



(51) International Patent Classification:

G01R 31/36 (2006.01) A61N 1/378 (2006.01)
A61N 1/37 (2006.01) A61N 1/39 (2006.01)

(21) International Application Number:

PCT/SE2009/000363

(22) International Filing Date:

10 July 2009 (10.07.2009)

(25) Filing Language:

English

(26) Publication Language:

English

(71) Applicant (for all designated States except US): **ST. JUDE MEDICAL AB** [SE/SE]; S-175 84 Järfälla (SE).

(72) Inventors; and

(75) Inventors/Applicants (for US only): **DANIELSSON, Therese** [SE/SE]; Stigbergsv. 9, S-752 42 Uppsala (SE). **HERSTEDT, Marie** [SE/SE]; Folkungagatan 103, S-116 30 Stockholm (SE). **SVAHN, Johan** [SE/SE]; Karlsbodavägen 42, S-168 67 Bromma (SE). **TULLBERG, Mattias** [SE/SE]; Norrlandsgatan 34F, S-752 29 Uppsala (SE). **WILLIAMSON, Richard** [US/US]; 425 Idaho Avenue, Apt. 8, Santa Monica, CA 90403 (US).

(74) Agent: **ST. JUDE MEDICAL AB**; Patent Department, S-175 84 Järfälla (SE).

(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PE, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

— of inventorship (Rule 4.17(iv))

Published:

— with international search report (Art. 21(3))

(54) Title: BATTERY DISCHARGE MEASUREMENT DEVICE AND METHOD

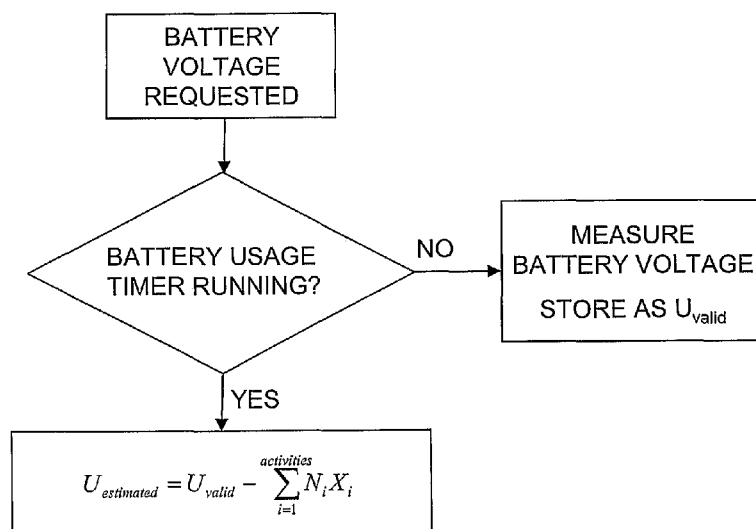


FIG. 6

(57) Abstract: A battery discharge measurement device (100) for determining the state of discharge for a battery (200) comprises a battery voltage measurement unit (110) adapted to measure and store a battery voltage and a battery usage activity detector (130) for detecting a predefined battery usage activity draining current from the battery (200) and triggering a voltage recovery period. A processor unit (120) is provided for estimating a battery voltage of the battery (200) during the voltage recovery period based on the measured and stored battery voltage and the number of predefined battery usage activities detected since the battery voltage measurement unit (110) measured the battery voltage of the battery (200).

Title

Battery discharge measurement device and method

Field of the invention

- 5 The present invention relates to a device and to a method for determining the state of discharge for a battery according to the preambles of the independent claims.

Background of the invention

- At present, a wide variety of implantable medical devices (IMDs) are commercially
10 available for clinical implantation that are programmable in a variety of operating modes and are interrogatable using high-speed wireless telemetry transmissions, e.g. radio frequency (RF) telemetry transmission. Such medical devices include implantable cardiac pacemakers, cardioverter/defibrillators, cardiomyostimulators,
pacemaker/cardioverter/defibrillators, drug delivery systems, cardiac and other
15 physiologic monitors, electrical stimulators including nerve and muscle stimulators, deep brain stimulators, and cochlear implants, and heart assist devices or pumps etc. Most such IMDs comprise electronic circuitry and an IMD battery that provides power to the electronic circuitry and that depletes in energy over time. Therefore, it is necessary to monitor the state of battery in such IMDs so that the IMD can be replaced before the
20 battery depletes to a state that renders the IMD inoperable.

The present invention is in particular applicable for IMDs, however, the invention is also generally useful in any application where it is required to be able to determine the state of discharge of a battery.

25

- QHR (Q High Rate) batteries, which is based upon a combination of two cathode materials; CF_x (Carbon Monofluoride) and SVO (Silver Vanadium Oxide), are being introduced in implantable cardioverter/defibrillator and tachycardia devices to replace the presently used SVO batteries to increase longevity and enable HV stable charge times.
30 QHR battery is a high-performing, high-rate battery especially designed for the mentioned medical applications. Compared to traditional high-rate cells the QHR cell has superior

deliverable energy density, lower internal resistance, higher current pulse capability and exceptional discharge stability.

Together with an industry-standard lithium anode, the QHR cell combines the high-power advantage of SVO with the exceptional discharge stability of CF_x in a laminated plate cathode design, with multiple plate design flexibility. An SVO/ CF_x parallel cell design within the same casing is disclosed e.g. in US-6,926,991. The energy-dense CF_x enables long cell life at low discharge rates, while SVO provides intermittent, high-rate current application upon demand for therapy application, resulting in a cathode system that maximizes device performance.

For SVO batteries, estimates of the remaining longevity to elective replacement indication (ERI) and end of service (EOS) have been based upon battery voltage measurements in the device.

However, for QHR batteries, use of wireless telemetry, e.g. RF-telemetry, or charging of the high voltage (HV) capacitors, affect the battery voltage for longer time after the high current use. For charging of the HV capacitors, which has the largest impact, the battery voltage may be affected for extended periods which may exceed 20 days after the charge. During this time period the voltage first recovers to the value characteristic of its state of discharge, and may then also during a transient period continue to increase to higher than the expected value. The whole period is herein denoted voltage recovery period or time. During the voltage recovery period, real time measurement of the battery voltage cannot be used for correctly assessing the remaining longevity. Further, during the voltage recovery time ERI or EOS cannot be triggered on the measured battery voltage.

The recovery period duration depends e.g. on the amount of discharged capacity and the amount of high current used. The latter can for example be the number of HV charges.

US-6,671,552 relates to a system and method for determining remaining battery life for an implantable medical device. The battery may comprise a combination of silver vanadium oxide and CF_x . The estimates of the remaining life estimates are derived by periodically

measuring battery voltage, and estimating the estimated past current drain of the IMD comprising an average of the sum of the quiescent current drain and therapy delivery current drain, and determining the estimated remaining longevity from the measured voltage and the estimated past current drain.

5

The object of the present invention is to enable an improved estimation of the state of discharge of a battery during specified battery usage activities, and in particular for QHR batteries used in implantable medical devices, e.g. cardioverters and defibrillators in order to enable ERI detection during voltage recovery periods and also to obtain estimates of the remaining longevity to ERI.

10

Summary of the invention

The above-mentioned object is achieved by the present invention according to the independent claims.

15

Preferred embodiments are set forth in the dependent claims.

According to the present invention a voltage subtraction device and method is used to trigger ERI and to obtain estimates of the remaining longevity during the voltage recovery times in which real time measurements of the battery voltage cannot be used.

20

In a battery voltage region before ERI, battery voltage determinations made during the voltage recovery times will present a voltage estimated according to the present invention.

Generally this voltage is estimated as: The most recent valid battery voltage measurement value (i.e. not measured during the recovery time period) subtracted by X millivolts per battery usage activity that has occurred since the valid measurement was taken. This calculated battery voltage is then used for e.g. ERI triggering or for conservative estimates of remaining longevity.

25

The factor X may be chosen to correspond to the expected voltage decrease caused by both the capacity used by the battery usage activity and the pacing and sensing capacity

30

consumption during the voltage recovery time, and the risk of late ERI triggering is then substantially decreased.

5 An estimated voltage is presented at times when a real time battery voltage measurement gives invalid readings.

Thus, the capacity used by both HV charging and pacing and sensing during its associated voltage recovery time may be translated to a decrease in battery voltage as a factor of X mV per HV charge.

10

In another embodiment the capacity used by HV charging only is determined as one battery usage activity, which is translated into a decrease in battery voltage per charge. The actual capacity used by sensing and pacing during the recovery period is another battery usage activity and is measured to provide an exact measure of battery voltage decrease during said recovery period.

15

For a period of the battery discharge curve where it is most likely to reach ERI and the capability to alert is most important, the battery voltage can be approximated to a linear function for the discharge capacity. This function is used to determine the factor of X mV per battery usage activity.

20

The device and method according to the present invention is simple and easy to implement, and designed and optimized to be effective with regards to the capacity and possibilities of a typical micro controller in an implantable device.

25

Short description of the appended drawings

Figure 1 is a schematic block diagram illustrating the present invention.

Figure 2 is a graph illustrating the approximately linear relationship between the battery voltage and discharge capacity in the $U_{\text{threshold}}$ to ERI region.

30 Figures 3-5 are graphs illustrating various aspects of the present invention.

Figure 6 is a flow diagram illustrating the method of the present invention.

Figure 7 is a flow diagram illustrating an embodiment of the method of the present invention.

Detailed description of preferred embodiments of the invention

5 The invention will now be described in detail with references to the appended drawings.

With reference to figure 1 the present invention relates to a battery discharge measurement device 100 for determining the state of discharge for a battery 200, preferably a QHR battery 200, but the present invention is also applicable for other battery types.

10

The device 100 comprises a battery voltage measurement unit 110 adapted to measure and store a battery voltage, and a processor unit 120 connected to said battery voltage measurement unit 110.

15 The device 100 further comprises a battery usage activity detector 130 connected to said units 110, 120 and adapted to detect predefined battery usage activities draining current of the battery 200. In a typical embodiment, such a predefined battery usage activity causes a voltage recovery period or time for the battery 200. During this voltage recovery period direct voltage measurements conducted by the battery voltage measurement unit 110
20 cannot be used for correctly assessing the remaining longevity of the battery 200. The present embodiments solve this problem through the operation of the battery usage activity detector 130. Thus, this battery usage activity detector 130 detects and calculates the number of predefined battery usage activities that has occurred since the battery voltage measurement unit 110 determined a valid battery measurement voltage. The processor unit
25 120 uses the this valid battery measurement voltage determined and stored by the battery voltage measurement unit 110 together with information of the calculated number of predefined battery usage activities as determined by the battery usage activity detector 130.

30 This means that during a voltage recovery period the battery voltage previously measured by the battery voltage measurement unit prior the voltage recovery period is modified with a factor related to the battery usage activity detected by the battery usage activity detector

130. This modification of the valid battery voltage allows correct estimation of battery voltage even during voltage recovery periods for the battery 200.

In a particular embodiment, the battery usage activity detector 130 process predefined battery usage activities and to generate a battery usage activity signal in response of detected and processed usage activities. The signal is applied to at least one battery usage timer 140 resulting in that the timer 140 is started and set to run for a specified duration related to said battery usage activity.

There are different types of battery activities. Each type of battery usage activity is given an index number i . X_i represents the battery voltage decrease caused by one battery usage activity with index number i . N_i represent the number of battery activities with index number i that has occurred.

The battery voltage obtained, by the battery voltage measurement unit 110, when no battery usage timer is running is a valid battery measurement voltage U_{valid} .

In the case a battery usage timer is running an estimated battery voltage $U_{\text{estimated}}$ is estimated, by the processor unit 120 as:

$$U_{\text{estimated}} = U_{\text{valid}} - \sum_{i=1}^{\text{activities}} N_i X_i$$

where

N_i is the number of battery usage activities with index number i ,

X_i is a factor related to the battery usage activity with index number i , i.e. representing the battery drain caused by the battery usage activity.

A summation is made for activities of different types having index no. 1,2,3.....to determine the voltage $U_{\text{estimated}}$ following a battery usage activity. Thus, in order to determine the estimated battery voltage $U_{\text{estimated}}$ the sum of factors representing all battery usage activities that occur during the period when the timer 140 is running is subtracted from the valid battery voltage.

It should be noted that the sum may relate to the same or different battery usage activities, i.e. different activities results in different X_s . Thus it is observed that the formula above may be used in sequence if a battery usage activity occurs while the battery usage timer 140 is running. In such a case the current $U_{estimated}$ is inserted as U_{valid} in the formula above when a new $U_{estimated}$ is estimated to account for the latest battery usage activity. The parameter X_i in the equation is determined using one or many of the following, non-exhaustive, list of inputs:

- The expected battery variation
- The expected current load variation
- The estimated capacity per battery usage activity
- The estimated capacity used in recovery period

The battery usage activities may thus be any high current use of the battery 200. For example, but not limited to, HV charging, telemetry, and antitachy pacing.

With references to the graphs in figures 3-5 various aspects of the present invention will now be discussed. In the graphs the y-axis represents the battery voltage in volt and the x-axis represents the time (e.g. in days or hours).

The theoretical expected battery voltage is denoted by a dashed line, the assumed probable battery voltage behaviour is denoted by a dashed-dotted line, the valid battery voltage measurements are denoted by "X", the calculated battery voltage values are denoted by "O".

The dashed area represents the time when the battery usage timer is running.

By referring now to figure 3.

A battery usage activity (i) occurs N_i number of times (in this case five) which virtually would drain the battery to a lower voltage instantaneously (see the leap in the dashed line). However, the nature of the battery and it's chemistry is not such that the voltage of the battery immediately after a high current drain battery usage activity does not correspond to

the new actual remaining capacity. Instead, during a period after a battery usage activity like this, the voltage behaves in a way (dashed – dotted line) that is different from the known voltage-capacity relationship. This prevents temporarily the voltage to be used to determine remaining capacity.

5

There is a controlled period, see dashed area, during which we can not get a valid and reliable voltage measurement from the battery. During this voltage recovery period the voltage is estimated instead of being measured. The voltage is preferably estimated according to the formula above. Thus, the latest known valid value is used as a starting

10

point. The X_i factor which is individual for each type of battery usage activity is multiplied by the number of times it occurred (in this case five). If two or more battery usage activities occur simultaneously or within the timeframe of between two consecutive measurements, their negative contributions to the expected voltage are all summed together (as the situation is in figure 4). In figure 3 we only have one battery usage

15

activity.

There are two options for deriving the X_i factor of a battery usage activity. It can either be deducted so that the expected normal current drain during the following uncertain time period is accounted for, which is the case in figure 3 (this explains why the calculated battery voltage becomes and remains the voltage expected at the end of the time period). Or, it can represent just the specific battery usage activity and not take into account the normal current drain. In the latter case the actual current drain measured by a fuel gauge or other means can be represented by a battery usage activity and thereby have its own subtraction factor X_i . This is further discussed in relation to figure 5.

25

In figure 4 an initial battery usage activity, denoted i , has triggered a controlled period, i.e. started a timer. However, in this case another battery usage activity, denoted j , occurs before the first time period has elapsed. The second battery usage activity will cause the timer period to be updated (elongated) and the battery voltage estimated will include the subtraction factor for the second battery usage activity.

30

Described more in detail, the timer is started by the first battery usage activity, one or many battery usage activities, and an estimated battery voltage is calculated using the above equation, i.e. the last valid battery voltage is decreased by the sum of voltage values from all battery usage activities. As seen from the graph the estimated voltage value is well below the expected battery voltage (the dashed line), the reason is that also a safety margin is included when the voltage value of a battery usage activity is determined. The expected battery voltage is the battery voltage the device would measure if voltage recovery was instantaneous. Moreover, the expected battery voltage would also follow the known voltage-depleted capacity curve. Later, a further battery usage activity (a second battery usage activity), occurs. As the timer still is running, also the voltage values representing this second battery usage activity is decreased from the calculated voltage value. Probably this second battery usage activity also influences the duration of the timer period such that it is increased.

The situation shown in figure 5 is similar to the situation shown in figure 3. However, in this case the updated fuel gauge value is considered a battery usage activity for every battery measurement made during the controlled period. The fuel gauge measurement will not update the controlled period.

The battery voltage values are e.g. calculated regularly, e.g. once each day, until the timer period has lapsed. Naturally, other calculation frequencies may be applied, e.g. a preset number of hours, e.g. every 10th hour. The calculation may also be performed on demand, e.g. under the control of an external programming device, or as a consequence of a battery usage activity or other external influences, e.g. high temperature.

According to a preferred embodiment the battery voltage measurement unit is adapted to determine a linear battery discharge curve being a representation of the relationship between the battery voltage decrease per used mA hour capacity. This battery discharge curve is illustrated in figure 2. Preferably, a presumption to perform the calculation of the battery voltage is that the most recent valid battery measurement U_{valid} is less than a set threshold value $U_{\text{threshold}}$. $U_{\text{threshold}}$ generally designates the start of the linear part of the expected battery discharge curve.

According to one embodiment the device comprises one battery usage timer commonly activated by all battery usage activities, or as an alternative the device comprises a number of battery usage timers, each related to a specified battery usage activity.

5

Thus, HV charging and wireless high-speed telemetry both may start (separate) recovery timers in the firmware. Voltage recovery time due to HV charging may be combined in one recovery timer or kept as two separate timers, depending on choice of implementation. Until the recovery timers expire all real time battery voltage measurements are marked
10 invalid and prohibited for ERI or EOS triggering against nominal ERI or EOS references and for use by the programmer for longevity estimates. During recovery periods other voltage references for ERI or EOS triggering apply if battery voltages are measured during this period. Battery voltage measurements during recovery period may be made as a safety precaution to provide an early alarm in case of a premature battery depletion but this
15 would not be a part of the normal ERI or EOS determination. Battery voltage measurements outside voltage recovery times are regarded as valid, i.e. are representative of the state of discharge.

As mentioned above the battery discharge measurement device is generally applicable but
20 in particular useful to determine the state of discharge of a battery in an implantable medical device. The battery usage activity, when applied in an IMD, is preferably related to the charging of a HV capacitor, the use of high-speed telemetry, e.g. RF telemetry, and/or pacing and sensing energy consumption. As discussed above one or many timers may be arranged, wherein one of the timers is related to the charging of a HV capacitor
25 and one of the timers is related to the use of RF telemetry.

The estimated $U_{\text{estimated}}$ is used e.g. to estimate the remaining longevity to elective replacement indication (ERI) and/or end of service (EOS) for the battery.

30 The present invention is also related to a method for determining the state of discharge for a battery. The method is schematically illustrated by the flow diagram of figure 6.

The method comprises:

- A) measuring and storing a battery voltage U_{valid} of said battery;
 - B) detecting at least one predefined battery usage activity; and
 - C) estimating a battery voltage $U_{\text{estimated}}$ of said battery during a recovery period
- 5 following a predefined battery usage activity based on the stored battery voltage U_{valid} and a number of predefined battery usage activities detected since measuring the battery voltage U_{valid} .

In a particular embodiment the method also comprises:

- 10 D) processing predefined battery usage activities and generating a battery usage activity signal in response of detected and processed usage activities;
- E) applying the battery usage activity signal to at least one battery usage timer resulting in that the timer is started and set to run for a specified duration related to the battery usage activity;
- 15 F) obtaining the battery voltage when no battery usage timer is running and denoting it a valid battery measurement voltage U_{valid} , and
- G) estimating a battery voltage $U_{\text{estimated}}$ when a battery usage timer is running, as:

$$U_{\text{estimated}} = U_{\text{valid}} - \sum_{i=1}^{\text{activities}} N_i X_i$$

20

where

N_i represent the number of battery usage activities with index number i that has occurred, X_i is a factor related to the battery usage activity with index number i , i.e. representing the battery drain caused by the battery usage activity with index number i .

- 25 all different activities each having its own index are summed to provide a voltage decrease from the last measurement U_{valid} .

In the flow diagram in figure 6 a battery voltage request may be caused either by the normal battery status measurement (e.g. at regular intervals), or by a battery usage

30 activity, e.g. HF charging, telemetry, etc.

According to a further embodiment (see figure 7) the method further comprises determining a linear battery discharge curve being a representation of the relationship between the battery voltage decrease per used mA hour capacity. A presumption to perform the estimation of battery voltage is that the most recent valid battery measurement

5 U_{valid} is less than a set threshold value $U_{\text{threshold}}$, (see figure 2). $U_{\text{threshold}}$ generally designates the start of the linear part of the expected battery discharge curve. The method according to this embodiment is illustrated by the flow diagram in figure 7.

$U_{\text{threshold}}$ is selected after which the battery discharge curve shows an approximately linear

10 relationship between the milli volts battery decrease per used milli ampere hour capacity until ERI is reached (see figure 2). When the battery voltage in a valid measurement is below $U_{\text{threshold}}$ the method and device according to the present invention is used to estimate an expected battery voltage that is used for ERI triggering and longevity estimates for battery voltage measurements taken during recovery. This ensures ERI

15 triggering even if e.g. HV charges occur frequently for a patient causing all real time battery measurements during a long time to be invalid. The $U_{\text{threshold}}$ voltage is selected at a sufficiently long time before ERI to make it improbable to miss triggering of both $U_{\text{threshold}}$ and ERI due to constantly being in a recovery period and hence only having invalid battery voltage measurements. The slope of the battery discharge curve may change

20 during the battery life, thus the linear parts of the curve might change. Generally, the present invention is applicable to all linear parts of the discharge curve, i.e. the threshold values used to defined the linear range may be variable.

The linear voltage subtraction method and device according to the present invention may

25 for example be implemented as follows:

In the $U_{\text{threshold}}$ to ERI range at all invalid battery voltage measurements a factor of X milli volts (mV) per HV charging that has occurred since the most recent valid battery measurement is subtracted from the voltage of the valid measurement. This calculated

30 battery voltage is then used for ERI triggering, or by an external programmer device for longevity estimates. The factor X is chosen to correspond to the expected battery voltage decrease caused by both the capacity used by the HV charge, wireless telemetry and the

5 pacing and sensing capacity consumption during the voltage recovery time. Choosing a factor of X mV per HV charge is possible thanks to the recognition of an approximately linear battery voltage to discharged capacity relation ship in this $U_{\text{threshold}}$ to ERI region (see figure 2). It is the latest valid battery voltage measurement in the range between $U_{\text{threshold}}$ to ERI or the last $U_{\text{estimated}}$ depending on which is most recent that will be used for the calculation.

10 Although the present invention is described in connection with ICDs and QHR batteries the voltage subtraction method and device according to the present invention may also be applicable for other types of devices and other battery types. The method and device are advantageous for any device and battery for which the battery must temporarily supply a higher current to support a temporary feature, causing the battery voltage to be affected for some time after the high current use. Estimations similar to those disclosed in the present application are useful for any period of battery discharge curve where the relationship
15 between the battery voltage and the discharge capacity is approximately linear.

The present invention is not limited to the above-described preferred embodiments. Various alternatives, modifications and equivalents may be used. Therefore, the above embodiments should not be taken as limiting the scope of the invention, which is defined
20 by the appending claims.

Claims

1. A battery discharge measurement device (100) for determining a state of discharge of a battery (200), comprising

a battery voltage measurement unit (110) adapted to measure and store a battery voltage,

a processor unit (120) connected to said battery voltage measurement unit (110), characterized by

a battery usage activity detector (130) connected to said processor unit (120) and adapted to detect predefined battery usage activities,

wherein said processor unit (120) is adapted to estimate a battery voltage $U_{estimated}$ based on said stored battery voltage and a number of predefined battery usage activities detected by said battery usage activity detector (130) since said battery voltage measurement unit (110) measured said battery voltage.

2. Battery discharge measurement device according to claim 1, wherein said predefined battery usage activities trigger a voltage recovery period, said battery voltage measurement unit (110) is adapted to measure said battery voltage prior said voltage recovery period and said processor unit (120) is adapted to estimate said battery voltage $U_{estimated}$ based on said stored battery voltage and said number of predefined battery usage activities during said voltage recovery period.

3. Battery discharge measurement device according to claim 1 or 2, wherein said battery usage activity detector (130) is adapted to process said predefined battery usage activities and to generate a battery usage activity signal in response of detected and processed usage activities, said battery usage activity signal is applied to at least one battery usage timer (140) resulting in that said battery usage timer (140) is started and set to run for a specified duration related to said battery usage activity, said battery voltage measured, by said battery voltage measurement unit (110), when no battery usage timer is running is a valid battery measurement voltage U_{valid} , wherein a battery voltage $U_{estimated}$ is estimated, by said processor unit (120), when a battery usage timer (140) is running, as:

$$U_{estimated} = U_{valid} - \sum_{i=1}^{activities} N_i X_i$$

where

N_i is the number of battery usage activities having index i ,

X_i is a factor related to said battery usage activity i , i.e. representing the battery drain caused by said battery usage activity, and

5 *activities* represent the number of different kinds of battery usage activities .

4. Battery discharge measurement device according to claim 3, wherein said battery voltage measurement unit (110) is adapted to determine a linear battery discharge curve being a representation of a relationship between the battery voltage decrease per used
10 ampere-hour capacity and that a presumption to perform said estimation is that the most recent valid battery measurement U_{valid} is less than a threshold value $U_{\text{threshold}}$ representing the start of the linear part of the curve.

5. Battery discharge measurement device according to claim 3 or 4, wherein said
15 battery discharge measurement device (100) comprises one battery usage timer (140) commonly activated by all battery usage activities.

6. Battery discharge measurement device according to claim 3 or 4, wherein said battery discharge measurement device (100) comprises a number of battery usage timers
20 (140), each related to a specified battery usage activity.

7. Battery discharge measurement device according to any of the claims 1 to 6, wherein said battery (200) is a QHR battery (200).

25 8. Implantable medical device comprising a battery discharge measurement device (100) according to any of claims 1-7.

9. Implantable medical device according to claim 8, wherein said battery usage activity is the charging of a high voltage (HV) capacitor, the use of wireless telemetry, and/or
30 pacing and sensing energy consumption.

10. Implantable medical device according to claim 8 or 9, wherein said battery usage

activity detector (130) is adapted to process said predefined battery usage activities and to generate a battery usage activity signal in response of detected and processed usage activities, said battery usage activity signal is applied to at least one battery usage timer (140), one of said at least one battery usage timer (140) is related to the charging of a HV capacitor.

11. Implantable medical device according to claim 8 or 9, wherein said battery usage activity detector (130) is adapted to process said predefined battery usage activities and to generate a battery usage activity signal in response of detected and processed usage activities, said battery usage activity signal is applied to at least one battery usage timer (140), one of said at least one battery usage timer (140) is related to the use of wireless telemetry.

12. Implantable medical device according to any of the claims 8 to 11, wherein said estimated battery voltage $U_{\text{estimated}}$ is used to estimate the remaining longevity to elective replacement indication (ERI) and/or end of service (EOS) for said battery (200).

13. Method for determining a state of discharge for a battery (200), comprising measuring and storing a battery voltage of said battery (200); detecting at least one predefined battery usage activity; estimating a battery voltage $U_{\text{estimated}}$ of said battery (200) based on said stored battery voltage and a number of predefined battery usage activities detected since measuring said battery voltage of said battery (200).

14. Method according to claim 13, wherein said predefined battery usage activities trigger a voltage recovery period for said battery (200), said measuring said battery voltage of said battery (200) is performed prior said voltage recovery period and said estimating said battery voltage $U_{\text{estimated}}$ is performed during said voltage recovery period.

15. Method according to claim 13 or 14, further comprising processing predefined battery usage activities and generating a battery usage activity signal in response of detected and processed usage activities;

applying said battery usage activity signal to at least one battery usage timer (140) resulting in that said battery usage timer (140) is started and set to run for a specified duration related to said battery usage activity;

obtaining the battery voltage when no battery usage timer (140) is running and

5 denoting it a valid battery measurement voltage U_{valid} , and

estimating said battery voltage $U_{\text{estimated}}$ when a battery usage timer (140) is running, as:

$$U_{\text{estimated}} = U_{\text{valid}} - \sum_{i=1}^{\text{activities}} N_i X_i$$

10 where

N_i is the number of battery usage activities having index i ,

X_i is a factor related to said battery usage activity index i , i.e. representing the battery drain caused by said battery usage activity, and

activities represent the number of different kinds of battery usage activities.

15

16. Method according to claim 15, further comprising determining a linear battery discharge curve being a representation of the relationship between the battery voltage decrease per used ampere-hour capacity and that a presumption to perform said estimation is that the most recent valid battery measurement U_{valid} is less than a threshold value

20 $U_{\text{threshold}}$ representing the start of the linear part of the curve.

17. Method according to any of the claims 13 to 16, wherein the battery (200) is a QHR battery (200).

25

1/7

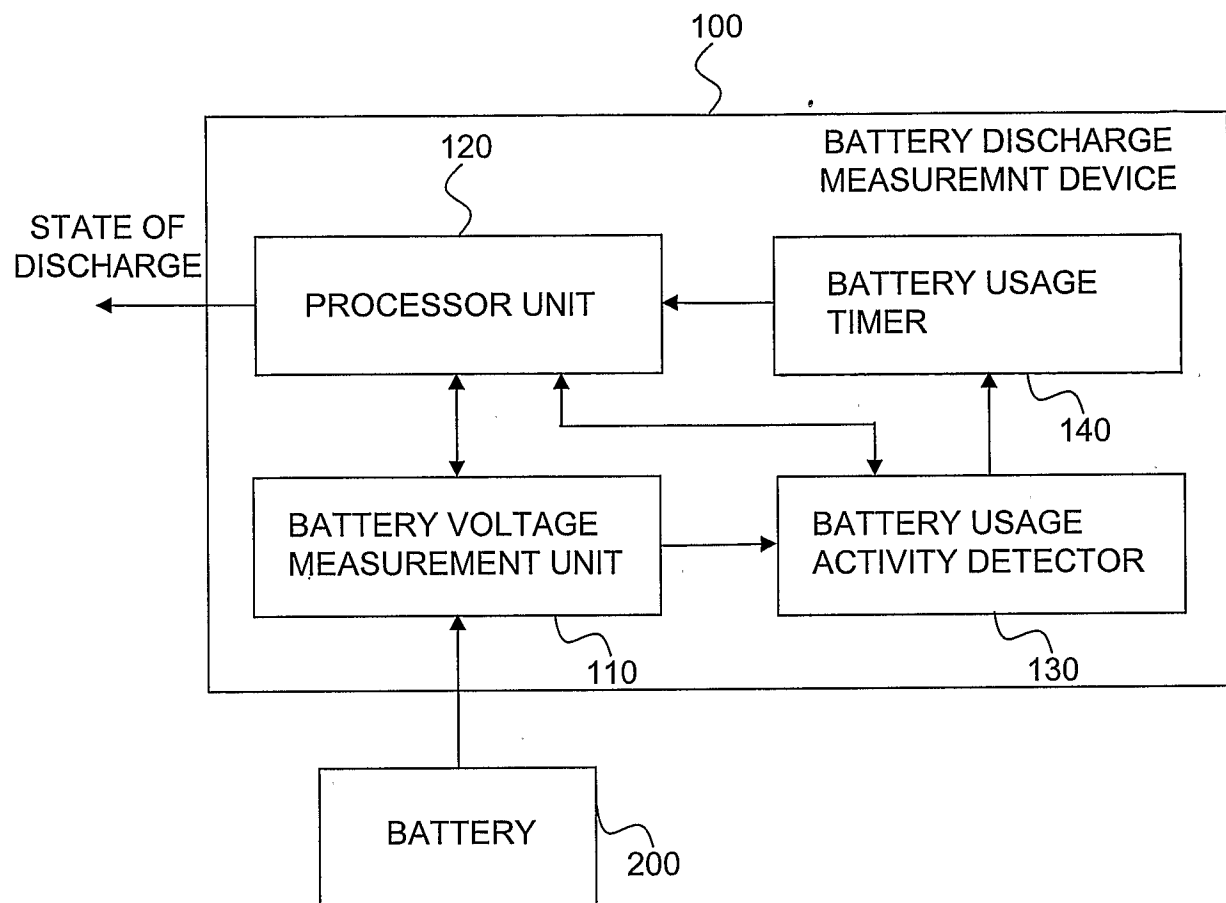


FIG. 1

2/7

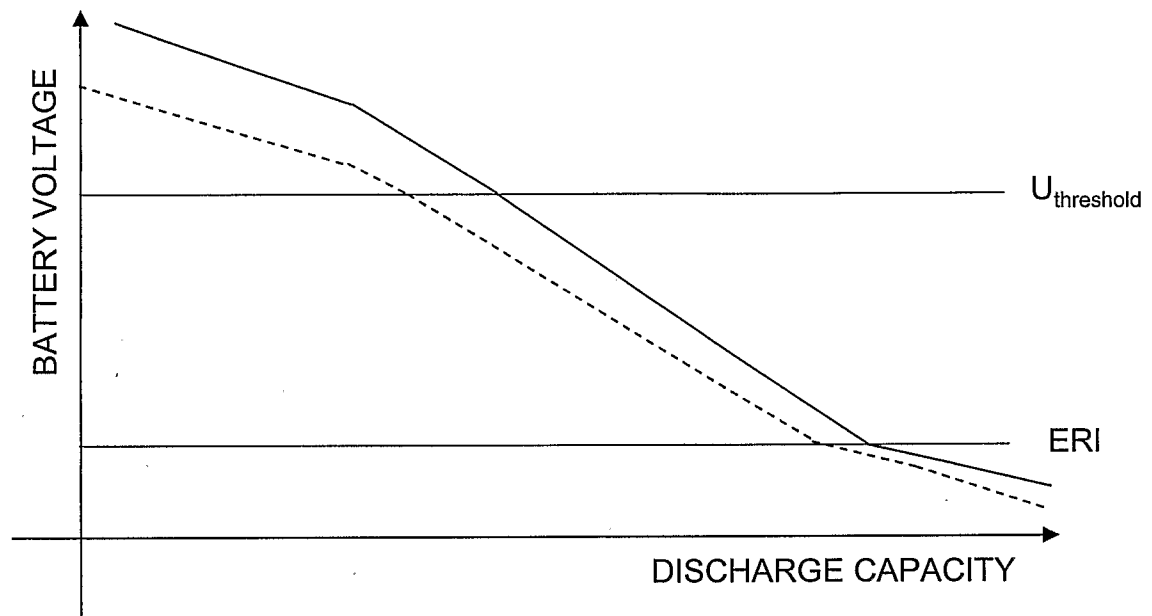


FIG. 2

3/7

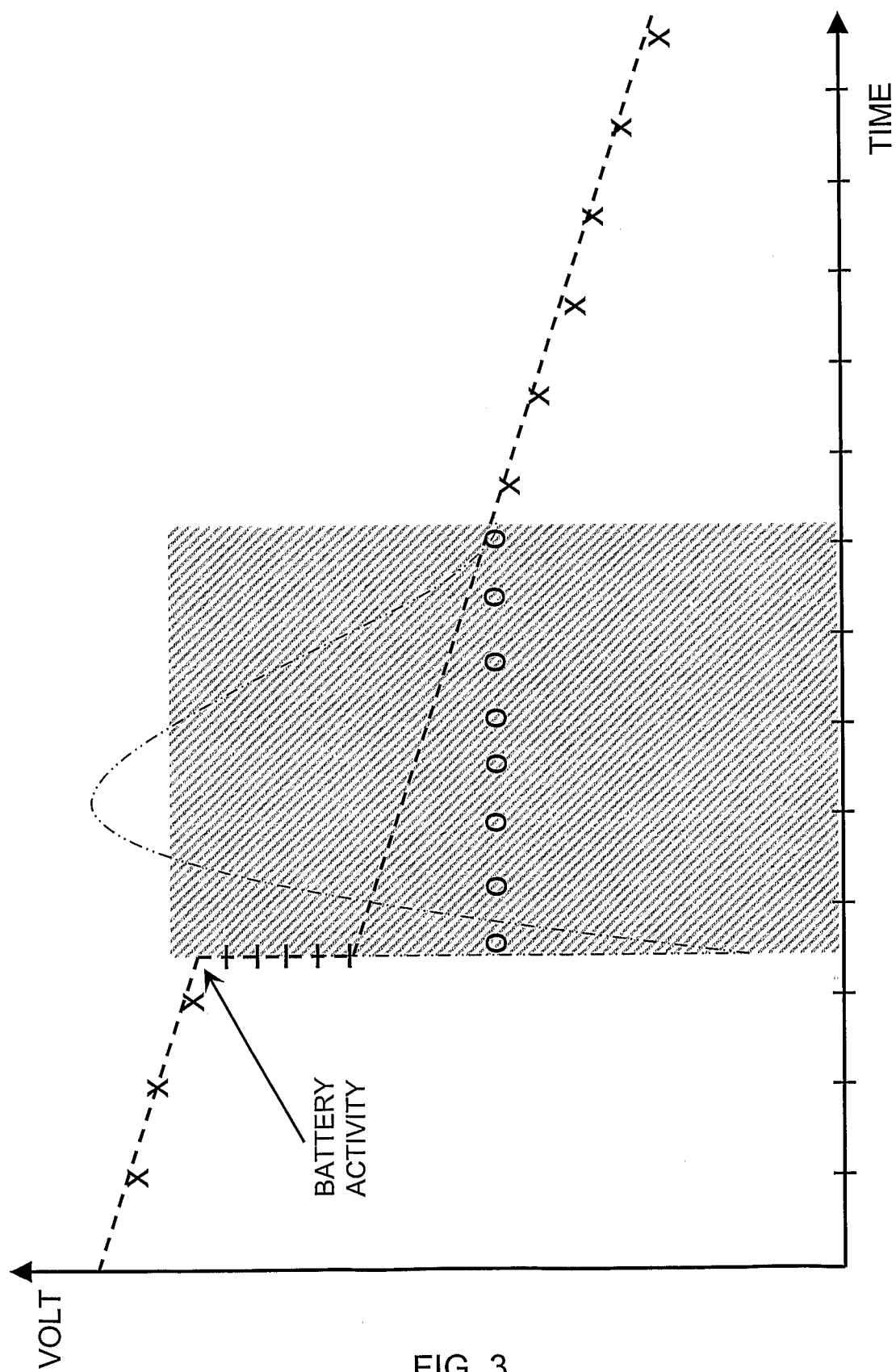


FIG. 3

4/7

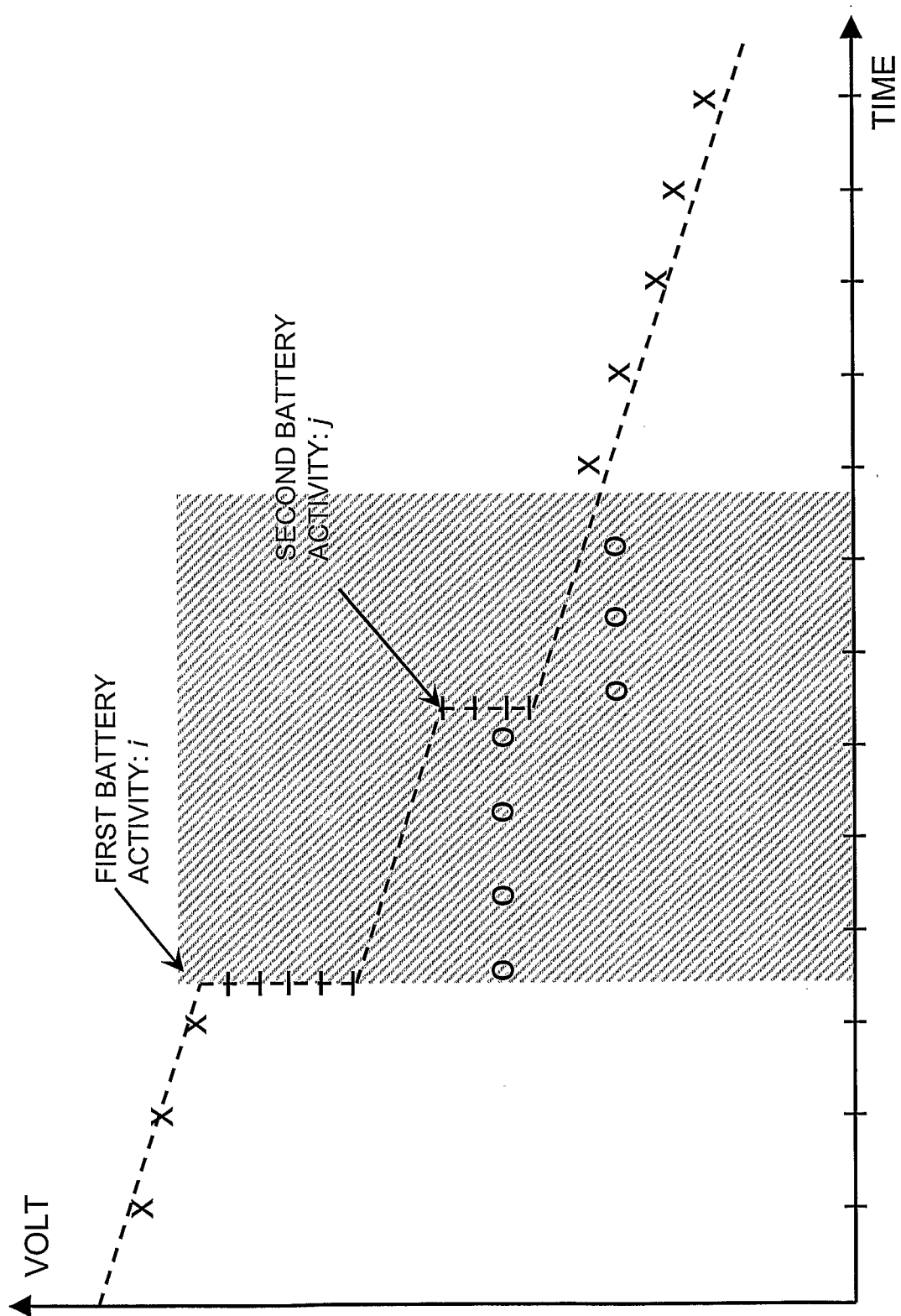


FIG. 4

5/7

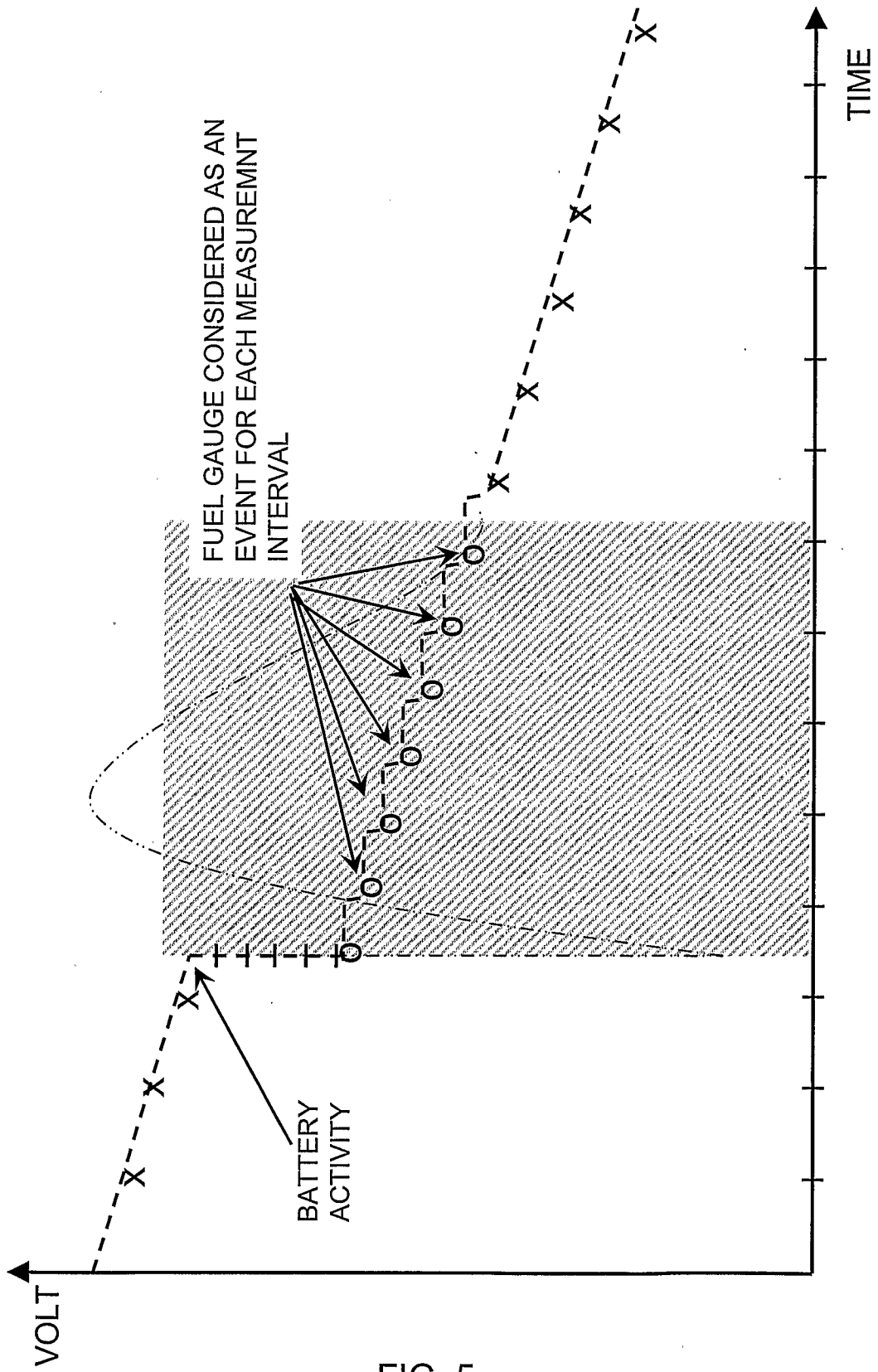


FIG. 5

6/7

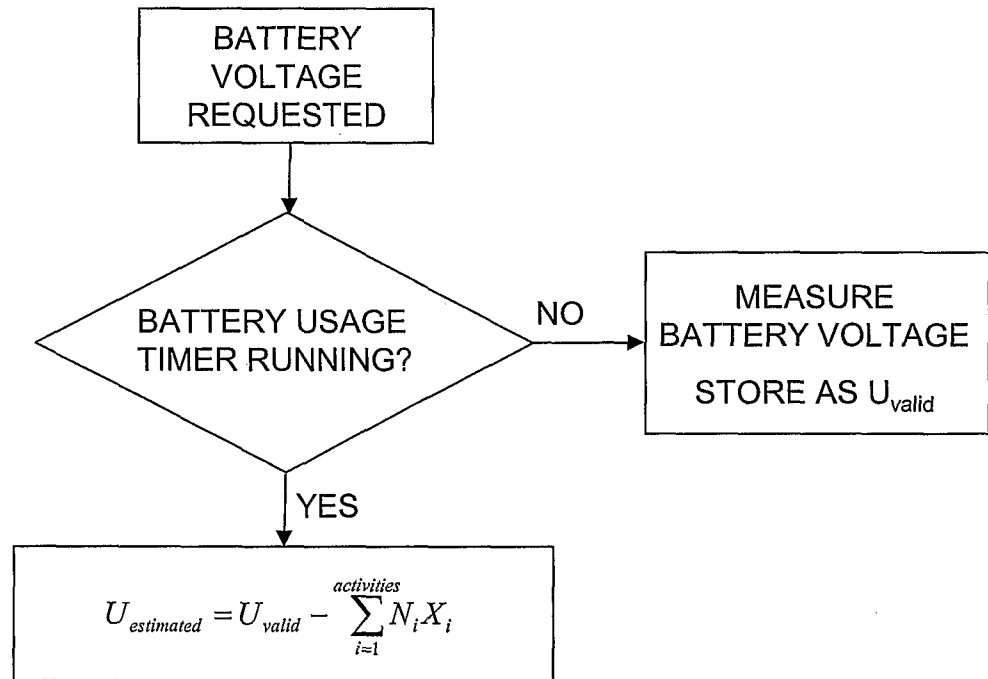


FIG. 6

7/7

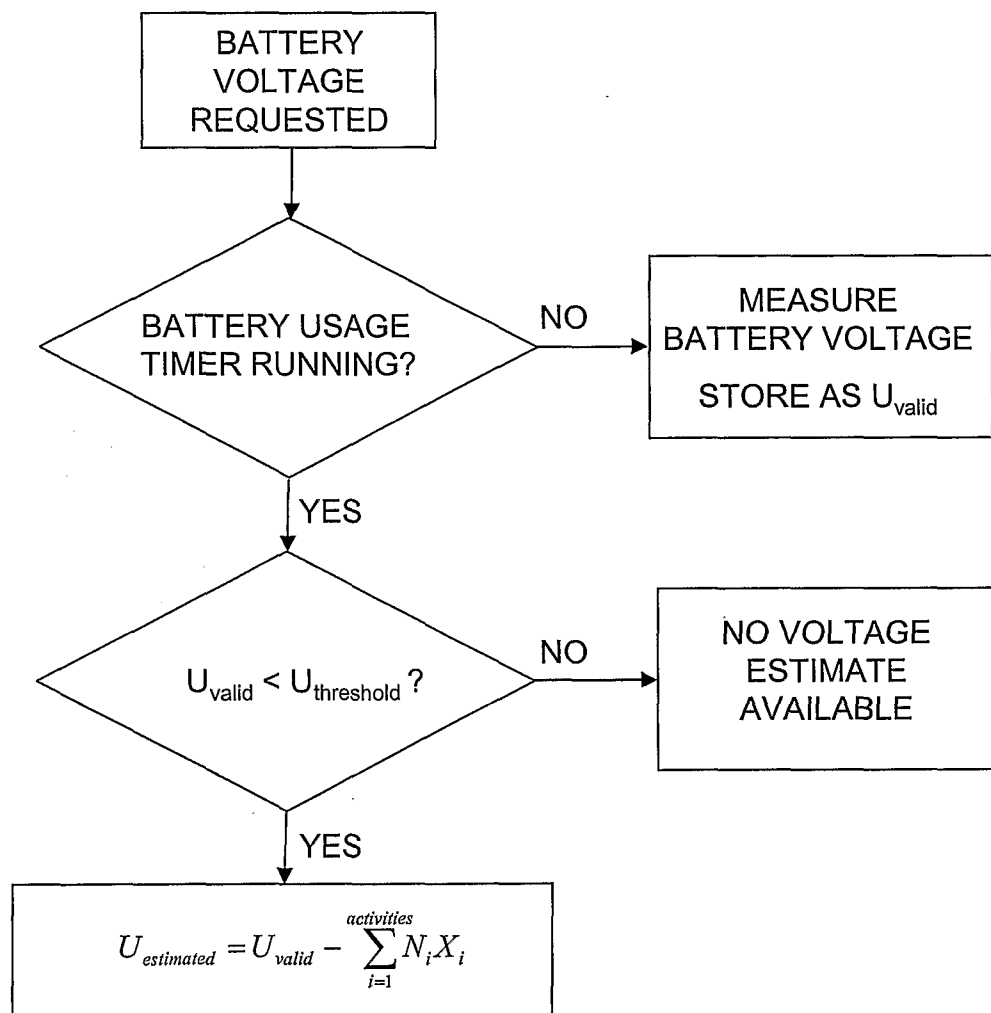


FIG. 7

INTERNATIONAL SEARCH REPORT

International application No.

PCT/SE2009/000363

A. CLASSIFICATION OF SUBJECT MATTER

IPC: see extra sheet

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC: A61N, G01R

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

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-INTERNAL, WPI DATA, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2006015347 A2 (ACCESS CARDIOSYSTEMS, INC.), 9 February 2006 (09.02.2006), page 10 - page 11; page 21, line 4; page 21, line 16 - line 21, page 22, line 5; page 23, line 19; claims 2,5-7,9, 26,27,31; abstract	1,7-13,17
A	--	2-6,14-16
A	US 20050017685 A1 (REES ET AL), 27 January 2005 (27.01.2005), figures 1,2, claims 1-3,19,26, abstract, paragraphs (0005),(0008),(0018)-(0023), (0025)-(0026),(0032)-(0040),(0052)-(0053),(0057), (0059)-(0062),(0070),(0079),(0093)	1-6,13-16
	--	

☒ Further documents are listed in the continuation of Box C.☒ See patent family annex.

* Special categories of cited documents:

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

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

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

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

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

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

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

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

"&" document member of the same patent family

Date of the actual completion of the international search

30 March 2010

Date of mailing of the international search report

01-04-2010

Name and mailing address of the ISA/

Swedish Patent Office

Box 5055, S-102 42 STOCKHOLM

Facsimile No. +46 8 666 02 86

Authorized officer

Agneta Siedel / JA A

Telephone No. +46 8 782 25 00

INTERNATIONAL SEARCH REPORT

International application No.

PCT/SE2009/000363

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 6108579 A (SNELL ET AL), 22 August 2000 (22.08.2000), column 9 - column 18, figures 5,7, abstract --	1-17
A	US 20050088145 A1 (LOCH), 28 April 2005 (28.04.2005), abstract, paragraphs (0002),(0020), (0023),(0025)-(0027),(0030),(0037),(0038) --	1-17
A	US 6167309 A (LYDEN), 26 December 2000 (26.12.2000), column 1, line 1 - line 14; column 4, line 64 - column 5, line 36; column 7, line 34 - column 9, line 3, abstract --	1-17
A	US 6820019 B1 (KELLY ET AL), 16 November 2004 (16.11.2004), abstract, paragraphs (0053)-(0054) --	1-17
A	US 20030149455 A1 (OBEL ET AL), 7 August 2003 (07.08.2003), abstract --	1-17
A	US 20040104706 A1 (OOI ET AL), 3 June 2004 (03.06.2004), figure 1, abstract -- -----	1-7,13-17

International patent classification (IPC)**G01R 31/36** (2006.01)**A61N 1/37** (2006.01)**A61N 1/378** (2006.01)**A61N 1/39** (2006.01)**Download your patent documents at www.prv.se**

The cited patent documents can be downloaded:

- From "Cited documents" found under our online services at www.prv.se (English version)
- From "Anförda dokument" found under "e-tjänster" at www.prv.se (Swedish version)

Use the application number as username. The password is

ECXRQPDCLW.

Paper copies can be ordered at a cost of 50 SEK per copy from PRV InterPat (telephone number 08-782 28 85).

Cited literature, if any, will be enclosed in paper form.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/SE2009/000363

WO	2006015347	A2	09/02/2006	NONE			
US	20050017685	A1	27/01/2005	NONE			
US	6108579	A	22/08/2000	NONE			
US	20050088145	A1	28/04/2005	NONE			
US	6167309	A	26/12/2000	CA	2303095 A	25/03/1999	
				EP	1019742 A	19/07/2000	
				WO	9914612 A	25/03/1999	
US	6820019	B1	16/11/2004	WO	0108749 A	08/02/2001	
US	20030149455	A1	07/08/2003	NONE			
US	20040104706	A1	03/06/2004	NONE			