elektroden fliesst, und die konfiguriert ist, einen Betriebsparameter der Quelle (332) und/oder der Senke (334) basierend auf dem Vergleich einzustellen, so dass der Strom, der von der ausgewählten Stromquelle (332) bereitgestellt wird, im Wesentlichen derselbe ist wie der Strom, der von der Stromsenke (334) aufgenommen wird.

2. Medizinisches Gerät (290) nach Anspruch 1, das weiterhin umfasst:

einen Speicher, worin die Betriebsparameter der ausgewählten Stromquelle (332) und/oder der ausgewählten Stromsenke (334) in dem Speicher für die nachfolgende Benutzung gespeichert sind.

3. Medizinisches Gerät (290) nach Anspruch 2, wobei die Elektroden (201 a, 201 b, 201 c) konfiguriert sind, elektrischen Stimulationsstrom an einen Empfänger des medizinischen Geräts (290) abzugeben, und wobei das medizinische Gerät (290) konfiguriert ist, die gespeicherten Betriebsparameter zu verwenden, den elektrischen Stimulationsstrom zu erzeugen.

4. Medizinisches Gerät (290) nach Anspruch 1, wobei jede Stromquelle (332) einen P-Typ Digital-zu-Analog-Wandler (PDAC) umfasst, und wobei jede Stromsenke (334) einen N-Typ Digital-zu-Analog-Wandler (NDAC) umfasst.

5. Medizinisches Gerät (290) nach Anspruch 1, wobei die Kalibrieranordnung (380) weiterhin umfasst:

einen Vergleicher (330), der konfiguriert ist, den Strom, der von einer Stromquelle (332) bereitgestellt ist, mit der Stromsenke (334) durch einen NDAC zu vergleichen; und
einen Prozessor (382), der konfiguriert ist, die Betriebsparameter des PDAC und/oder des NDAC basierend auf dem Vergleich einzustellen.

6. Medizinisches Gerät (290) nach Anspruch 5, wobei die Kalibrieranordnung (380) eine Vielzahl von Vergleichern umfasst, die jeweils konfiguriert sind, Vergleiche des Stroms, der von einer Stromquelle (332) bereitgestellt ist, mit dem Strom, der von einer Stromsenke (334) aufgenommen wird, durchzuführen; und
wobei die Kalibrieranordnung (380) mindestens einen Vergleicher (330) für jede Elektrode (201 a, 201 b, 201 c) umfasst.

7. Medizinisches Gerät (290) nach Anspruch 1, wobei der einstellbare Betriebsparameter eines DAC die digital gesteuerte Ausgabe des DAC mit einem Viel-

fach-Bit-Wert ist, und wobei die verglichenen bis auf das niedrigst wertige Bit des DAC-Werts verglichen werden.

8. Medizinisches Gerät (290) nach Anspruch 1, wobei die Kalibrieranordnung (380) weiterhin umfasst:

einen Widerstand und Analog-zu-Digital-Wandler (ADC), die konfiguriert sind, den Strom, der von einer Stromquelle (332) bereitgestellt ist, mit dem Strom, der von einer Stromsenke (334) aufgenommen wird, zu vergleichen; und
einen Prozessor (382), der konfiguriert ist, die Betriebsparameter der Stromquelle (332) und/oder der Stromsenke (334) basierend auf dem Vergleich einzustellen.

9. Verfahren zum Kalibrieren von Stromquellen (332) und Stromsenken (334) in einem stimulierenden medizinischen Gerät (290) gemäß einem der Ansprüche 1 bis 8, wobei das Verfahren umfasst:

Auswählen einer Stromquelle (332) und einer Stromsenke (334);
gekennzeichnet durch
Vergleichen des Stroms, der von der ausgewählten Stromquelle (332) bereitgestellt wird, und des Stroms, der von der ausgewählten Stromsenke (334) aufgenommen wird, wenn die Schalter offenstehen, so dass kein Strom zwischen den Elektroden fliesst; und
Einstellen eines Betriebsparameters der Quelle (332) und/oder der Senke (334) basierend auf der Bewertung, so dass der Strom, der von der ausgewählten Stromquelle (332) bereitgestellt wird, im Wesentlichen derselbe ist wie der Strom, der von der Stromsenke (334) aufgenommen wird.

10. Verfahren nach Anspruch 9, das weiterhin umfasst:

Speichern der Betriebsparameter der ausgewählten Stromquelle (332) und/oder der ausgewählten Stromsenke (334) zur nachfolgenden Verwendung.

11. Verfahren nach Anspruch 9, wobei jede der Stromquellen (332) einen P-Typ Digital-zu-Analog-Wandler (PDAC) umfasst, und wobei jede der Stromsenken (334) einen N-Typ Digitalzu-Analog-Wandler (NDAC) umfasst.

12. Verfahren nach Anspruch 9, wobei die Vorrichtung (290) eine Vielzahl von Vergleichern (330) umfasst, und wobei das Verfahren weiterhin umfasst:

Bewerten des Stroms, der von der ausgewählten Stromquelle (332) bereitgestellt wird, und des Stroms, der von der ausgewählten Stromsenke (334) aufgenommen wird, mit einem ersten Vergleicher (330);
Auswählen einer zweiten Stromquelle und einer zweiten Stromsenke; und
Bewerten des Stroms, der von der zweiten ausgewählten Stromquelle bereitgestellt wird, und des Stroms, der von der zweiten ausgewählten Stromsenke aufgenommen wird, mit einem zweiten Vergleicher.

13. Verfahren nach Anspruch 9, wobei der einstellbare Betriebsparameter eines DAC die digital gesteuerte Ausgabe des DAC mit einem Vielfach-Bit-Wert ist, und wobei das Einstellen eines Betriebsparameters der Quelle (332) und/oder der Senke (334) umfasst:

Einstellen des niedrigst wertigen Bits dieses Ausgabewerts der Stromquelle (332) und/oder der Senke (334), so dass der Strom, der von der ausgewählten Quelle (332) bereitgestellt wird, und der Strom, der von der ausgewählten Stromsenke (334) aufgenommen wird, im Wesentlichen gleich sind.

14. Verfahren nach Anspruch 9, wobei das medizinische Gerät (290) einen Widerstand und Analog-zu-Digital-Wandler (ADC) umfasst, und wobei das Bewerten des Stroms, der von der ausgewählten Stromquelle (332) bereitgestellt wird, und des Stroms, der von der ausgewählten Stromsenke (334) aufgenommen wird, umfasst:

Sequenzielles Abzweigen des Stroms, der von der Stromquelle (332) bereitgestellt wird, und des Stroms, der von der Stromsenke (334) aufgenommen wird, zu dem Widerstand;
Messen der Spannung mit dem ADC während jedes sequenziellen Abzweigens und
Vergleichen der gemessenen Spannungen, um die Unterschiede der Ströme zu bestimmen.

15. Verfahren nach Anspruch 9, das weiterhin umfasst:

Auswählen einer zweiten Stromquelle und einer zweiten Stromsenke;
Bewerten des Stroms, der von der zweiten ausgewählten Stromquelle bereitgestellt wird, und des Stroms, der von der zweiten ausgewählten Stromsenke aufgenommen wird, mit einem zweiten Vergleicher;
Wiederholen der Auswahl der Stromquellen und Senken und des Vergleiches der Ströme bis eine gewünschte Anzahl von Stromquellen und Senken verglichen wurden.

Revendications

1. Dispositif médical de stimulation (290) comprenant :

une pluralité d'électrodes (201A, 201B, 201C) ; et
une source de courant (332) et un récepteur de courant (334) pouvant être connecté électriquement à chacune des électrodes (201A, 201B, 201C) par l'intermédiaire de commutateurs électriques ;
caractérisé par
un agencement d'étalonnage (380) configuré pour comparer le courant fourni par une source sélectionnée des sources de courant (332) au courant reçu par un récepteur sélectionné des récepteurs de courant (334) lorsque lesdits commutateurs sont réglés ouverts de sorte qu'aucun courant ne circule vers les électrodes, et configuré pour régler un paramètre fonctionnel d'au moins une de la source (332) et du récepteur (334) en se basant sur ladite comparaison, de sorte que le courant fourni par la source de courant sélectionnée (332) est sensiblement le même que le courant reçu par le récepteur de courant (334).

2. Dispositif médical (290) selon la revendication 1, comprenant en outre :

une mémoire, dans laquelle les paramètres fonctionnels d'un ou plusieurs des sources de courant sélectionnées (332) et du récepteur de courant sélectionné (334) sont enregistrés dans la mémoire pour utilisation ultérieure.

3. Dispositif médical (290) selon la revendication 2, dans lequel les électrodes (201A, 201B, 201C) sont configurées pour délivrer un courant de stimulation électrique au porteur du dispositif médical (290), et dans lequel le dispositif médical (290) est configuré pour utiliser les paramètres fonctionnels mémorisés pour générer le courant de stimulation électrique.

4. Dispositif médical (290) selon la revendication 1, dans lequel chaque source de courant (332) comprend un convertisseur numérique-analogique de type p (PCNA), et dans lequel chaque récepteur de courant (334) comprend un convertisseur numérique-analogique de type n (NCNA).

5. Dispositif médical (290) selon la revendication 1, dans lequel l'agencement d'étalonnage (380) comprend en outre :

un comparateur (330) configuré pour comparer le courant fourni par une source de courant (332) au récepteur de courant (334) par un NCNA ; et
un processeur (382) configuré pour régler les paramètres fonctionnels d'au moins un du PCNA et du NCNA en se basant sur la comparaison.

6. Dispositif médical (290) selon la revendication 5, dans lequel l'agencement d'étalonnage (380) comprend une pluralité de comparateurs, chacun étant configuré pour effectuer des comparaisons du courant fourni par une source de courant (332) au courant reçu par un récepteur de courant (334) ; et
dans lequel l'agencement d'étalonnage (380) comprend au moins un comparateur (330) pour chaque électrode (201A, 201B, 201C).

7. Dispositif médical (290) selon la revendication 1, dans lequel le paramètre fonctionnel réglable d'un CNA est la sortie commandée numériquement du CNA ayant une valeur sur plusieurs bits et dans lequel les éléments comparés sont mis en correspondance à moins du bit le moins significatif de cette valeur de CNA.

8. Dispositif médical (290) selon la revendication 1, dans lequel l'agencement d'étalonnage (380) comprend en outre :

une résistance et un convertisseur analogique-numérique (CAN) configuré pour comparer le courant fourni par une source de courant (332) au courant reçu par un récepteur de courant (334) ; et
un processeur (382) configuré pour régler les paramètres fonctionnels d'au moins un de la source de courant (332) et du récepteur de courant (334) en se basant sur la comparaison.

9. Procédé d'étalonnage de sources de courant (332) et de récepteurs de courant (334) dans un dispositif médical de stimulation (290) selon l'une quelconque des revendications 1 à 8, le procédé comprenant :

la sélection d'une source de courant (332) et d'un récepteur de courant (334) ;
caractérisé par
la comparaison du courant fourni par la source de courant sélectionnée (332) et du courant reçu par le récepteur de courant sélectionné (334) lorsque lesdits commutateurs sont réglés ouverts de sorte qu'aucun courant ne circule vers les électrodes ; et
le réglage d'un paramètre fonctionnel d'au moins un de la source (332) et du récepteur (334) en se basant sur l'évaluation, de sorte que le courant fourni par la source de courant sélectionnée (332) est sensiblement le même que le courant reçu par le récepteur de courant (334).

10. Procédé selon la revendication 9, comprenant en outre :

la mémorisation des paramètres fonctionnels d'un ou plusieurs de la source de courant sélectionnée (332) et du récepteur de courant sélectionné (334) pour utilisation ultérieure.

11. Procédé selon la revendication 9, dans lequel chacune des sources de courant (332) comprend un convertisseur numérique-analogique de type p (PCNA), et dans lequel chacun des récepteurs de courant (334) comprend un convertisseur numérique-analogique de type n (NCNA).

12. Procédé selon la revendication 9, dans lequel le dispositif (290) comprend une pluralité de comparateurs (330) et dans lequel le procédé comprend en outre :

l'évaluation du courant fourni par la source de courant sélectionnée (332) et du courant reçu par le récepteur de courant sélectionné (334) au moyen d'un premier comparateur (330) ;
la sélection d'une seconde source de courant et d'un second récepteur de courant ; et
l'évaluation du courant fourni par la seconde source de courant sélectionnée et du courant reçu par le second récepteur de courant sélectionné au moyen d'un second comparateur.

13. Procédé selon la revendication 9, dans lequel le paramètre fonctionnel réglable d'un CNA est la sortie commandée numériquement du CNA ayant une valeur sur plusieurs bits et dans lequel le réglage d'un paramètre fonctionnel d'au moins un de la source (332) et du récepteur (334) comprend :

le réglage du bit le moins significatif de cette valeur de sortie d'au moins un de la source de courant (332) ou du récepteur (334) de sorte que le courant fourni par la source sélectionnée (332) et le courant reçu par le récepteur de courant sélectionné (334) sont sensiblement les mêmes.

14. Procédé selon la revendication 9, dans lequel le dispositif médical (290) comprend une résistance et un convertisseur analogique-numérique (CAN), et dans lequel l'évaluation du courant fourni par la source de courant sélectionnée (332) et du courant reçu par le récepteur de courant sélectionné (334) comprend :

le détournement en séquence vers la résistance du courant fourni par la source de courant (332) et du courant reçu par le récepteur du courant (334) ;
la mesure de la tension au moyen du CAN pendant chaque détournement en séquence ; et
la comparaison des tensions mesurées pour déterminer la différence des courants.

15. Procédé selon la revendication 9, comprenant en outre :

la sélection d'une seconde source de courant et d'un second récepteur de courant ;
l'évaluation du courant fourni par la seconde source de courant sélectionnée et du courant reçu par le second récepteur de courant sélectionné au moyen d'un second comparateur ;
la répétition de la sélection des sources et des récepteurs de courant et de la comparaison des courants jusqu'à avoir comparé un nombre désiré de sources et de récepteurs de courant.

FIG. 1

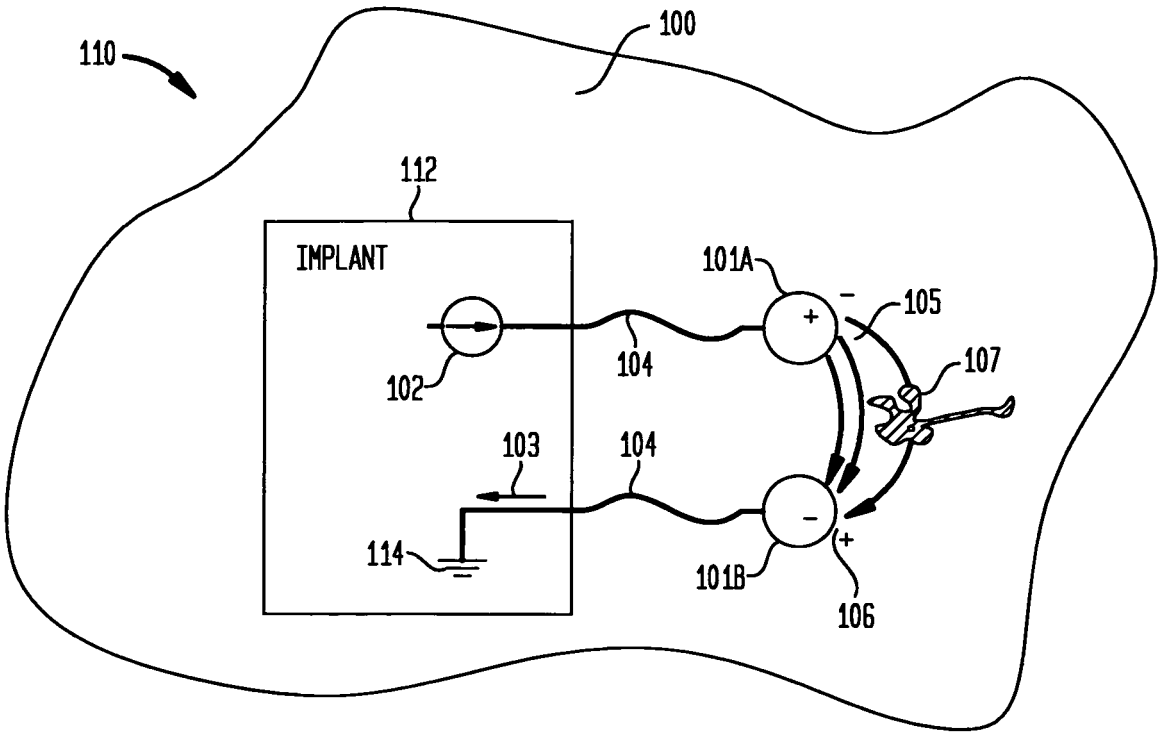

110
100
112
IMPLANT
101A
105
107
102
104
103
104
114
101B
106

FIG. 2

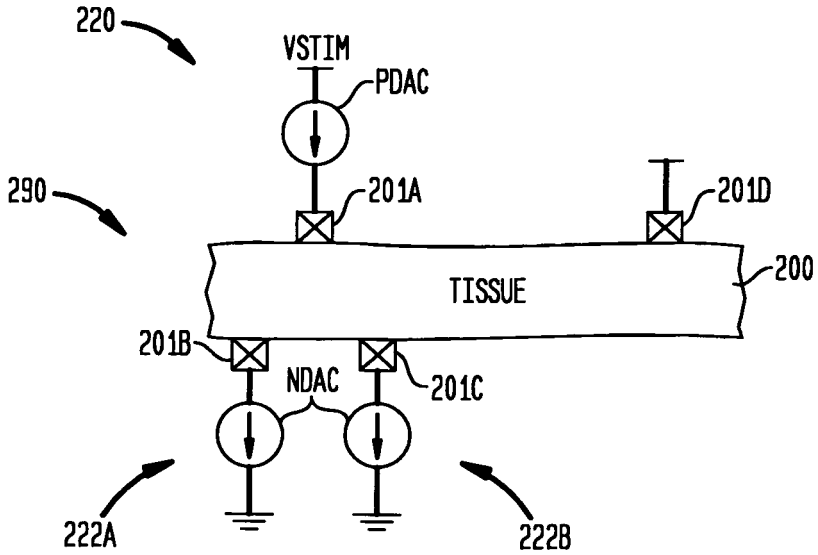

220
VSTIM
PDAC
290
201A
201D
TISSUE
200
201B
NDAC
201C
222A
222B

FIG. 3

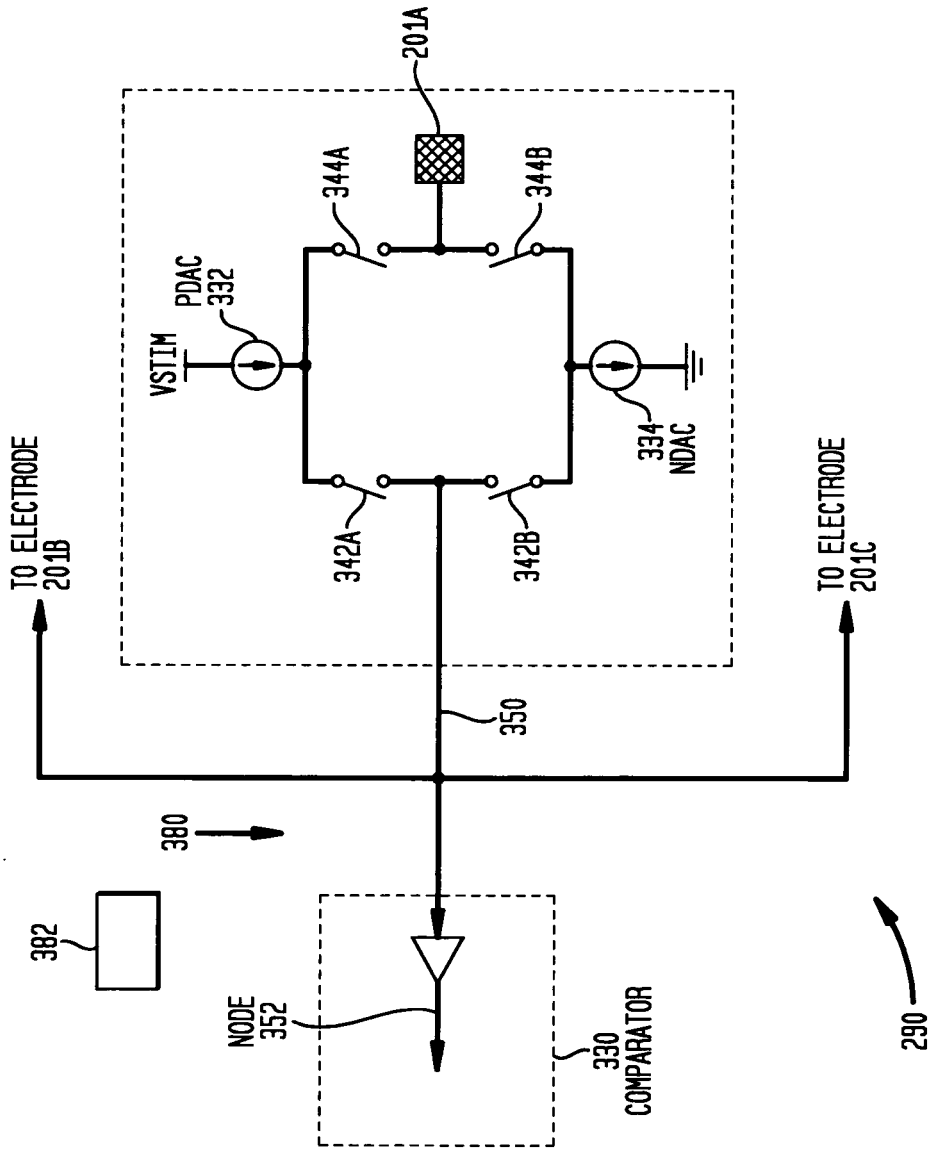
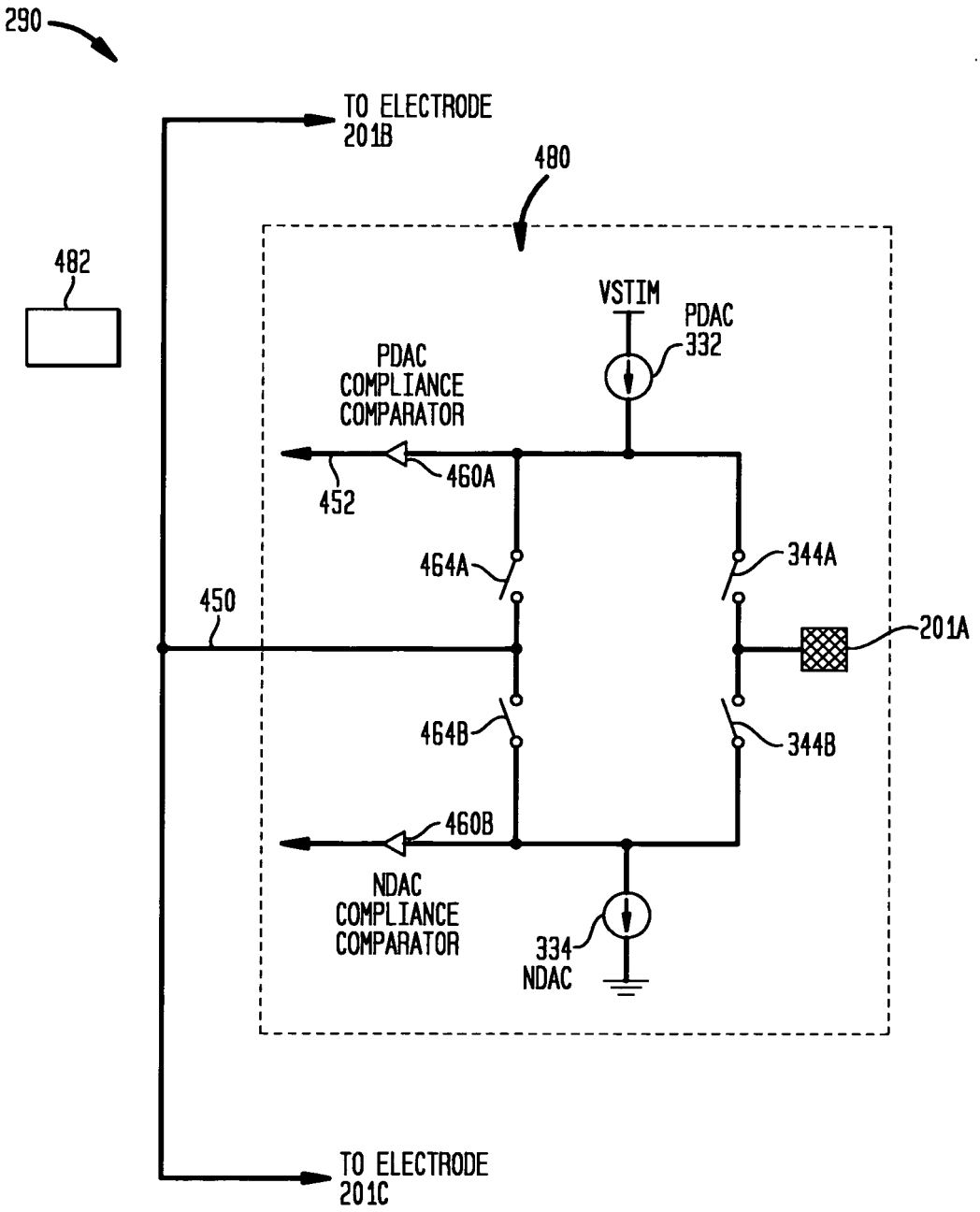

201A
344A
344B
PDAC
332
VSTIM
334
NDAC
342A
342B
TO ELECTRODE
201B
TO ELECTRODE
201C
350
380
382
NODE
352
330
COMPARATOR
290

FIG. 4


290
TO ELECTRODE 201B
480
482
VSTIM
PDAC 332
PDAC COMPLIANCE COMPARATOR
460A
452
464A
344A
450
201A
464B
344B
460B
NDAC COMPLIANCE COMPARATOR
334 NDAC
TO ELECTRODE 201C

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- GB 2449546 A **[0007]**
- US 20070135868 A1 **[0008]**

专利名称(译)	在刺激的医疗设备中校准电流源和吸收器		
公开(公告)号	EP2477692B1	公开(公告)日	2015-10-21
申请号	EP2010816789	申请日	2010-09-20
[标]申请(专利权)人(译)	耳蜗有限公司		
申请(专利权)人(译)	COCHLEAR有限公司		
当前申请(专利权)人(译)	COCHLEAR有限公司		
[标]发明人	MARKEY MATHEW MOGHE YOSHODHAN		
发明人	MARKEY, MATHEW MOGHE, YOSHODHAN		
IPC分类号	A61N1/36 H03M1/10 A61B5/00 G01R35/00 A61N1/372 A61N1/02		
CPC分类号	A61N1/025 A61N1/36038 A61N1/372 H03M1/1009		
优先权	2009217394 2009-09-18 AU		
其他公开文献	EP2477692A4 EP2477692A2		
外部链接	Espacenet		

摘要(译)

一种刺激性医疗装置，包括多个电极，以及连接到每个电极的电流源和电流吸收器。该医疗设备还包括校准装置，该校准装置被配置为将由所选择的一个电流源提供的电流与当前接收器中选定的一个电流吸收器进行比较，并且被配置为调整源和电源中的至少一个的操作参数。基于所述比较吸收，使得由所选电流源提供的电流与由电流吸收器吸收的电流基本相同。

FIG. 1

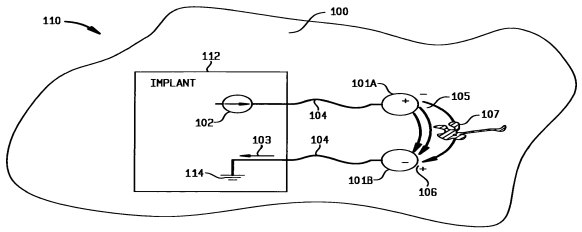


FIG. 2