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(54) **MEDICAL DEVICE AND SYSTEM FOR DETERMINING A HEMODYNAMIC PARAMETER USING INTRACARDIAC IMPEDANCE**

MEDIZINISCHE VORRICHTUNG UND SYSTEM ZUR BESTIMMUNG EINES HÄMODYNAMISCHEN PARAMETERS MIT INTRAKARDIALER IMPEDANZ

DISPOSITIF MEDICAL ET SYSTEME POUR DETERMINER UN PARAMETRE HEMODYNAMIQUE A L'AIDE DE L'IMPEDANCE CARDIAQUE

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Description

TECHNICAL FIELD

[0001] The present invention generally relates to medical devices for determining a measure of hemodynamic parameters such as the cardiac output, the stroke volume, or the contractility of a patient and in particular to implantable medical devices such as a pacemaker or cardioverter/defibrillators (ICDs) and systems including such a device and an external programmer for determining a measure of a hemodynamic parameter such as the cardiac output, the stroke volume, or the contractility of a patient for use, for example, in trending heart failure or in an AV/VV optimization scheme.

BACKGROUND OF THE INVENTION

[0002] Intracardiac impedance variations has been found to reflect the cardiac function and may hence be utilized for heart therapy in an implantable medical device such as a heart stimulator. In particular, the cardiac impedance has been found to be of great therapeutic value since the cardiac impedance correlates well with hemodynamic parameters such as, for example, cardiac output and stroke volume.

[0003] Implantable medical devices of this above-mentioned general type is known. For example, according to U.S. 2005/0215914 the ventricular impedance is used as a measure of end-diastolic volume in order to detect heart failure. The measured impedance, which is in inverse proportion to the ventricular end-diastolic value, is compared with threshold values representative of the onset and severity of heart failure and for comparison against previously detected ventricular end-diastolic values of the patient for use in tracking the progression of heart failure over time.

[0004] U.S. 2004/0078058 describes a heart stimulator including an analyzer that analyzes at least one predetermined parameter of an average impedance morphology curve for use for the control of the stimulation. A parameter having a value that is primarily dependent on the left ventricular ejection is used. The parameter may, for example, be the integrated area below the averaged impedance morphology curve versus time, maximum or minimum value of the average impedance morphology curve, or the difference between the maximum and minimum value of the average impedance morphology curve.

[0005] U.S. 5,843,137 discloses a method and apparatus for automatic determination of a pacing stimulations threshold. Values such as maximum, minimum and direction values that characterize the morphology of the impedance waveform is used to discriminate between capture and loss of capture.

[0006] U.S. 6,134,472 describes an implantable heart stimulation device that measures electrical impedance to obtain a measure of the ventricular filling. The impedance is measured at the time when the impedance reaches a peak value, which occurs at an approximately fixed time about 250 to 300 ms after the stimulation pulse, and immediately prior to emission of a stimulation pulse. The difference between these two measurement values provides a measure of the stroke volume. This procedure requires a precise synchronization between the impedance measurements and the stimulation pulses in order to provide a measure of the stroke volume and accordingly it may be sensitive to disturbances and/or time delays.

[0007] EP 1 384 492 A1 discloses a heart stimulator for electric stimulation of a patient's heart that comprises an impedance measuring unit adapted to measure the impedance (Z) between at least two measuring electrodes intended to be implanted in a patient such that volume changes of at least one of the chambers of the left heart result in changes in the measured impedance. Analysing means are provided for analysing the measured impedance for the control of the stimulation of the heart. A calculation means is provided to calculate an average impedance morphology curve during a time interval of several cardiac cycles. The analysing means are adapted to analyse the average impedance morphology curve for use for the control of the stimulation to optimise the patient hemodynamics.

[0008] Thus, there is a need of an improved implantable medical device that is capable of providing a reliable and accurate measure of hemodynamic parameters such as stroke volume, cardiac output, or contractility.

BRIEF DESCRIPTION OF THE INVENTION

[0009] An object of the present invention is to provide an improved implantable medical device that is capable of providing a reliable and accurate measure of hemodynamic parameters such as stroke volume, cardiac output, or contractility.

[0010] Another object of the present invention is to provide a system including an implantable medical device and an external programmer apparatus that is capable of providing a reliable and accurate measure of hemodynamic parameters such as stroke volume, cardiac output, or contractility.

[0011] A further object of the present invention is to provide an implantable medical device and a system including an implantable medical device and an external programmer apparatus that are capable of providing a reliable and accurate measure of hemodynamic parameters such as stroke volume, cardiac output, or contractility for use in optimizing settings

of the implantable device, for example, pacing parameters or for deriving a condition or change of a condition of a patient.

[0012] These and other objects are achieved according to the present invention by providing a medical device having the features defined in the independent claim. Preferable embodiments of the invention are characterised by the dependent claims.

[0013] According to an aspect of the present invention, there is provided an implantable medical device including a pulse generator adapted to produce cardiac stimulating pacing pulses, the device being connectable to at least one lead comprising electrodes for delivering the pulses to cardiac tissue of a heart of a patient. The implantable medical device comprises an impedance measuring unit connectable to at least two electrodes adapted to measure cardiac impedance of the heart, the impedance measuring unit being adapted to provide impedance information corresponding to the measured impedance; an impedance morphology determining unit adapted to receive the impedance information and to determine an impedance morphology curve from the impedance information; and a calculation unit adapted to detect an extreme point section of the impedance morphology curve and to calculate a measure of a hemodynamic parameter of the heart utilizing the extreme point section.

[0014] According to a second aspect of the present invention, there is provided a medical system including an external programmer apparatus comprising a communication unit and an implantable medical device including a pulse generator adapted to produce cardiac stimulating pacing pulses, the implantable device being connectable to at least one lead comprising electrodes for delivering the pulses to cardiac tissue of a heart of a patient, and a communication unit, wherein the external apparatus and the implantable device are adapted for two-way communication of data using the communication units. The implantable medical device further comprises an impedance measuring unit connectable to at least two electrodes adapted to measure cardiac impedance of the heart, the impedance measuring unit being adapted to provide impedance information corresponding to the measured impedance. The external apparatus is adapted to obtain the impedance information via the communication unit and further comprises an impedance morphology determining unit adapted to receive the impedance information and to determine an impedance morphology curve from the impedance information; and a calculation unit adapted to detect an extreme point section of the impedance morphology curve and to calculate a measure of a hemodynamic parameter of the heart utilizing the extreme point section.

[0015] According to a third aspect of the present invention, there is provided a medical system including an external programmer apparatus comprising a communication unit and an implantable medical device including a pulse generator adapted to produce cardiac stimulating pacing pulses, the implantable device being connectable to at least one lead comprising electrodes for delivering the pulses to cardiac tissue of a heart of a patient, and a communication unit, wherein the external apparatus and the implantable device are adapted for two-way communication of data using the communication units. The implantable medical device further comprises an impedance measuring unit connectable to at least two electrodes adapted to measure cardiac impedance of the heart, the impedance measuring unit being adapted to provide impedance information corresponding to the measured impedance; and an impedance morphology determining unit adapted to receive the impedance information and to determine an impedance morphology curve from the impedance information. The external apparatus is adapted to obtain the impedance morphology curve via the communication unit and further comprises a calculation unit adapted to detect an extreme point section of the impedance morphology curve and to calculate a measure of a hemodynamic parameter of the heart utilizing the extreme point section.

[0016] Thus, the present invention is based on the insight that the intracardiac impedance variations reflect the cardiac function and hence can be utilized for heart therapy in an implantable medical device such as a heart stimulator and that the cardiac impedance has been found to be of great therapeutic value since the cardiac impedance correlates very well with hemodynamic parameters such as, for example, cardiac output and stroke volume. In particular, the actual shape of the cardiac impedance signal and the morphology of the peak section and its immediate surroundings has been found to contain valuable information regarding the hemodynamic performance of a patient. This information is, according to the present invention, used to determine or calculate a measure of a hemodynamic parameter of the patient, for example, cardiac output, stroke volume, or contractility. This measure may, in turn, be used to control heart stimulation to optimize hemodynamics or to trend, for example, the development of heart failure.

[0017] According to the second aspect of the present invention, the programmer obtains impedance data from the implantable device and performs the impedance morphology determination and the calculation of the hemodynamic measure. That is, the impedance data processing is mainly performed in the programmer and thus the data processing executed in the implantable device can be minimized. The impedance data transfer to the programmer may be performed continuously or at regular intervals.

[0018] According to the third aspect of the present invention, the programmer obtains impedance curves from the implantable device and performs the calculation of the hemodynamic measure. That is, the calculation of the hemodynamic measure is performed in the programmer and thus the data processing executed in the implantable device can be reduced. The transfer of impedance curves to the programmer may be performed continuously or at regular intervals.

[0019] In one embodiment of the present invention, the implantable medical device includes an analyzer adapted to analyze the measure to optimize at least one pacing parameter of the pulse generator or to derive a change of a condition of the patient. Thereby, the heart stimulation pulses may be controlled such that the patient hemodynamics is optimized.

For example, an AV/VV interval may be optimized. The obtained measure can also be used to trend conditions such as, for example, heart failure. In an alternative embodiment, the analyzer is arranged in the external programmer apparatus.

[0020] According another embodiment of the present invention, the calculation unit is adapted to calculate the measure by means of the shape of the impedance morphology curve in a time window surrounding the peak section of the impedance morphology curve.

[0021] In a further embodiment of the present invention, the impedance morphology determining unit is adapted to determine an averaged impedance morphology curve from the impedance information during a time interval of a plurality of cardiac cycles of the heart. For example, a predetermined number of consecutive heart beats may be used to create the averaged impedance curve. In an alternative embodiment, the impedance morphology determining unit is adapted to perform a filtering procedure of the received impedance information and to determine an impedance morphology curve from the filtered impedance information.

[0022] In another embodiment of the present invention, the calculation unit is adapted to detect the maximum value of the impedance morphology curve and to centre the time window about the value. The maximum value or peak section of the curve may be located by using the first and second time derivatives of the curve section.

[0023] In yet another embodiment of the present invention, the calculation unit is adapted to fit a polynomial of degree two to the section of the impedance morphology curve in the time window.

[0024] According to further embodiment of the present invention, a curvature component of the polynomial is used as the measure. The second degree constant has been found to contain information of the magnitude of the curvature of the cardiac impedance waveform and may thus be used as the measure of the shape of the cardiac impedance signal, and, in turn, as a measure of the hemodynamic parameter, for example, the stroke volume or the cardiac output.

[0025] In another embodiment of the procedure for calculating the measure according to the present invention, the sample corresponding to the maximum value is identified, a window centred about the maximum value containing a predetermined number of samples is defined, the values of the start and end samples of the window, respectively, are identified, an average value of the start and end values is calculated, and a ratio of the average value and the maximum value is calculated as the measure. According to an alternative, a window centred about the maximum value having a predetermined length of time is defined and the samples corresponding to the start and end of the time window are identified and used to calculate the ratio.

[0026] Alternatively, to calculate the measure of the hemodynamic parameter, the sample corresponding to the maximum value is identified, a window centred about the maximum value containing a predetermined number of samples is defined, and an area of the window by adding the values of the predetermined number of samples is calculated as the measure. According to an alternative, a window centred about the maximum value having a predetermined length of time is defined and the values of the samples included in the time window are added up to calculate the area.

[0027] In a further embodiment of the procedure for calculating the measure in accordance with the present invention, the sample corresponding to the maximum value is identified, a time window centred about the maximum value containing a predetermined number of samples is defined, the values of the start and end values of the window, respectively, are identified, a first average slope from the sample corresponding to the start value to the sample corresponding to the maximum value is calculated, a second average slope from the sample corresponding to the maximum value to the sample corresponding to the end value is calculated, and the first slope and the second slope is used to calculate the measure. For example, a ratio between the slopes or a product of the slopes can be calculated.

[0028] In yet another embodiment of the present invention, a time window is defined at a predetermined amplitude in relation to the maximum value and a width of the time window as the measure is calculated.

[0029] In one embodiment, the resistive part of the cardiac impedance is used. Furthermore, the impedance information may also or alternatively, for example, include the magnitude of the complex impedance, the real and/or imaginary part (i.e. the inductive or capacitive part) of the complex impedance.

[0030] According to further embodiments, the hemodynamic parameter is stroke volume, cardiac output, or contractility.

[0031] The features that characterize the invention will be better understood from the following description used in conjunction with the accompanying drawings. It is to be expressly understood that the drawings is for the purpose of illustration and description and is not intended as a definition of the limits of the invention. These and other objects attained, and advantages offered, by the present invention will become more fully apparent as the description that now follows is read in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0032] In the following detailed description, reference will be made to the accompanying drawings, of which:

Fig. 1 is block diagram of the primary functional components of an embodiment of the implantable medical device according to the present invention.

Fig. 2 is a block diagram of a part of the embodiment of the implantable medical device shown in Fig. 1.

Fig. 3 is a general block diagram of an embodiment of the system according to the present invention.

5 Fig. 4 is block diagram of the primary functional components of an embodiment of the implantable medical device of the system shown in Fig. 4 according to the present invention.

Fig. 5 is a general block diagram of another embodiment of the system according to the present invention.

10 Fig. 6 is block diagram of the primary functional components of an embodiment of the implantable medical device of the system shown in Fig. 5 according to the present invention.

Fig. 7 is a flow chart illustrating steps for determining a measure of a hemodynamic parameter.

15 Fig. 8 is a flow chart of a calculation procedure

Fig. 9 is a flow chart of another calculation procedure

Fig. 10 is a flow chart of yet another calculation procedure.

20 Fig. 11 is a flow chart of a further calculation procedure

DETAILED DESCRIPTION OF THE INVENTION

25 **[0033]** With reference first to Fig. 1, an embodiment of the implantable medical device according to the present invention will be shown. This embodiment of the present invention is implemented in the context of a pacemaker 20 implanted in a patient (not shown). The pacemaker 20 comprises a housing being hermetically sealed and biologically inert. Normally, the housing is conductive and may, thus, serve as an electrode. One or more pacemaker leads, where only two are shown in Fig. 1, 2 6a and 2 6b, are electrically coupled to the pacemaker 20 in a conventional manner. The leads 26a, 26b extend into the heart (not shown) via a vein of the patient. One or more conductive electrodes for receiving electrical cardiac signals and/or for delivering electrical pacing to the heart are arranged near the distal ends of the leads 26a, 26b. As the skilled man in the art realizes, the leads 26a, 26b may be implanted with its distal end located in either the atrium or ventricle of the heart.

30 **[0034]** The leads 26a, 26b may be unipolar or bipolar, and may include any of the passive or active fixation means known in the art for fixation of the lead to the cardiac tissue. For example, a good fixation of electrodes can be obtained by means of a screw-in electrodes. Alternatively, the lead distal tip (not shown) may include a tined tip or a fixation helix.

[0035] The leads 26a, 26b comprises one or more electrodes, such a tip electrode or a ring electrode, arranged to, inter alia, transmit pacing pulses for causing depolarization of cardiac tissue adjacent to the electrode(-s) generated by a pace pulse generator 22 under influence of a control circuit 23 comprising a microprocessor. The control circuit 23 controls, inter alia, pace pulse parameters such as output voltage and pulse duration. A memory circuit 31 is connected to the control circuit 27, which memory circuit 35 may include a random access memory (RAM) and/or a non-volatile memory such as a read-only memory (ROM). Detected signals from the patients heart are processed in an input circuit 33 and are forwarded to the microprocessor of the control circuit 27 for use in logic timing determination in known manner.

35 **[0036]** Furthermore, an impedance measuring unit 25 is adapted to carry out impedance measurements of the cardiac impedance of the patient. The impedance vector used should preferably capture the filling and emptying of the ventricle (right or left). The impedance measuring unit 25 is thus arranged to apply excitation current pulses between a first electrode and a second electrode arranged to positioned, for example, within a heart of the patient. In one embodiment which does not form part of the invention, the current is emitted between a right ventricular tip electrode and a left ventricular tip electrode. The first and second electrode may also be positioned outside the heart. The impedance measuring unit 40 25 is also arranged to measure the voltage between a third and fourth electrode arranged, for example, at a lead 26a, or 26b. The third and fourth electrode are arranged such that they can be located within the heart of the patient, for example, in a vein/artery of the heart. In one embodiment which does not form part of the invention, the voltage is sensed between a right ventricular ring electrode and a left ventricular ring electrode.

45 **[0037]** According to another embodiment which does not form part of the invention, tri-polar measurements are used to perform the impedance measurements where the current is sent out between an RV-tip (i.e. the distal electrode in a bipolar lead located in right ventricle) and an RV-coil (i.e. the conductor in a bipolar lead having a helical configuration located in the right ventricle) and the voltage is measured between an RV-ring (i.e. the proximal electrode in a bipolar lead located in right ventricle) and the RV-coil.

[0038] The impedance measuring unit 25 may comprise an amplifier (not shown) that amplifies the evoked voltage response, i.e. the measured voltage, and may be synchronized in a multiplier with the excitation current. Thus, the impedance measuring unit 25 obtains the cardiac impedance given by the delivered current and the evoked voltage response. Then, the impedance information corresponding to the measured impedance is sent to an impedance processing unit 21.

[0039] The impedance information used may include the resistive part of the cardiac impedance. Furthermore, the impedance information may also or alternatively, for example, include the magnitude of the complex impedance, the real and/or imaginary part (i.e. the inductive or capacitive part) of the complex impedance.

[0040] The impedance processing unit 21 may be adapted to determine an averaged impedance morphology curve from the received impedance information during a time interval of a plurality of cardiac cycles. In another embodiment, the received impedance information is filtered and a morphology curve based on the impedance information obtained during one heart beat is determined. The signals may be bandpass filtered to remove the DC-component. Furthermore, an extreme point section of the impedance morphology curve is detected and a measure of a hemodynamic parameter of the heart, for example, stroke volume, cardiac output, or contractility, utilizing the extreme point section is calculated. In one embodiment, the extreme point section is a peak section. Different approaches for calculating the measure will be discussed below. Thereafter, the obtained measure is analyzed to optimize at least one pacing parameter of the pulse generator or to derive a change of a condition of the patient. The control circuit 23 may be connected to the impedance processing unit 21 to control the heart stimulation pulse generator 22 in response to the output from the impedance processing unit 21 such that the patient hemodynamics can be optimized. For example, an AV/VV interval may be optimized. The obtained measure can also be used to trend, for example, heart failure.

[0041] With reference to Fig. 2, an embodiment of the impedance processing unit 21 will be described. An impedance morphology determining unit 27 is adapted to receive the impedance information corresponding to the measured impedance from the impedance measuring unit 25. The impedance morphology determining unit 27 may be adapted to determine an averaged impedance morphology curve from the received impedance information during a time interval of a plurality of cardiac cycles. In another embodiment, the received impedance information is median filtered and a morphology curve based on the impedance signal obtained during one heart beat is determined.

[0042] In a calculation unit 29, an extreme point section of the impedance morphology curve is detected and a measure of a hemodynamic parameter of the heart, for example, stroke volume, cardiac output, or contractility, utilizing the extreme point section is calculated. In one embodiment, the extreme point section is a peak section. The measure obtained from the calculation unit 29 is analyzed in an analyzer 31 to optimize at least one pacing parameter of the pulse generator or to derive a change of a condition of the patient. The control circuit 23 may be connected to the analyzer 31 for the optimization discussed above.

[0043] The implantable medical device 20 is powered by a battery (not shown), which supplies electrical power to all electrical active components of the medical device 20. Data contained in, for example, the memory circuit 35 can be transferred to a programmer (not shown in Fig. 1) via a communication unit 37, e.g. a telemetry unit, including a programmer interface for use in analyzing system conditions, patient information, etc. The analyzer 31 may also transfer data to the programmer via the communication unit 37.

[0044] With reference now to Figs. 3-6, embodiments of the system according to the present invention will be discussed. Like or similar parts in Fig. 1, 2, 4 and 6 are denoted with the same reference numerals and therefore the description of such parts will omitted since they were discussed above with respect to Figs. 1 and 2. Likewise, like or similar parts in Fig. 3 and 5 are denoted with the same reference numerals and therefore the description of such parts will omitted since they were discussed above with respect to Fig. 3.

[0045] With reference first to Fig. 3 and 4, one embodiment of the system according to the present invention will be described. In Fig. 3, it can be seen that the system 50 includes an implantable medical device 40, which is shown in more detail in Fig. 4, and an external programmer apparatus 51. The implantable device 40 and the external programmer 51 are adapted for two-way communication of data between each other via communication units 37 and 53, respectively. In this embodiment, the implantable medical device 40 comprises the impedance morphology determining unit 27 adapted to receive the impedance information from the impedance measuring unit 25 and to determine an impedance morphology curve from the impedance information. The impedance morphology curves can be stored in the memory circuit 37 or they may be buffered locally in the impedance morphology determining unit 27 before being transferred to the external programmer apparatus 51 via the communication units 37 and 53, respectively. This data transfer can be performed either continuously or at predetermined intervals of time. In the external programmer apparatus 51, the received impedance morphology data is processed in a calculation unit 55 to detect an extreme point section of the impedance morphology curve (or extreme points sections of respective curves) and a measure of a hemodynamic parameter of the heart, for example, stroke volume, cardiac output, or contractility, utilizing the extreme point section is calculated using the extreme point section. In one embodiment, the extreme point section is a peak section. The measure obtained from the calculation unit 55 may be analyzed in an analyzer 57 to optimize at least one pacing parameter of the pulse generator of the implantable medical device 40 or to derive a change of a condition of the patient. The updated pacing parameters

may be communicated to the implantable medical device 40 via the communication units 53 and 37, respectively, to control the heart stimulation pulse generator 22 in response to the output from the impedance processing unit 57 such that the patient hemodynamics can be optimized. For example, an AV/VV interval may be optimized. The obtained measure can also be used to trend, for example, heart failure.

[0046] With reference first to Fig. 5 and 6, another embodiment of the system according to the present invention will be described. In Fig. 5, it can be seen that the system 70 includes an implantable medical device 60, which is shown in more detail in Fig. 6, and an external programmer apparatus 71. The implantable device 60 and the external programmer 71 are adapted for two-way communication of data between each other via communication units 37 and 53, respectively. In this embodiment, the impedance information data from the impedance measuring unit 25 is streamed to the external programmer apparatus 71. Alternatively, the impedance information data can be stored in the memory circuit 37 or buffered locally in the impedance measuring unit 25 before being transferred to the external programmer apparatus 71 via the communication units 37 and 53, respectively. This data transfer can be performed at predetermined intervals of time. In the external programmer apparatus 71, the received impedance data is processed in a impedance morphology determination unit 54 to determine an averaged impedance morphology curve from the received impedance information during a time interval of a plurality of cardiac cycles. In another embodiment, the received impedance information filtered and a morphology curve based on the impedance signal obtained during one heart beat is determined. In the calculation unit 55 an extreme point section of the impedance morphology curve (or extreme points sections of respective curves) and a measure of a hemodynamic parameter of the heart, for example, stroke volume, cardiac output, or contractility, utilizing the extreme point section is calculated using the extreme point section. In one embodiment, the extreme point section is a peak section. The measure obtained from the calculation unit 55 may be analyzed in an analyzer 57 to optimize at least one pacing parameter of the pulse generator of the implantable medical device 60 or to derive a change of a condition of the patient. The updated pacing parameters may be communicated to the implantable medical device 60 via the communication units 53 and 37, respectively, to control the heart stimulation pulse generator 22 in response to the output from the impedance processing unit 57 such that the patient hemodynamics can be optimized. For example, an AV/VV interval may be optimized. The obtained measure can also be used to trend, for example, heart failure.

[0047] Turning now to Fig. 7, a general description of a method for calculating the measure of a hemodynamic parameter will be given. First, at step 100, it may be checked whether at least one predetermined measurement criteria is fulfilled.

[0048] However, this step is optional. At step 102, impedance measurements of the cardiac impedance of the patient is performed. If the criteria check step is performed, the measurement step 102 is performed if the predetermined criteria is fulfilled. Thereafter, at step 104, an averaged impedance morphology curve from the received impedance information during a time interval of a plurality of cardiac cycles is determined. In another method, the received impedance information is filtered and a morphology curve based on the impedance signal obtain during one heart beat is determined. As discussed above, this step may be performed either in the implantable medical device or in the external programmer apparatus. If the morphology curves are calculated in the programmer, the impedance data may streamed over to the programmer from the implantable device or is may be transferred at regular intervals. If the curves are calculated in the implantable device, the curves may be transferred on a continuous basis or at regular intervals. Then, at step 106, an extreme point section of the impedance morphology curve is detected. In one embodiment, the extreme point section is a peak section. A measure of a hemodynamic parameter of the heart, for example, stroke volume, cardiac output, or contractility, utilizing the extreme point section is calculated. Different approaches for calculating the measure will be discussed below. The calculation step may be executed in the programmer or in the implantable device.

[0049] Thereafter, at step 108, the obtained measure may be analyzed to optimize at least one pacing parameter of the pulse generator or to derive a change of a condition of the patient. The control circuit 23 may receive the updated pacing parameters to control the heart stimulation pulse generator 22 in response to the output from the such that the patient hemodynamics can be optimized. For example, an AV/VV interval may be optimized. The obtained measure can also be used to trend, for example, heart failure.

[0050] Referring now to Figs. 8-12, different calculations procedures for calculating the measure of a hemodynamic parameter of the heart, for example, stroke volume, cardiac output, or contractility according to the present invention will be described. As discussed above, the actual shape of the cardiac impedance signal and especially the morphology of the extreme points sections, e.g. the peak point section, and the immediate surroundings contain information of the hemodynamic status of the patient that can be used to obtain the above-mentioned relative measure of the hemodynamic parameter.

[0051] With reference first to Fig. 8, a first calculation procedure will be discussed. First, at step 120, an extreme point of the impedance morphology curve is detected. In this procedure, a top part or peak value of the impedance morphology curve is detected and time window having a predetermined length is centered about this peak value. To locate the peak section of the curve, minima and maxima in the first and second time derivative of the curve can be used. Thereafter, at step 122, a polynomial of a predetermined degree, e.g. a 2nd degree polynomial, is adapted to the curve section of the predetermined time window. If the 2nd degree polynomial is used, it will hence be the following form: $a \cdot x^2 + b \cdot x + c$. Then, at step 124, the constant a is stored as a measure of the curvature of the waveform peak and is used

as a measure of the hemodynamic parameter.

[0052] Turning instead to Fig. 9, another calculation procedure will be discussed. First, at step 130, an extreme point of the impedance morphology curve is detected. In this procedure, a top part or peak value of the impedance morphology curve is detected and time window having a predetermined length is centered about this peak value. Then, at step 132, the sample, S_n , corresponding to the maximum value or peak value is identified. Subsequently, at step 134, a window consisting of samples S_{n-m} to S_{n+m} centred about the maximum value containing a predetermined number $2m+1$ of samples, wherein m may be a number between 5 and 35 with $f_s=128\text{Hz}$ (corresponding to 40-280 mS). Thereafter, at step 136, the values of the start and end points or samples of the window, respectively, are identified and an average value of the start and end values are calculated in accordance with:

$$\frac{\text{Value}_{S_{n+m}} + \text{Value}_{S_{n-m}}}{2} = \alpha$$

[0053] Then, at step 138, a measure of the hemodynamic parameter is calculated as a ratio of the average value and the maximum value β in accordance with:

$$\text{Measure of hemodynamic parameter} = \frac{\alpha}{\beta}$$

[0054] With reference now to Fig. 10, a further calculation procedure will be discussed. First, at step 140, an extreme point of the impedance morphology curve is detected. In this procedure, a top part or peak value of the impedance morphology curve is detected and a time window having a predetermined length is centered about this peak value. Then, at step 142, the sample, S_n , corresponding to the maximum value or peak value is identified. Subsequently, at step 144, a window consisting of samples S_{n-m} to S_{n+m} centred about the maximum value containing a predetermined number $2m+1$ of samples, wherein m may be a number between 5 and 35 with $f_s=128\text{Hz}$ (corresponding to 40-280 mS). Thereafter, at step 146, the area of the defined curve section is estimated by adding up sample values for the samples S_{n-m} to S_{n+m} . This can be performed with or without time- or amplitude normalization. Finally, at step 148, the calculated area is used as the measure of the hemodynamic parameter, for example, cardiac output or stroke volume.

[0055] Turning to Fig. 11, yet another procedure will be discussed. First, at step 150, an extreme point of the impedance morphology curve is detected. In this procedure, a top part or peak value of the impedance morphology curve is detected and time window having a predetermined length is centered about this peak value. Then, at step 152, the sample, S_n , corresponding to the maximum value or peak value is identified. Subsequently, at step 154, a window consisting of samples S_{n-m} to S_{n+m} centred about the maximum value containing a predetermined number $2m+1$ of samples, wherein m may be a number between 5 and 35 with $f_s=128\text{Hz}$ (corresponding to 40-280 mS). Thereafter, at step 156, the average slopes from sample S_{n-m} to the maximum point, A, and from the maximum point to the sample S_{n+m} , B, are calculated, respectively. Finally, at step 158, the measure is calculated as the ratio between the slopes in accordance with the following:

$$\text{Measure of hemodynamic parameter} = \frac{A}{-B}.$$

[0056] This ratio thus describes a warpedness of the section of the curve of the window.

[0057] Alternatively, the measure can be calculated as:

$$\text{Measure of hemodynamic parameter} = A \cdot (-B).$$

[0058] According to a further alternative, the measure is calculated as:

$$\text{Measure of hemodynamic parameter} = \frac{1}{A + (-B)} .$$

[0059] According to still another procedure, a time window at a predetermined amplitude in relation to the maximum value is defined and a width of the time window is calculated as the measure.

[0060] It is to be understood that the above description of the invention and the accompanying drawings is to be regarded as a non-limiting example thereof and that the scope of protection is defined by the appended patent claims.

Claims

1. An implantable medical device including a pulse generator adapted to produce cardiac stimulating pacing pulses, said device being connectable to at least one lead comprising electrodes for delivering said pulses to cardiac tissue of a heart of a patient, comprising:

an impedance measuring unit connectable to at least two electrodes adapted to measure cardiac impedance of said heart, said impedance measuring unit being adapted to provide impedance information corresponding to said measured impedance;

an impedance morphology determining unit adapted to receive said impedance information and to determine an impedance morphology curve from said impedance information; **characterized in that** said medical device comprises

a calculation unit adapted to detect an extreme point section of said impedance morphology curve and to calculate a measure of a hemodynamic parameter of said heart utilizing said an extreme point section.

2. The implantable medical device according to claim 1, wherein said extreme point section is a peak section.

3. The implantable medical device according to claim 1 or 2, further comprising an analyzer adapted to analyze said measure to optimize at least one pacing parameter of said pulse generator or to derive a change of a condition of said patient.

4. The implantable medical device according to claim 2 or 3, wherein said calculation unit is adapted to calculate said measure by means of the shape of the impedance morphology curve in a time window surrounding said peak section of said impedance morphology curve.

5. The implantable medical device according to any one of preceding claims, wherein said impedance morphology determining unit is adapted to determine an averaged impedance morphology curve from said impedance information during a time interval of a plurality of cardiac cycles of said heart.

6. The implantable medical device according to any one of claims 1-4, wherein said impedance morphology determining unit is adapted to perform a filtering procedure of said received impedance information and to determine an impedance morphology curve from said filtered impedance information.

7. The implantable medical device according to any one of preceding claims, wherein said calculation unit is adapted to detect the maximum value of said impedance morphology curve and to centre said time window about said value.

8. The implantable medical device according to any one of preceding claims, wherein said calculation unit is adapted to fit a polynomial of degree two to the section of the impedance morphology curve in said time window.

9. The implantable medical device according to claim 8, wherein said calculation unit is adapted to calculate a curvature component of said polynomial as said measure.

10. The implantable medical device according to claim 7, wherein said calculation unit is adapted to:

identify the sample corresponding to the maximum value;
define a window centred about the maximum value containing a predetermined number of samples;
identify the values of the start and end samples of said window, respectively;

calculate an average value of said start and end values; and
calculate a ratio of said average value and said maximum value as said measure.

- 5 11. The implantable medical device according to claim 7, wherein said calculation unit is adapted to identify the sample corresponding to the maximum value;
define a window centred about the maximum value containing a predetermined number of samples; and
calculating an area of said window by adding the values of said predetermined number of samples as said measure.
- 10 12. The implantable medical device according to claim 7, wherein said calculation unit is adapted to identify the sample corresponding to the maximum value;
define a time window centred about the maximum value containing a predetermined number of samples;
identify the values of the start and end values of said window, respectively;
calculate a first average slope from the sample corresponding to said start value to said sample corresponding to said maximum value;
15 calculate a second average slope from the sample corresponding to the maximum value to the sample corresponding to the end value; and
calculate a ratio between said first slope and said second slope as said measure.
- 20 13. The implantable medical device according to claim 7, wherein said calculation unit is adapted to define a time window at a predetermined amplitude in relation to the maximum value; and
calculating a width of said time window as said measure.
- 25 14. The implantable medical device according to any one of preceding claims, wherein said hemodynamic parameter is stroke volume, cardiac output, or contractility.
- 30 15. A medical system including an external programmer apparatus comprising a communication unit and an implantable medical device including a pulse generator adapted to produce cardiac stimulating pacing pulses, said implantable device being connectable to at least one lead comprising electrodes for delivering said pulses to cardiac tissue of a heart of a patient, and a communication unit, said external apparatus and said implantable device being adapted for two-way communication of data using said communication units,
wherein said implantable medical device further comprises an impedance measuring unit connectable to at least two electrodes adapted to measure cardiac impedance of said heart, said impedance measuring unit being adapted to provide impedance information corresponding to said measured impedance; and
35 wherein said external apparatus is adapted to obtain said impedance information via said communication unit and further comprises
an impedance morphology determining unit adapted to receive said impedance information and to determine an impedance morphology curve from said impedance information; **characterized in that** said medical system comprises
a calculation unit adapted to detect an extreme point section of said impedance morphology curve and to calculate
40 a measure of a hemodynamic parameter of said heart utilizing said an extreme point section.
16. The system according to claim 15, wherein said extreme point section is a peak section.
- 45 17. The system according to claim 15 or 16, wherein said external programmer apparatus further comprises an analyzer adapted to analyze said measure to optimize at least one pacing parameter of said pulse generator or to derive a change of a condition of said patient, said external apparatus being adapted to communicate said at least one pacing parameter to said implantable device.
- 50 18. The system according to claim 15 or 16, wherein said external programmer apparatus is adapted to communicate said measure to said implantable device and wherein said implantable medical device further comprises an analyzer adapted to analyze said measure to optimize at least one pacing parameter of said pulse generator or to derive a change of a condition of said patient.
- 55 19. The system according to claim 17, or 18, wherein said calculation unit is adapted to calculate said measure by means of the shape of the impedance morphology curve in a time window surrounding said peak section of said impedance morphology curve.
20. The system according to any one of preceding claims 15-19, wherein said impedance morphology determining unit

is adapted to determine an averaged impedance morphology curve from said impedance information during a time interval of a plurality of cardiac cycles of said heart.

21. The system according to any one of claims 15-20, wherein said impedance morphology determining unit is adapted to perform a filtering procedure of said received impedance information and to determine an impedance morphology curve from said filtered impedance information.

22. The system according to any one of preceding claims 15-21, wherein said calculation unit is adapted to detect the maximum value of said impedance morphology curve and to centre said time window about said value.

23. The system according to any one of preceding claims 15-22, wherein said calculation unit is adapted to fit a polynomial of degree two to the section of the impedance morphology curve in said time window.

24. The system according to claim 23, wherein said calculation unit is adapted to calculate a curvature component of said polynomial as said measure.

25. The system according to claim 22, wherein said calculation unit is adapted to:

identify the sample corresponding to the maximum value;
define a window centred about the maximum value containing a predetermined number of samples;
identify the values of the start and end values of said window, respectively;
calculate an average value of said start and end values; and
calculate a ratio of said average value and said maximum value as said measure.

26. The system according to claim 22, wherein said calculation unit is adapted to
identify the sample corresponding to the maximum value;
define a window centred about the maximum value containing a predetermined number of samples; and
calculating an area of said window by adding the values of said predetermined number of samples as said measure.

27. The system according to claim 22, wherein said calculation unit is adapted to
identify the sample corresponding to the maximum value;
define a time window centred about the maximum value containing a predetermined number of samples;
identify the values of the start and end values of said window, respectively
calculate a first average slope from the sample corresponding to said start value to said sample corresponding to said maximum value;
calculate a second average slope from the sample corresponding to the maximum value to the sample corresponding to the end value; and
calculate said measure using said first slope and said second slope.

28. The system according to claim 22, wherein said calculation unit is adapted to
define a time window at a predetermined amplitude in relation to the maximum value; and
calculating a width of said time window as said measure.

29. The system according to any one of preceding claims 15-28, wherein said hemodynamic parameter is stroke volume, cardiac output, or contractility.

30. A medical system including an external programmer apparatus comprising a communication unit and an implantable medical device including a pulse generator adapted to produce cardiac stimulating pacing pulses, said implantable device being connectable to at least one lead comprising electrodes for delivering said pulses to cardiac tissue of a heart of a patient, and a communication unit, said external apparatus and said implantable device being adapted for two-way communication of data using said communication units,
wherein said implantable medical device further comprises an impedance measuring unit connectable to at least two electrodes adapted to measure cardiac impedance of said heart, said impedance measuring unit being adapted to provide impedance information corresponding to said measured impedance; and
an impedance morphology determining unit adapted to receive said impedance information and to determine an impedance morphology curve from said impedance information; and
wherein said external apparatus is adapted to obtain said impedance morphology curve via said communication unit; **characterized in that** said medical system comprises

a calculation unit adapted to detect an extreme point section of said impedance morphology curve and to calculate a measure of a hemodynamic parameter of said heart utilizing said an extreme point section.

5 Patentansprüche

1. Implantierbare medizinische Vorrichtung, die einen Impulsgenerator aufweist, der angepasst ist, Herzstimulations-
erregungsimpulse zu erzeugen, wobei die Vorrichtung mit mindestens einer Leitung verbunden werden kann, die
Elektroden zum Abgeben der Impulse an Herzgewebe eines Herzes eines Patienten umfasst, umfassend:

eine Impedanzmesseinheit, die mit mindestens zwei Elektroden verbunden werden kann und angepasst ist,
die kardiale Impedanz des Herzes zu messen, wobei die Impedanzmesseinheit angepasst ist, Impedanzinfor-
mationen, die der gemessenen Impedanz entsprechen, bereitzustellen,

eine Impedanzmorphologie-Bestimmungseinheit, die angepasst ist, die Impedanzinformationen zu empfangen
und eine Impedanzmorphologiekurve anhand der Impedanzinformationen zu bestimmen, **dadurch gekenn-
zeichnet, dass** die medizinische Vorrichtung Folgendes umfasst:

eine Berechnungseinheit, die angepasst ist, einen Extremwertabschnitt der Impedanzmorphologiekurve zu
erkennen und ein Maß eines hämodynamischen Parameters des Herzes unter Verwendung des einen Extrem-
wertabschnitts zu berechnen.

2. Implantierbare medizinische Vorrichtung nach Anspruch 1, wobei der Extremwertabschnitt ein Höchstwertabschnitt
ist.

3. Implantierbare medizinische Vorrichtung nach Anspruch 1 oder 2, ferner umfassend einen Analysator, der angepasst
ist, das Maß zu analysieren, um mindestens einen Erregungsparameter des Impulsgenerators zu optimieren oder
eine Änderung eines Zustands des Patienten abzuleiten.

4. Implantierbare medizinische Vorrichtung nach Anspruch 2 oder 3, wobei die Berechnungseinheit angepasst ist, das
Maß mittels der Form der Impedanzmorphologiekurve in einem Zeitfenster, das den Höchstwertabschnitt der Im-
pedanzmorphologiekurve umgibt, zu berechnen.

5. Implantierbare medizinische Vorrichtung nach einem der vorhergehenden Ansprüche, wobei die Impedanzmorpho-
logie-Bestimmungseinheit angepasst ist, anhand der Impedanzinformationen während eines Zeitintervalls mehrerer
Herzzyklen des Herzes eine gemittelte Impedanzmorphologiekurve zu bestimmen.

6. Implantierbare medizinische Vorrichtung nach einem der Ansprüche 1 bis 4, wobei die Impedanzmorphologie-
Bestimmungseinheit angepasst ist, die empfangenen Impedanzinformationen einem Filtervorgang zu unterziehen
und anhand der gefilterten Impedanzinformationen eine Impedanzmorphologiekurve zu bestimmen.

7. Implantierbare medizinische Vorrichtung nach einem der vorhergehenden Ansprüche, wobei die Berechnungseinheit
angepasst ist, den Maximalwert der Impedanzmorphologiekurve zu erkennen und das Zeitfenster um den Wert
herum zu zentrieren.

8. Implantierbare medizinische Vorrichtung nach einem der vorhergehenden Ansprüche, wobei die Berechnungseinheit
angepasst ist, ein Polynom des Grades 2 an den Abschnitt der Impedanzmorphologiekurve in dem Zeitfenster
anzupassen.

9. Implantierbare medizinische Vorrichtung nach Anspruch 8, wobei die Berechnungseinheit angepasst ist, eine Krüm-
mungskomponente des Polynoms als das Maß zu berechnen.

10. Implantierbare medizinische Vorrichtung nach Anspruch 7, wobei die Berechnungseinheit angepasst ist:

den Abtastwert zu erkennen, der dem Maximalwert entspricht;

ein Fenster, das um den Maximalwert herum zentriert ist, zu definieren, das eine festgelegte Zahl von Abtast-
werten enthält;

die Werte der Anfangs- beziehungsweise Endabtastwerte des Fensters zu erkennen;

einen Durchschnittswert aus dem Anfangs- und Endwert zu berechnen, und

ein Verhältnis aus dem Durchschnittswert und dem Maximalwert als das Maß zu berechnen.

11. Implantierbare medizinische Vorrichtung nach Anspruch 7, wobei die Berechnungseinheit angepasst ist, den Abtastwert zu erkennen, der dem Maximalwert entspricht; ein Fenster, das um den Maximalwert herum zentriert ist, zu definieren, das eine festgelegte Zahl von Abtastwerten enthält; und
 5 eine Fläche des Fensters durch Addieren der Werte der festgelegten Zahl von Abtastwerten als das Maß zu berechnen.

12. Implantierbare medizinische Vorrichtung nach Anspruch 7, wobei die Berechnungseinheit angepasst ist, den Abtastwert zu erkennen, der dem Maximalwert entspricht;
 10 ein Zeitfenster, das um den Maximalwert herum zentriert ist, zu definieren, das eine festgelegte Zahl von Abtastwerten enthält;
 die Werte des Anfangs- beziehungsweise Endwerts des Fensters zu erkennen;
 eine erste Durchschnittsneigung von dem Abtastwert, der dem Anfangswert entspricht, auf den Abtastwert, der dem Maximalwert entspricht, zu berechnen;
 15 eine zweite Durchschnittsneigung von dem Abtastwert, der dem Maximalwert entspricht, auf den Abtastwert, der dem Endwert entspricht, zu berechnen; und
 ein Verhältnis zwischen der ersten Neigung und der zweiten Neigung als das Maß zu berechnen.

13. Implantierbare medizinische Vorrichtung nach Anspruch 7, wobei die Berechnungseinheit angepasst ist,
 20 ein Zeitfenster bei einer festgelegten Amplitude bezogen auf den Maximalwert zu definieren, und
 eine Breite des Zeitfensters als das Maß zu berechnen.

14. Implantierbare medizinische Vorrichtung nach einem der vorhergehenden Ansprüche, wobei der hämodynamische Parameter Schlagvolumen, Herzminutenvolumen oder Kontraktionsfähigkeit ist.
 25

15. Medizinisches System, das ein externes Programmiergerät, das eine Kommunikationseinheit umfasst, und eine implantierbare medizinische Vorrichtung aufweist, die einen Impulsgenerator, der angepasst ist, Herzstimulations-
 30 erregungsimpulse zu erzeugen, wobei die implantierbare Vorrichtung mit mindestens einer Leitung verbunden werden kann, die Elektroden zum Abgeben der Impulse an Herzgewebe eines Herzes eines Patienten umfasst, und
 eine Kommunikationseinheit aufweist, wobei das externe Gerät und die implantierbare Vorrichtung für eine Zwei-
 wege-Datenkommunikation unter Verwendung der Kommunikationseinheiten angepasst sind,
 wobei die implantierbare medizinische Vorrichtung ferner eine Impedanzmesseinheit umfasst, die mit mindestens
 35 zwei Elektroden verbunden werden kann und angepasst ist, die kardiale Impedanz des Herzes zu messen, wobei
 die Impedanzmesseinheit angepasst ist, Impedanzinformationen, die der gemessenen Impedanz entsprechen, be-
 reitzustellen, und
 wobei das externe Gerät angepasst ist, die Impedanzinformationen über die Kommunikationseinheit zu erhalten
 und ferner Folgendes umfasst
 eine Impedanzmorphologie-Bestimmungseinheit, die angepasst ist, die Impedanzinformationen zu empfangen und
 eine Impedanzmorphologiekurve anhand der Impedanzinformationen zu bestimmen, **dadurch gekennzeichnet,**
 40 **dass** das medizinische System Folgendes umfasst:

eine Berechnungseinheit, die angepasst ist, einen Extremwertabschnitt der Impedanzmorphologiekurve zu
 erkennen und ein Maß eines hämodynamischen Parameters des Herzes unter Verwendung des einen Extrem-
 wertabschnitts zu berechnen.

 45

16. System nach Anspruch 15, wobei der Extremwertabschnitt ein Höchstwertabschnitt ist.

17. System nach Anspruch 15 oder 16, wobei das externe Programmiergerät ferner einen Analysator umfasst, der
 50 angepasst ist, das Maß zu analysieren, um mindestens einen Erregungsparameter des Impulsgenerators zu opti-
 mieren oder eine Änderung eines Zustands des Patienten abzuleiten, wobei das externe Gerät angepasst ist, den
 mindestens einen Erregungsparameter an die implantierbare Vorrichtung zu übertragen.

18. System nach Anspruch 15 oder 16, wobei das externe Programmiergerät angepasst ist, das Maß an die implan-
 55 tierbare Vorrichtung zu übertragen, und wobei die implantierbare medizinische Vorrichtung ferner einen Analysator
 umfasst, der angepasst ist, das Maß zu analysieren, um mindestens einen Erregungsparameter des Impulsge-
 nerators zu optimieren oder eine Änderung eines Zustands des Patienten abzuleiten.

19. System nach Anspruch 17 oder 18, wobei die Berechnungseinheit angepasst ist, das Maß mittels der Form der

Impedanzmorphologiekurve in einem Zeitfenster, das den Höchstwertabschnitt der Impedanzmorphologiekurve umgibt, zu berechnen.

- 5 20. System nach einem der vorhergehenden Ansprüche 15 bis 19, wobei die Impedanzmorphologie-Bestimmungseinheit angepasst ist, anhand der Impedanzinformationen während eines Zeitintervalls mehrerer Herzzyklen des Herzes eine gemittelte Impedanzmorphologiekurve zu bestimmen.
- 10 21. System nach einem der Ansprüche 15 bis 20, wobei die Impedanzmorphologie-Bestimmungseinheit angepasst ist, die empfangenen Impedanzinformationen einem Filtervorgang zu unterziehen und anhand der gefilterten Impedanzinformationen eine Impedanzmorphologiekurve zu bestimmen.
- 15 22. System nach einem der vorhergehenden Ansprüche 15 bis 21, wobei die Berechnungseinheit angepasst ist, den Maximalwert der Impedanzmorphologiekurve zu erkennen und das Zeitfenster um den Wert herum zu zentrieren.
- 20 23. System nach einem der vorhergehenden Ansprüche 15 bis 22, wobei die Berechnungseinheit angepasst ist, ein Polynom des Grades 2 an den Abschnitt der Impedanzmorphologiekurve in dem Zeitfenster anzupassen.
24. System nach Anspruch 23, wobei die Berechnungseinheit angepasst ist, eine Krümmungskomponente des Polynoms als das Maß zu berechnen.
- 25 25. System nach Anspruch 22, wobei die Berechnungseinheit angepasst ist:
den Abtastwert zu erkennen, der dem Maximalwert entspricht;
ein Fenster, das um den Maximalwert herum zentriert ist, zu definieren, das eine festgelegte Zahl von Abtastwerten enthält;
die Werte des Anfangs- beziehungsweise Endwerts des Fensters zu erkennen;
einen Durchschnittswert aus dem Anfangs- und Endwert zu berechnen, und
ein Verhältnis aus dem Durchschnittswert und dem Maximalwert als das Maß zu berechnen.
- 30 26. System nach Anspruch 22, wobei die Berechnungseinheit angepasst ist,
den Abtastwert zu erkennen, der dem Maximalwert entspricht;
ein Fenster, das um den Maximalwert herum zentriert ist, zu definieren, das eine festgelegte Zahl von Abtastwerten enthält; und
eine Fläche des Fensters durch Addieren der Werte der festgelegten Zahl von Abtastwerten als das Maß zu be-
35 rechnen.
- 40 27. System nach Anspruch 22, wobei die Berechnungseinheit angepasst ist,
den Abtastwert zu erkennen, der dem Maximalwert entspricht;
ein Zeitfenster, das um den Maximalwert herum zentriert ist, zu definieren, das eine festgelegte Zahl von Abtastwerten enthält;
die Werte des Anfangs- beziehungsweise Endwerts des Fensters zu erkennen;
eine erste Durchschnittsneigung von dem Abtastwert, der dem Anfangswert entspricht, auf den Abtastwert, der dem
Maximalwert entspricht, zu berechnen;
eine zweite Durchschnittsneigung von dem Abtastwert, der dem Maximalwert entspricht, auf den Abtastwert, der
45 dem Endwert entspricht, zu berechnen; und
das Maß unter Verwendung der ersten Neigung und der zweiten Neigung zu berechnen.
- 50 28. System nach Anspruch 22, wobei die Berechnungseinheit angepasst ist,
ein Zeitfenster bei einer festgelegten Amplitude bezogen auf den Maximalwert zu definieren, und
eine Breite des Zeitfensters als das Maß zu berechnen.
29. System nach einem der vorhergehenden Ansprüche 15 bis 28, wobei der hämodynamische Parameter Schlagvo-
lumen, Herzminutenvolumen oder Kontraktionsfähigkeit ist.
- 55 30. Medizinisches System, das ein externes Programmiergerät, das eine Kommunikationseinheit umfasst, und eine
implantierbare medizinische Vorrichtung aufweist, die einen Impulsgenerator, der angepasst ist, Herzstimulations-
erregungsimpulse zu erzeugen, wobei die implantierbare Vorrichtung mit mindestens einer Leitung verbunden wer-
den kann, die Elektroden zum Abgeben der Impulse an Herzgewebe eines Herzes eines Patienten umfasst, und

eine Kommunikationseinheit aufweist, wobei das externe Gerät und die implantierbare Vorrichtung für eine Zwei-
 wege-Datenkommunikation unter Verwendung der Kommunikationseinheiten angepasst sind,
 wobei die implantierbare medizinische Vorrichtung ferner eine Impedanzmesseinheit umfasst, die mit mindestens
 zwei Elektroden verbunden werden kann und angepasst ist, die kardiale Impedanz des Herzes zu messen, wobei
 die Impedanzmesseinheit angepasst ist, Impedanzinformationen, die der gemessenen Impedanz entsprechen, be-
 reitzustellen, und
 eine Impedanzmorphologie-Bestimmungseinheit, die angepasst ist, die Impedanzinformationen zu empfangen und
 eine Impedanzmorphologiekurve anhand der Impedanzinformationen zu bestimmen, und
 wobei das externe Gerät angepasst ist, die Impedanzmorphologiekurve über die Kommunikationseinheit zu erhalten,
dadurch gekennzeichnet, dass das medizinische System Folgendes umfasst:

eine Berechnungseinheit, die angepasst ist, einen Extremwertabschnitt der Impedanzmorphologiekurve zu
 erkennen und ein Maß eines hämodynamischen Parameters des Herzes unter Verwendung des einen Extrem-
 wertabschnitts zu berechnen.

Revendications

1. Dispositif médical implantable comprenant un générateur d'impulsions adapté pour produire des impulsions exci-
 tatrices de stimulation cardiaque, ledit dispositif pouvant être connecté à au moins un conducteur comprenant des
 électrodes pour délivrer lesdites impulsions au tissu cardiaque d'un coeur d'un patient, comprenant :

une unité de mesure d'impédance pouvant être connectée à au moins deux électrodes adaptée pour mesurer
 l'impédance cardiaque dudit coeur, ladite unité de mesure d'impédance étant adaptée pour fournir des infor-
 mations d'impédance correspondant à ladite impédance mesurée ;

une unité de détermination de morphologie d'impédance adaptée pour recevoir lesdites informations d'impé-
 dance et pour déterminer une courbe de morphologie d'impédance à partir desdites informations d'impédance ;
caractérisé en ce que ledit dispositif médical comprend

une unité de calcul adaptée pour détecter une section de pointe extrême de ladite courbe de morphologie
 d'impédance et pour calculer une mesure d'un paramètre hémodynamique dudit coeur en utilisant ladite section
 de pointe extrême.

2. Dispositif médical implantable selon la revendication 1, dans lequel ladite section de pointe extrême est une section
 de pic.

3. Dispositif médical implantable selon la revendication 1 ou 2, comprenant en outre un analyseur adapté pour analyser
 ladite mesure pour optimiser au moins un paramètre excitateur dudit générateur d'impulsions ou pour déduire un
 changement d'une affection dudit patient.

4. Dispositif médical implantable selon la revendication 2 ou 3, dans lequel ladite unité de calcul est adaptée pour
 calculer ladite mesure au moyen de la forme de la courbe de morphologie d'impédance dans une fenêtre temporelle
 entourant ladite section de pic de ladite courbe de morphologie d'impédance.

5. Dispositif médical implantable selon l'une quelconque des revendications précédentes, dans lequel ladite unité de
 détermination de morphologie d'impédance est adaptée pour déterminer une courbe de morphologie d'impédance
 moyenne à partir desdites informations d'impédance pendant un intervalle de temps d'une pluralité de cycles car-
 diaques dudit coeur.

6. Dispositif médical implantable selon l'une quelconque des revendications 1 à 4, dans lequel ladite unité de déter-
 mination de morphologie d'impédance est adaptée pour exécuter une procédure de filtrage desdites informations
 d'impédance reçues et pour déterminer une courbe de morphologie d'impédance à partir desdites informations
 d'impédance filtrées.

7. Dispositif médical implantable selon l'une quelconque des revendications précédentes, dans lequel ladite unité de
 calcul est adaptée pour détecter la valeur maximum de ladite courbe de morphologie d'impédance et pour centrer
 ladite fenêtre temporelle autour de ladite valeur.

8. Dispositif médical implantable selon l'une quelconque des revendications précédentes, dans lequel ladite unité de

calcul est adaptée pour ajuster un polynôme de degré deux à la section de la courbe de morphologie d'impédance dans ladite fenêtre temporelle.

9. Dispositif médical implantable selon la revendication 8, dans lequel ladite unité de calcul est adaptée pour calculer une composante de courbure dudit polynôme en tant que ladite mesure.

10. Dispositif médical implantable selon la revendication 7, dans lequel ladite unité de calcul est adaptée pour :

identifier l'échantillon correspondant à la valeur maximum ;
définir une fenêtre centrée autour de la valeur maximum contenant un nombre prédéterminé d'échantillons ;
identifier les valeurs respectivement des échantillons de départ et de fin de ladite fenêtre ;
calculer une valeur moyenne desdites valeurs de départ et de fin ; et
calculer un rapport de ladite valeur moyenne et ladite valeur maximum en tant que ladite mesure.

11. Dispositif médical implantable selon la revendication 7, dans lequel ladite unité de calcul est adaptée pour identifier l'échantillon correspondant à la valeur maximum ;
définir une fenêtre centrée autour de la valeur maximum contenant un nombre prédéterminé d'échantillons ; et
calculer une surface de ladite fenêtre en additionnant les valeurs dudit nombre prédéterminé d'échantillons en tant que ladite mesure.

12. Dispositif médical implantable selon la revendication 7, dans lequel ladite unité de calcul est adaptée pour identifier l'échantillon correspondant à la valeur maximum ;
définir une fenêtre temporelle centrée autour de la valeur maximum contenant un nombre prédéterminé d'échantillons ;
identifier les valeurs respectivement des valeurs de départ et de fin de ladite fenêtre ;
calculer une première pente moyenne de l'échantillon correspondant à ladite valeur de départ audit échantillon correspondant à ladite valeur maximum ;
calculer une seconde pente moyenne de l'échantillon correspondant à la valeur maximum à l'échantillon correspondant à la valeur de fin ; et
calculer un rapport entre ladite première pente et ladite seconde pente en tant que mesure.

13. Dispositif médical implantable selon la revendication 7, dans lequel ladite unité de calcul est adaptée pour définir une fenêtre temporelle à une amplitude prédéterminée par rapport à la valeur maximum ; et
calculer une largeur de ladite fenêtre temporelle en tant que ladite mesure.

14. Dispositif médical implantable selon l'une quelconque des revendications précédentes, dans lequel ledit paramètre hémodynamique est le volume d'éjection systolique, le débit cardiaque ou la contractilité.

15. Système médical incluant un appareil programmeur externe comprenant une unité de transmission et un dispositif médical implantable incluant un générateur d'impulsions adapté pour produire des impulsions excitatrices de stimulation cardiaque, ledit dispositif implantable pouvant être connecté à au moins un conducteur comprenant des électrodes pour délivrer lesdites impulsions au tissu cardiaque d'un cœur d'un patient, et une unité de transmission, ledit appareil externe et ledit dispositif implantable étant adaptés pour la transmission bidirectionnelle de données en utilisant lesdites unités de transmission,
dans lequel ledit dispositif médical implantable comprend en outre une unité de mesure d'impédance pouvant être connectée à au moins deux électrodes adaptée pour mesurer l'impédance cardiaque dudit cœur, ladite unité de mesure d'impédance étant adaptée pour fournir des informations d'impédance correspondant à ladite impédance mesurée ; et
dans lequel ledit appareil externe est adapté pour obtenir lesdites informations d'impédance par le biais de ladite unité de transmission et comprend en outre
une unité de détermination de morphologie d'impédance adaptée pour recevoir lesdites informations d'impédance et pour déterminer une courbe de morphologie d'impédance à partir desdites informations d'impédance ; **caractérisé en ce que** ledit système médical comprend
une unité de calcul adaptée pour détecter une section de pointe extrême de ladite courbe de morphologie d'impédance et pour calculer une mesure d'un paramètre hémodynamique dudit cœur en utilisant ladite section de pointe extrême.

16. Système selon la revendication 15, dans lequel ladite section de pointe extrême est une section de pic.

- 5
17. Système selon la revendication 15 ou 16, dans lequel ledit appareil programmeur externe comprend en outre un analyseur adapté pour analyser ladite mesure pour optimiser au moins un paramètre excitateur dudit générateur d'impulsions ou pour déduire un changement d'une affection dudit patient, ledit appareil externe étant adapté pour transmettre ledit au moins un paramètre excitateur audit dispositif implantable.
- 10
18. Système selon la revendication 15 ou 16, dans lequel ledit appareil programmeur externe est adapté pour transmettre ladite mesure audit dispositif implantable et dans lequel ledit dispositif médical implantable comprend en outre un analyseur adapté pour analyser ladite mesure pour optimiser au moins un paramètre excitateur dudit générateur d'impulsions ou pour déduire un changement d'une affection dudit patient.
- 15
19. Système selon la revendication 17 ou 18, dans lequel ladite unité de calcul est adaptée pour calculer ladite mesure au moyen de la forme de la courbe de morphologie d'impédance dans une fenêtre temporelle entourant ladite section de pic de ladite courbe de morphologie d'impédance.
- 20
20. Système selon l'une quelconque des revendications précédentes 15 à 19, dans lequel ladite unité de détermination de morphologie d'impédance est adaptée pour déterminer une courbe de morphologie d'impédance moyenne à partir desdites informations d'impédance pendant un intervalle de temps d'une pluralité de cycles cardiaques dudit coeur.
- 25
21. Système selon l'une quelconque des revendications 15 à 20, dans lequel ladite unité de détermination de morphologie d'impédance est adaptée pour exécuter une procédure de filtrage desdites informations d'impédance reçues et pour déterminer une courbe de morphologie d'impédance à partir desdites informations d'impédance filtrées.
22. Système selon l'une quelconque des revendications précédentes 15 à 21, dans lequel ladite unité de calcul est adaptée pour détecter la valeur maximum de ladite courbe de morphologie d'impédance et pour centrer ladite fenêtre temporelle autour de ladite valeur.
- 30
23. Système selon l'une quelconque des revendications précédentes 15 à 22, dans lequel ladite unité de calcul est adaptée pour ajuster un polynôme de degré deux à la section de la courbe de morphologie d'impédance dans ladite fenêtre temporelle.
- 35
24. Système selon la revendication 23, dans lequel ladite unité de calcul est adaptée pour calculer une composante de courbure dudit polynôme en tant que ladite mesure.
- 40
25. Système selon la revendication 22, dans lequel ladite unité de calcul est adaptée pour :
- identifier l'échantillon correspondant à la valeur maximum ;
 - définir une fenêtre centrée autour de la valeur maximum contenant un nombre prédéterminé d'échantillons ;
 - identifier les valeurs respectivement des valeurs de départ et de fin de ladite fenêtre ;
 - calculer une valeur moyenne desdites valeurs de départ et de fin ; et
 - calculer un rapport de ladite valeur moyenne et ladite valeur maximum en tant que ladite mesure.
- 45
26. Système selon la revendication 22, dans lequel ladite unité de calcul est adaptée pour
- identifier l'échantillon correspondant à la valeur maximum ;
 - définir une fenêtre centrée autour de la valeur maximum contenant un nombre prédéterminé d'échantillons ; et
 - calculer une surface de ladite fenêtre en additionnant les valeurs dudit nombre prédéterminé d'échantillons en tant que ladite mesure.
- 50
27. Système selon la revendication 22, dans lequel ladite unité de calcul est adaptée pour
- identifier l'échantillon correspondant à la valeur maximum ;
 - définir une fenêtre temporelle centrée autour de la valeur maximum contenant un nombre prédéterminé d'échantillons ;
 - identifier les valeurs respectivement des valeurs de départ et de fin de ladite fenêtre,
 - calculer une première pente moyenne de l'échantillon correspondant à ladite valeur de départ audit échantillon correspondant à ladite valeur maximum ;
 - calculer une seconde pente moyenne de l'échantillon correspondant à la valeur maximum à l'échantillon correspondant à la valeur de fin ; et
 - calculer ladite mesure en utilisant ladite première pente et ladite seconde pente.
- 55

28. Système selon la revendication 22, dans lequel ladite unité de calcul est adaptée pour définir une fenêtre temporelle à une amplitude prédéterminée par rapport à la valeur maximum ; et calculer une largeur de ladite fenêtre temporelle en tant que ladite mesure.

29. Système selon l'une quelconque des revendications précédentes 15 à 28, dans lequel ledit paramètre hémodynamique est le volume d'éjection systolique, le débit cardiaque ou la contractilité.

30. Système médical comprenant un appareil programmeur externe comprenant une unité de transmission et un dispositif médical implantable comprenant un générateur d'impulsions adapté pour produire des impulsions excitatrices de stimulation cardiaque, ledit dispositif implantable pouvant être connecté à au moins un conducteur comprenant des électrodes pour délivrer lesdites impulsions au tissu cardiaque d'un coeur d'un patient, et une unité de transmission, ledit appareil externe et ledit dispositif implantable étant adaptés pour la transmission bidirectionnelle de données en utilisant lesdites unités de transmission, dans lequel ledit dispositif médical implantable comprend en outre une unité de mesure d'impédance pouvant être connectée à au moins deux électrodes adaptée pour mesurer l'impédance cardiaque dudit coeur, ladite unité de mesure d'impédance étant adaptée pour fournir des informations d'impédance correspondant à ladite impédance mesurée ; et une unité de détermination de morphologie d'impédance adaptée pour recevoir lesdites informations d'impédance et pour déterminer une courbe de morphologie d'impédance à partir desdites informations d'impédance ; et dans lequel ledit appareil externe est adapté pour obtenir ladite courbe de morphologie d'impédance par le biais de ladite unité de transmission ; **caractérisé en ce que** ledit système médical comprend une unité de calcul adaptée pour détecter une section de pointe extrême de ladite courbe de morphologie d'impédance et pour calculer une mesure d'un paramètre hémodynamique dudit coeur en utilisant ladite section de pointe extrême.

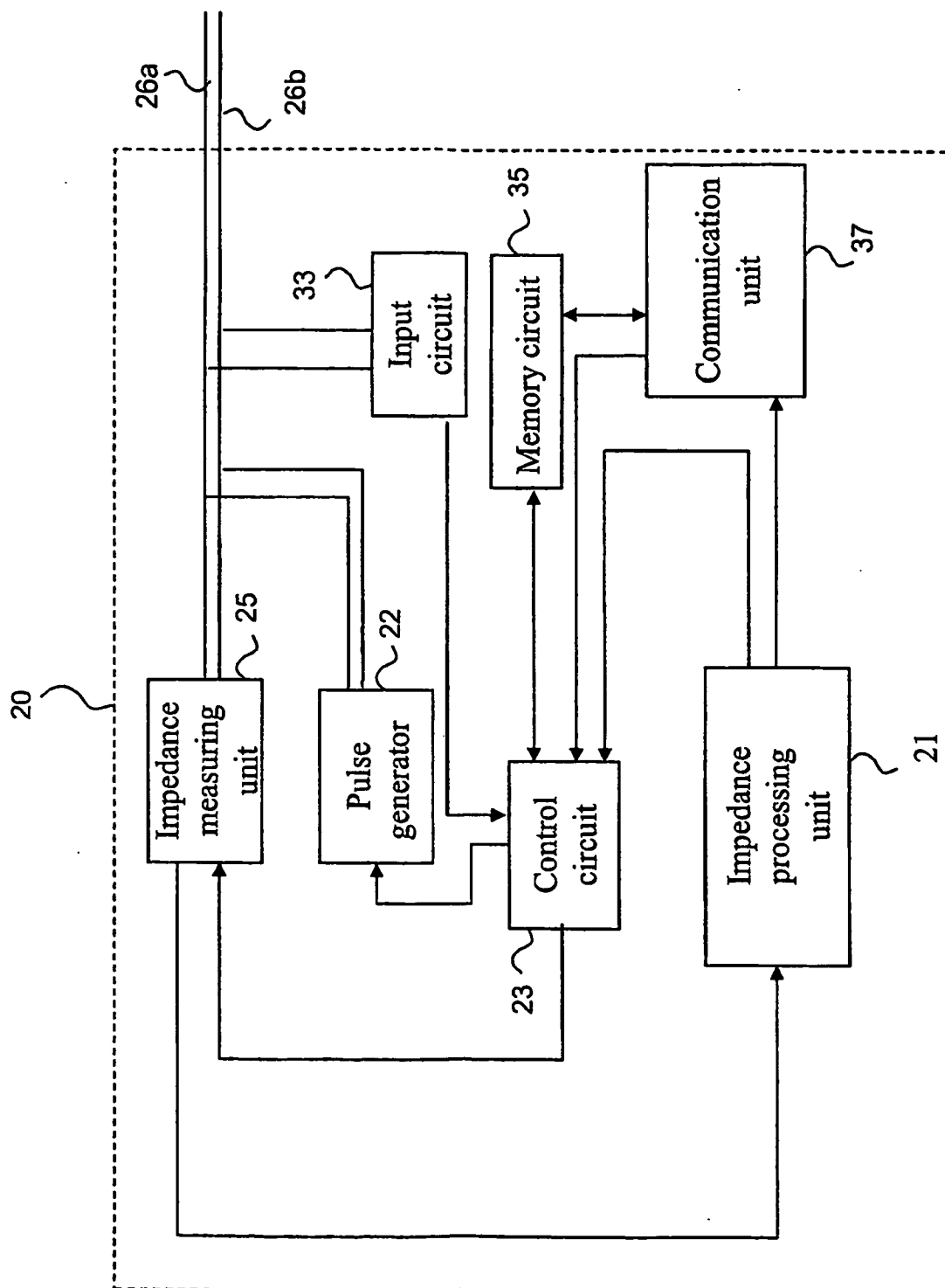
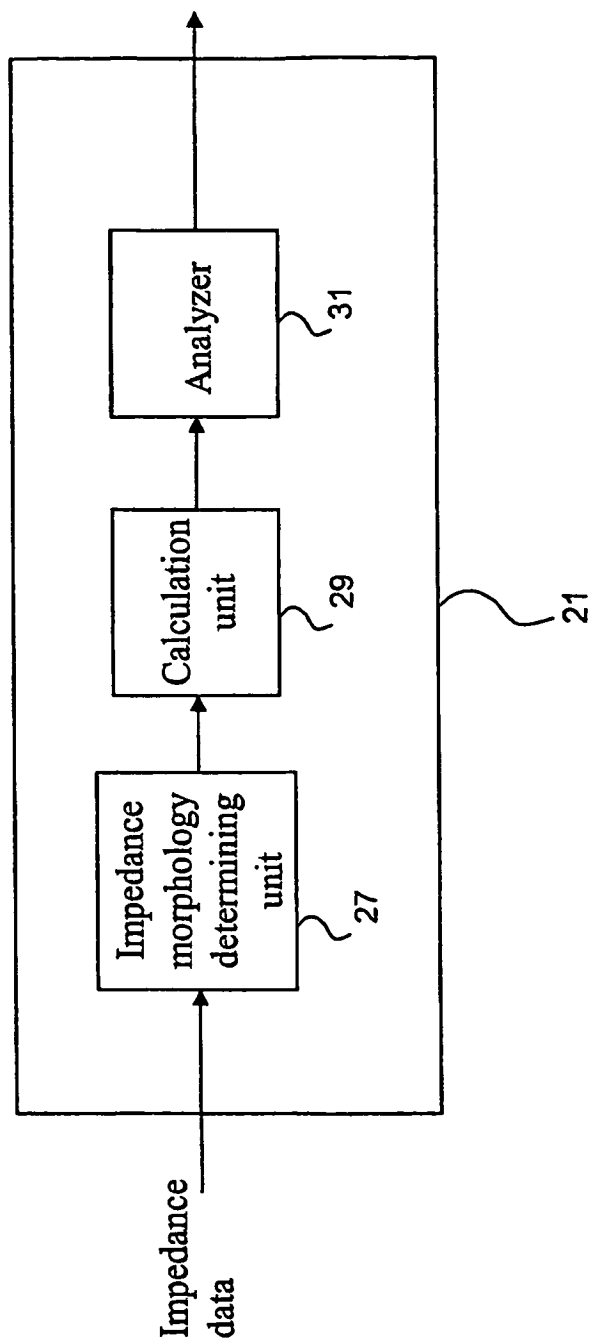


Fig. 1



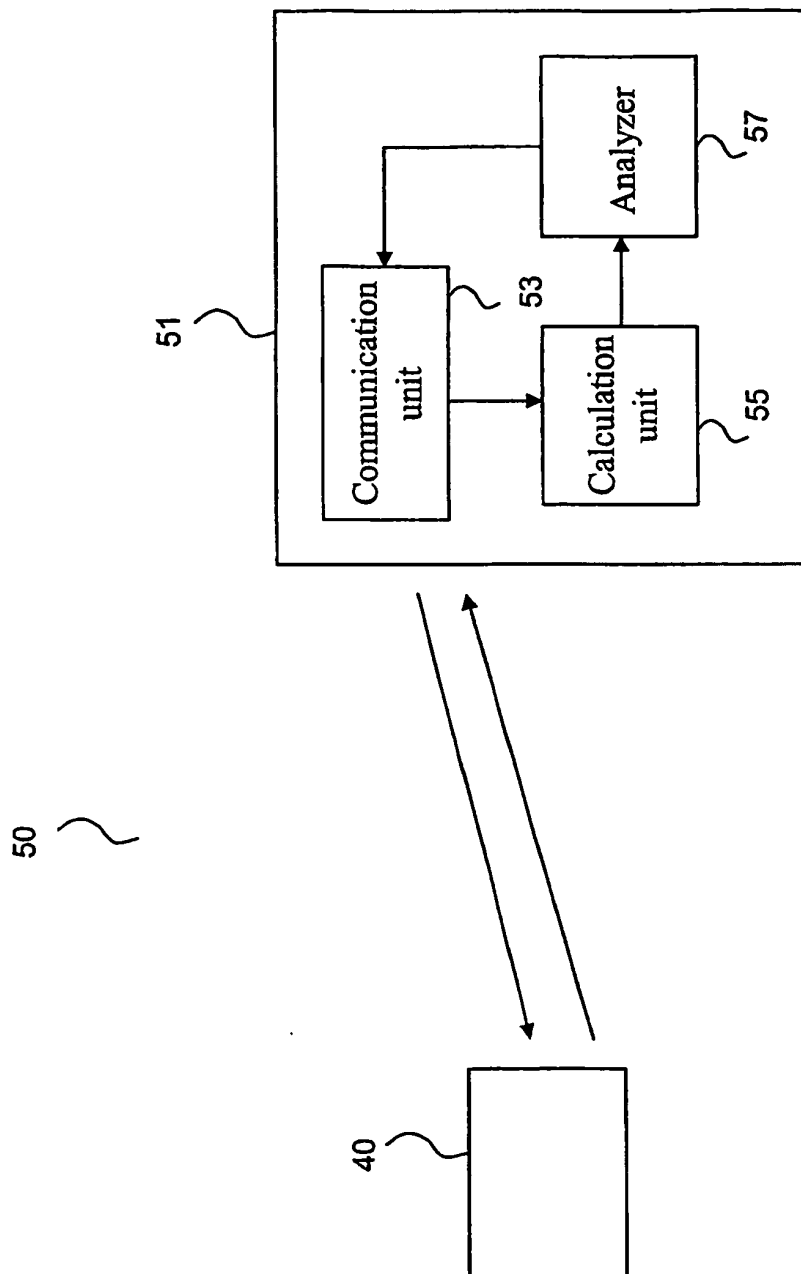


Fig. 3

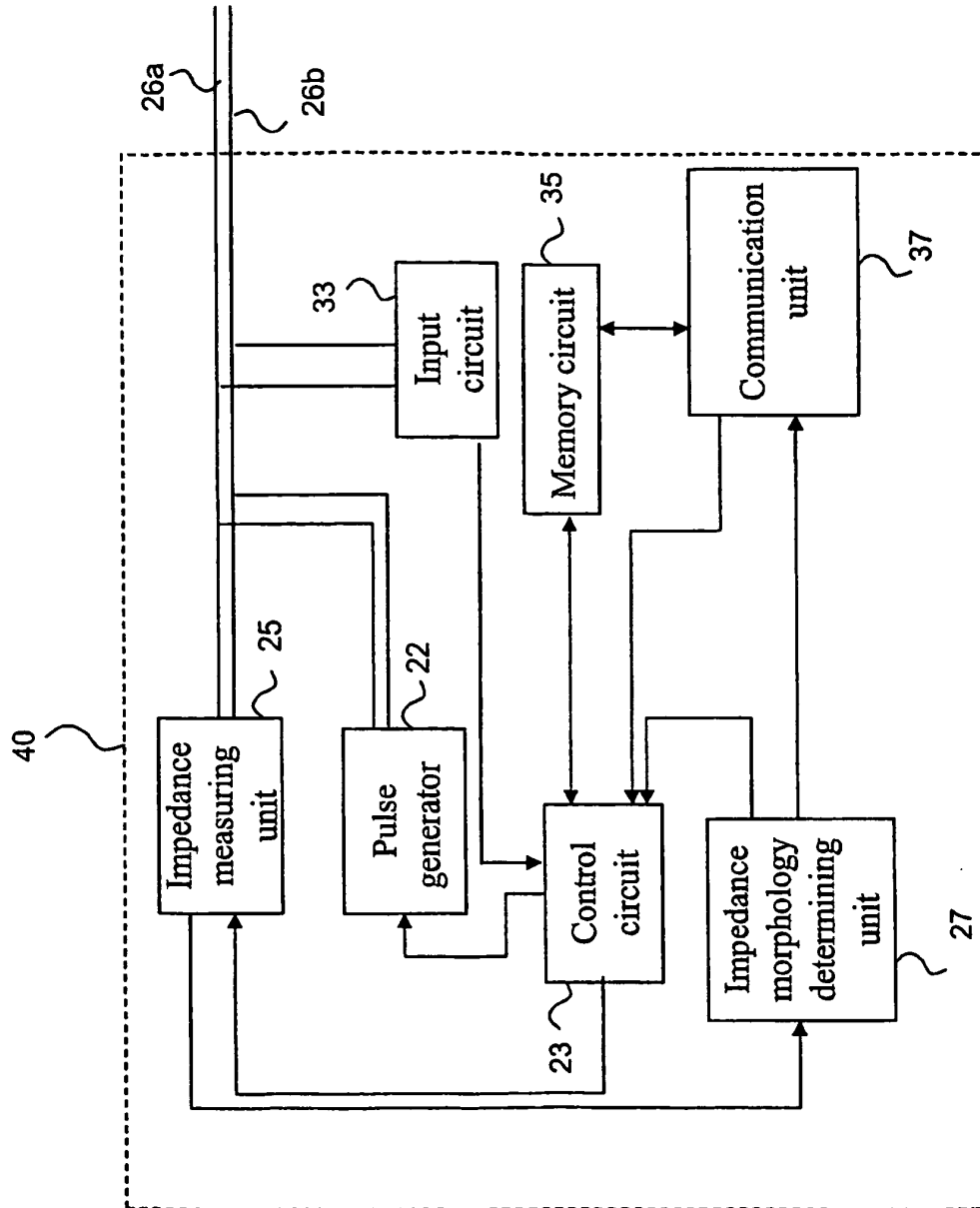


Fig. 4

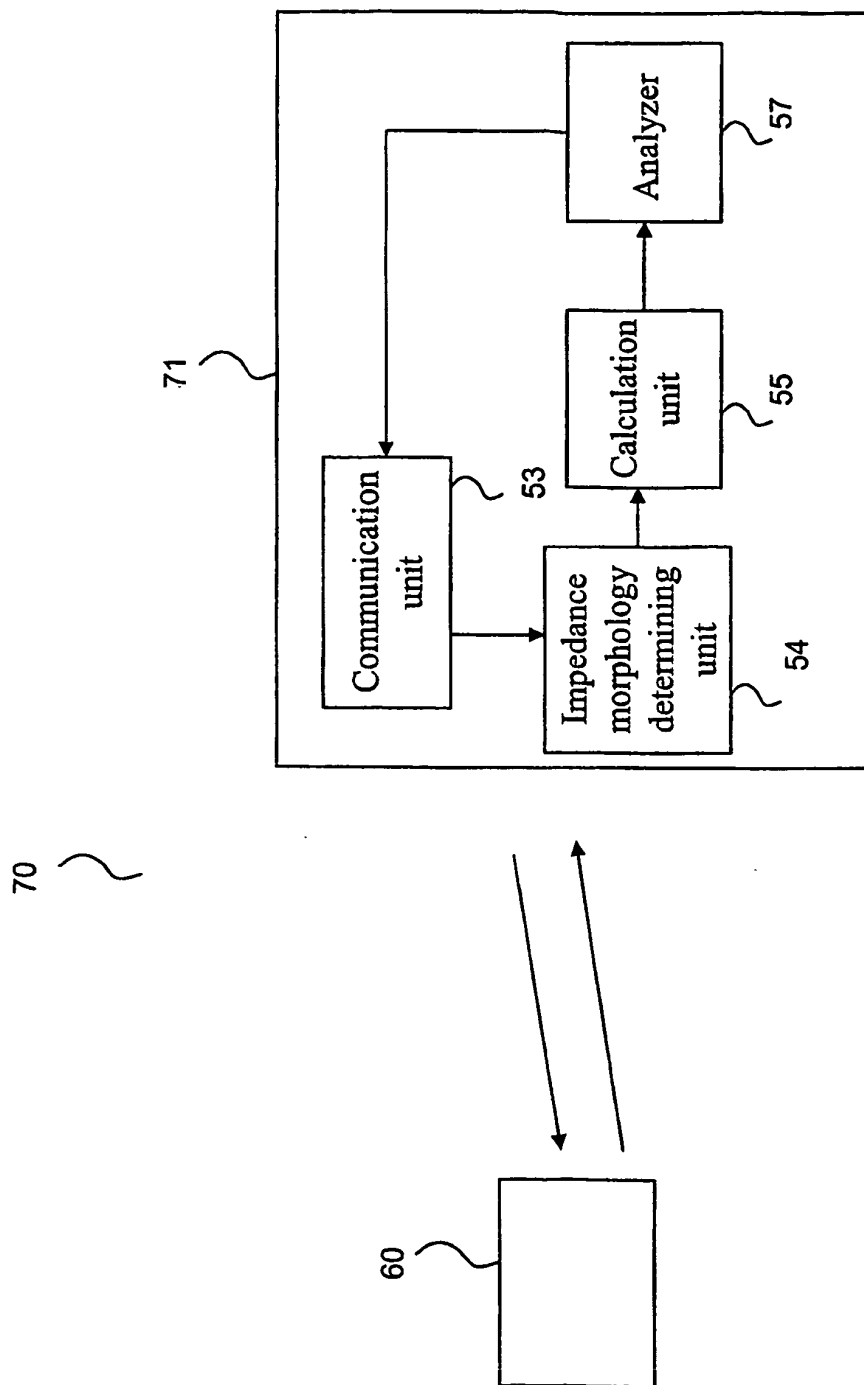


Fig. 5

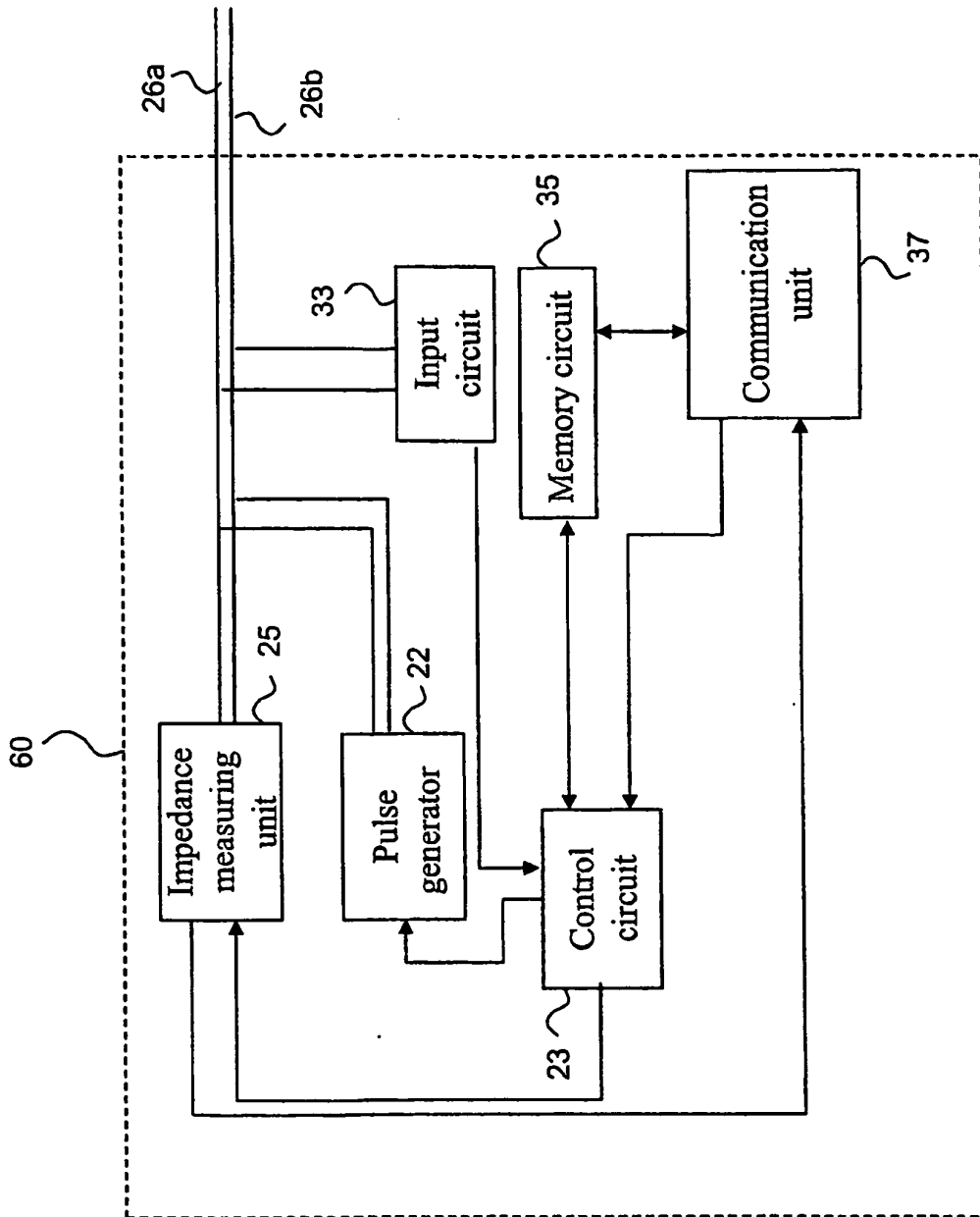


Fig. 6

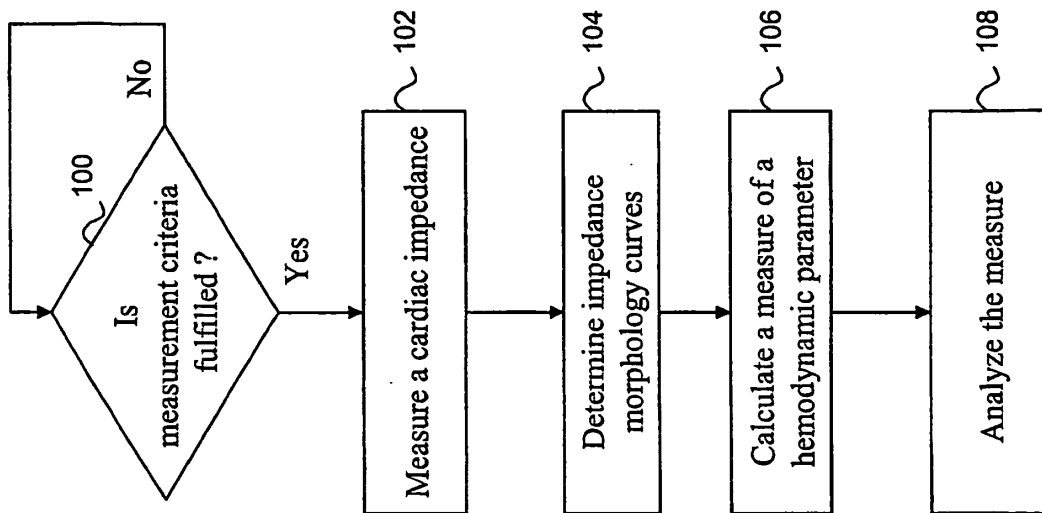
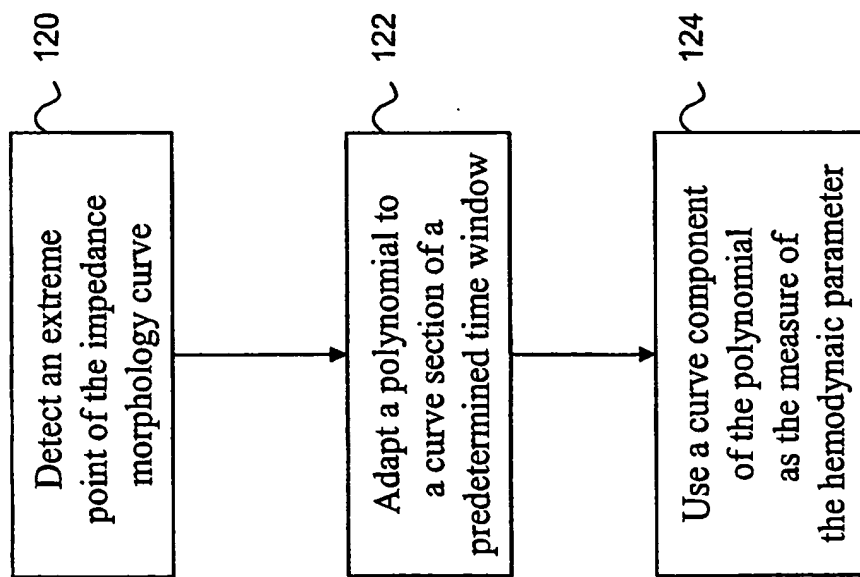


Fig. 7

**Fig. 8**

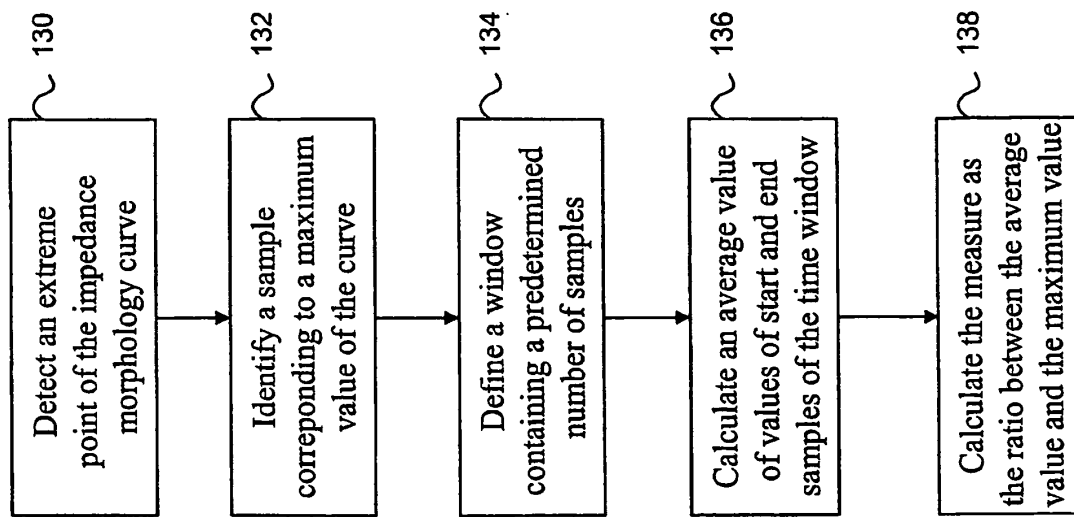
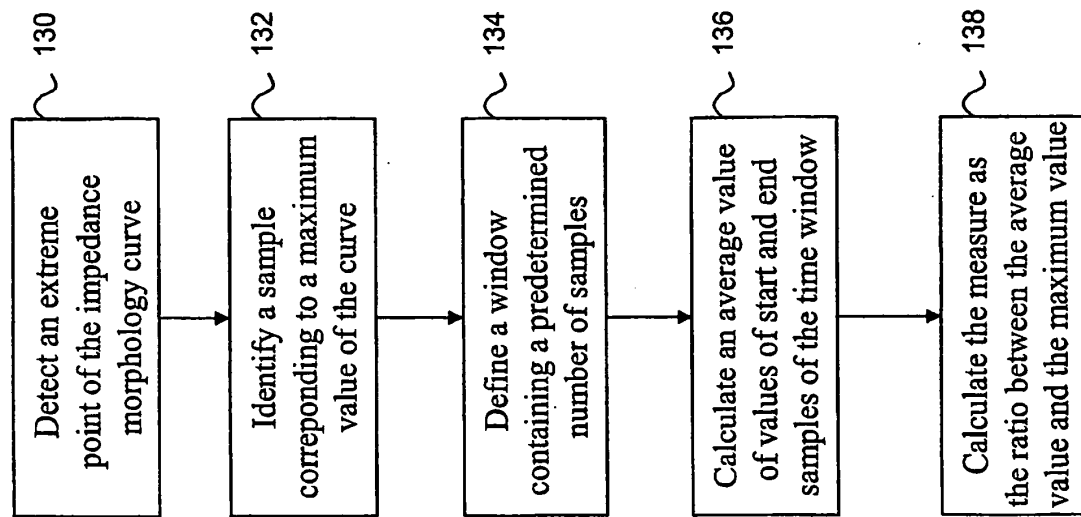
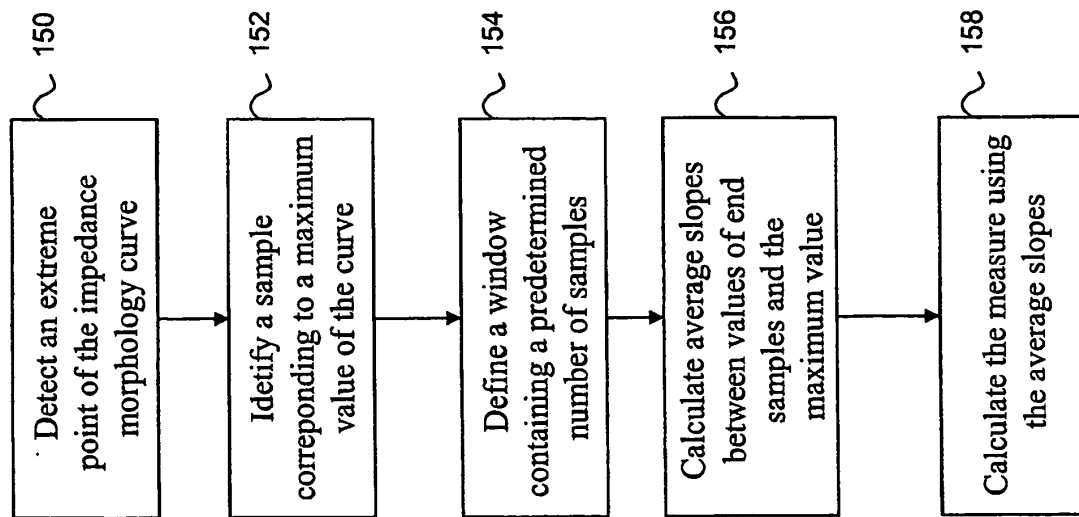


Fig. 9

**Fig. 10**

**Fig. 11**

REFERENCES CITED IN THE DESCRIPTION

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专利名称(译)	使用心内阻抗确定血液动力学参数的医疗装置和系统		
公开(公告)号	EP2035083B1	公开(公告)日	2012-08-08
申请号	EP2006747945	申请日	2006-06-21
申请(专利权)人(译)	ST.犹达医疗用品AB		
当前申请(专利权)人(译)	ST.犹达医疗用品AB		
[标]发明人	BLOMQVIST ANDREAS SVAHN JOHAN		
发明人	BLOMQVIST, ANDREAS SVAHN, JOHAN		
IPC分类号	A61B5/00 A61B5/0402 A61B5/053 A61N1/365		
CPC分类号	A61N1/36521 A61B5/0031 A61B5/02028 A61B5/053		
其他公开文献	EP2035083A4 EP2035083A1		
外部链接	Espacenet		

摘要(译)

本发明涉及可植入医疗设备，例如起搏器或心律转变器/除颤器（ICD），以及包括这种设备和外部编程器的系统，用于确定血液动力学参数的测量，例如心输出量，每搏输出量或收缩性。患者，例如，用于趋势性心力衰竭或AV / VV优化方案。可植入医疗设备适于测量心脏阻抗，心脏阻抗数据用于确定阻抗形态曲线，其又用于计算血液动力学参数的测量值。

$$\frac{\text{Value}_{S_{n+m}} + \text{Value}_{S_{n-m}}}{2} = \alpha$$