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Declarations under Rule 4.17:

— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*

— *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))*

Published:

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(54) Title: DUAL BATTERY FAST CHARGING DEFIBRILLATOR

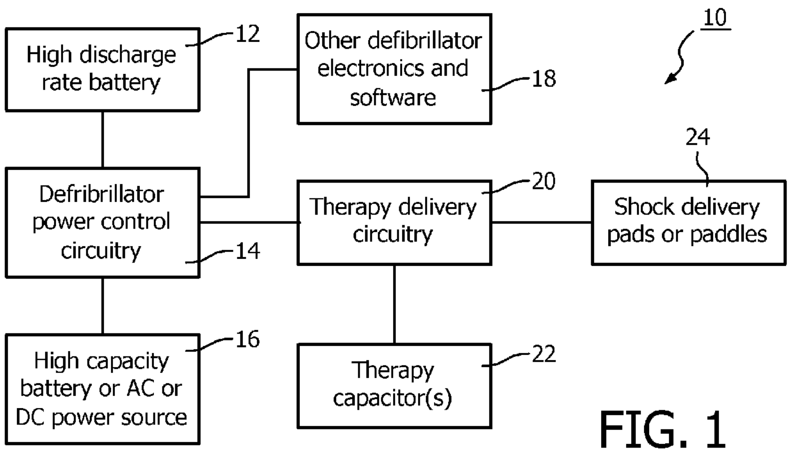

FIG. 1

(57) Abstract: A defibrillator includes a first battery (12) configured to provide a discharge rate to a capacitor suitable for generating a defibrillator shock. A power source (16) has a larger capacity than the first battery. A power control module (14) is coupled to the first battery and the power source and is configured to selectively enable connections between the first battery and the power source and from each of the first battery and the power source to the capacitor based on feedback from at least one of the first battery and the power source to reduce charge time.

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DUAL BATTERY FAST CHARGING DEFIBRILLATOR

BACKGROUND:

Technical Field

This disclosure relates to medical instruments and more particularly to a fast charging defibrillator.

Description of the Related Art

An external defibrillator needs to be highly portable so that it can be quickly carried to a patient who has sudden cardiac arrest to deliver a life-saving shock. The defibrillator typically operates on battery power. To deliver a shock, the defibrillator charges a capacitor to a high voltage – typically to over 2000 volts. Due to limitations on the discharge rate of batteries, it may require from 5 to 8 seconds or more to charge the capacitor. After sudden cardiac arrest, the chances of survival drop by 10% to 15% every minute, and several shocks may be needed to resuscitate the patient.

Discharge rate of batteries is specified as a fraction of capacity. Thus, a standard Lithium-ion battery cell designed for 2200 milli-amp-hour capacity and a maximum discharge rate of one times capacity (1C), can supply a peak discharge current of 2.2 amps. Lithium ion cells optimized for capacity can handle peak currents of 2C or 3C for short periods. However for safety, the maximum current output is usually limited to 1C or 1.5C.

SUMMARY

In accordance with the present principles, a defibrillator includes a first battery configured to provide a discharge rate to a capacitor suitable for generating a defibrillator shock. A power source has a larger capacity than the first battery. A power control module is coupled to the first battery and the power source and is configured to selectively enable connections between the first battery and the power source and from each of the first battery and the power source to the capacitor to reduce charge time.

Another defibrillator includes a first battery configured to provide a discharge rate to a capacitor suitable for generating a defibrillator shock. A second battery has a larger capacity than the first battery. A power control module is coupled between the first battery and the second battery and is configured to selectively enable connections between the first battery and the second battery and from each of the first battery and the second battery to the capacitor to reduce charge time and increase a recovery rate after a discharge. A delivery circuit is coupled to the power control module and the capacitor and configured to enable discharge of the capacitor to a shock delivery device, the delivery circuit providing feedback to the power control module for a state of the capacitor.

A method for charging a defibrillator includes providing a first battery configured to provide a discharge rate to a capacitor suitable for generating a defibrillator shock, a power source having a larger capacity than the first battery, and a power control module coupled to the first battery and the power source and configured to selectively enable connections between the first battery and the power source and from each of the first battery and the power source; and charging the capacitor in accordance with the power control module which selectively enables the connections in accordance with feedback from at least one of the first battery and the power source to reduce charge time of the capacitor.

These and other objects, features and advantages of the present disclosure will become apparent from the following detailed description of illustrative embodiments thereof, which is to be read in connection with the accompanying drawings.

BRIEF DESCRIPTION OF DRAWINGS

This disclosure will present in detail the following description of preferred embodiments with reference to the following figures wherein:

FIG. 1 is a block/flow diagram showing a dual source defibrillator in accordance with one embodiment;

FIG. 2 is a block/flow diagram showing power control circuit or module for the dual source defibrillator in accordance with one embodiment; and

FIG. 3 is a flow diagram showing a method for charging a defibrillator in accordance with an illustrative embodiment.

DETAILED DESCRIPTION OF EMBODIMENTS

In accordance with the present principles, a high discharge rate battery technology is employed to reduce defibrillator charge times by a factor of 8 or more. This results in a defibrillator that can charge its capacitor in less than one second. Because high discharge rate batteries have lower overall charge capacity, this high discharge rate battery can be complemented with a standard discharge rate battery to provide long battery operation times for the defibrillator.

The high-discharge rate battery achieves extremely fast capacitor charge times. There are several exemplary embodiments of a defibrillator that combine a high discharge rate battery with a high capacity battery. For pre-hospital usage, the high discharge rate battery can be used to charge the capacitor while a second battery with high capacity cells is used to power other operations and provide longer run times. For hospital usage where needed runtimes are shorter, the high discharge rate battery can be used to both operate the device and charge the capacitor. A high discharge rate battery is used to power the defibrillator instead of the high capacity battery to significantly reduce the time needed to charge the defibrillator capacitor so that a shock can be delivered to a patient more rapidly. Battery capacity varies with the discharge rate; therefore, a high discharge rate battery has a lower capacity than a standard discharge rate battery. To compensate for the reduced capacity of the high discharge rate battery, a second battery with high capacity can be used to provide extended runtimes when not charging the capacitor.

By way of reference, a 12 battery pack with a 4 serial/3 parallel arrangement of standard 2200 milli-amp-hour Lithium ion cells optimized for capacity can safely discharge at a maximum current of about 11 amps for a few seconds. This is sufficient power to charge a defibrillator capacitor in about 4 seconds for a 200J shock or about 7 seconds for a 360J shock. This type of battery pack will provide approximately 6.6 amp-hours capacity.

Lithium ion cells optimized for power can deliver pulsed currents of 30C to 40C. Thus, even a much smaller battery pack with just 4 serial Lithium ion cells optimized for discharge rate can discharge at a maximum current of about 40 amps. This is sufficient power to charge a defibrillator capacitor for a 200J shock in about a second. The drawback is that this type of battery pack will only provide approximately 1.6 amp-hours capacity. The present principles address these issues.

It also should be understood that the present invention will be described in terms of medical instruments; however, the teachings of the present invention are much broader and are applicable to any battery operated device that needs to draw higher current for short durations. In some embodiments, the present principles are employed in defibrillators used in hospitals or emergency vehicles, in homes, public places, etc. The elements depicted in the FIGS. may be implemented in various combinations of hardware and software and provide functions which may be combined in a single element or multiple elements.

The functions of the various elements shown in the FIGS. can be provided through the use of dedicated hardware as well as hardware capable of executing software in association with appropriate software. When provided by a processor or controller, the functions can be provided by a single dedicated processor, by a single shared processor, or by a plurality of individual processors, some of which can be shared. Moreover, explicit use of the term “processor” or “controller” should not be construed to refer exclusively to hardware capable of executing software, and can implicitly include, without limitation, digital signal processor (“DSP”) hardware, read-only memory (“ROM”) for storing software, random access memory (“RAM”), non-volatile storage, etc.

Moreover, all statements herein reciting principles, aspects, and embodiments of the invention, as well as specific examples thereof, are intended to encompass both structural and functional equivalents thereof. Additionally, it is intended that such equivalents include both currently known equivalents as well as equivalents developed in the future (i.e., any elements developed that perform the same function, regardless of structure). Thus, for example, it will be appreciated by those skilled in the art that the block diagrams presented herein represent conceptual views of illustrative system components and/or circuitry embodying the principles of the invention. Similarly, it will be appreciated that any flow charts, flow diagrams and the like represent various processes which may be substantially represented in computer readable storage media and so executed by a computer or processor, whether or not such computer or processor is explicitly shown.

Furthermore, embodiments of the present invention can take the form of or include a computer program product accessible from a computer-usable or computer-readable storage medium providing program code for use by or in connection with a computer or any instruction execution system. For the purposes of this description, a computer-usable or computer readable storage medium can be any apparatus that may include, store, communicate, propagate, or transport the program for use by or in connection with the instruction execution system, apparatus, or device. The medium can be an electronic, magnetic, optical, electromagnetic, infrared, or semiconductor system (or apparatus or device) or a propagation medium. Examples of a computer-readable medium include a semiconductor or solid state memory, magnetic tape, a removable computer diskette, a random access memory (RAM), a read-only memory (ROM), a rigid magnetic disk and an optical disk. Current examples of optical disks include compact disk – read only memory (CD-ROM), compact disk – read/write (CD-R/W), Blu-Ray™ and DVD.

Referring now to the drawings in which like numerals represent the same or similar elements and initially to FIG. 1, a block/flow diagram shows a defibrillator 10 in accordance with one embodiment. Defibrillator 10 includes a high discharge rate battery 12 and a high capacity power source 16. The selection of the type and usage of the energy sources (12, 16) is determined and controlled by defibrillator power control circuitry 14. Therapy delivery circuitry 20 controls the amount of energy and shapes of pulses delivered to shock delivery devices 24, which may include pads or paddles. Therapy delivery circuitry 20 provides access to therapy capacitors 22 to enable charging and discharging thereof. Defibrillator 10 may include other electronics or software programs 18. The electronics 18 may include other features, such as clocks, timers, power measurement devices, a light, a display, etc.

When the defibrillator 10 needs to deliver a shock, the therapy delivery circuitry 20 charges the therapy capacitor(s) 22 by routing current from the high discharge rate battery 12. When a user triggers the release of energy, the energy stored in therapy capacitor(s) 22 is discharged via pads or paddles 24 placed on a patient's chest. The power control circuitry 14 routes power from the available power sources, battery 12 and/or high capacity power source 16. The power for the defibrillator 10 is supplied by the high discharge rate battery 12. This battery 12 is charged by a second power source 16, which may include a high capacity battery (or an AC or DC battery charger).

The high discharge rate battery 12 is used to power the defibrillator 10 and charge the capacitor(s) 22. The capacitor(s) 22 is charged using the higher current output of the battery 12. The capacitor(s) 22 may also charged from the high capacity battery 16 (or an AC or DC charger).

Referring to FIG. 2, the power control circuitry 14 may include control software or circuitry controller 30 configured to determine the available capacity of each of the batteries 12 and 16 and may regulate access to battery terminals depending on the power requirements of the capacitors 22 (FIG. 1). The batteries or energy sources 12, 16 also provide data interfaces 35, 37, respectively, so that their current charge levels and other status can be read by the controller 30. The capacitors 22 and/or batteries 12, 16 provide feedback 33 to the power control circuitry 14 to permit the power control circuitry 14 to determine how quickly the capacitors 22 are charging or recharging or to determine the capabilities of the batteries 12, 16 for future use.

The data sent to the control circuitry or module 30 may include data bits or other signals configured to convey the amount of capacity/amount of charge/status of the batteries of power sources. The data may also include a charge rate from the capacitors 33. The input or feedback information may be employed to make a decision based upon a lookup table or other data structure stored in the control module 30. The data may be indexed to the data structure to determine the connection to be enabled/disabled or to otherwise control the power distribution between power sources. Other decision criteria may be employed as well including but not limited to programmed actions under given conditions, historic data, artificial intelligence, etc. For example, based on the charging rate or stored energy in the batteries 12, 16, especially after a shock has been deployed, the controller 30 selects whether to recharge the battery 12 from battery 16, recharge the capacitors directly from the battery 12, recharge the capacitors directly from the battery 16, or open up both batteries 12 and 16 to recharge the capacitors 22. The use of both sources becomes difficult when the sources include significantly different discharge rates. Charge regulators and other circuitry may be employed to condition the signal. The available charge of the batteries is a more important criterion. For example, if the high discharge battery has low charge, it might not be able to fully charge the capacitors. Then, the other power source would be selected and employed.

In one embodiment, the controller 30 selectively activates one or more switches 32, 34 and 36 to enable power output 38 from one, the other or both batteries 12 and 16. In one embodiment, the battery 16 may include a different DC source or even an AC source. In another embodiment, there may be more than two batteries and each battery may be selectively enabled using the controller 30.

In useful embodiments, the batteries 12 and 16 may include one or more of the following. A standard Lithium-ion battery cell, such as a CGR18650CG has a capacity of 2,200 mAh and a maximum discharge rate of 1C. Generally these cells are configured in series to realize the needed voltage (e.g., 4S provides a nominal voltage of 14.4V) and in parallel to increase the total discharge current (e.g., 3P provides a 3C maximum discharge rate). A 12 cell (4S3P) battery pack provides a capacity of 6.6 Amp-hours, with a maximum discharge of 2 Amps (derating the maximum discharge rate to improve reliability). High discharge rate battery cells are designed for applications such as power tools and remote-controlled model cars and planes where higher currents are needed to drive electric motors. A high discharge rate Lithium-ion cell, such as a APR18650M1, has a capacity of 1,100 mAh. A 4 cell (4S1P) battery pack provides a capacity of 1.1 Amp-hours and can reliably provide discharges of 30 Amps.

Different combinations of the elements presented in FIG. 1 can be employed to optimize a defibrillator / monitor for its intended use. Exemplary embodiments may include the following. Battery 12 may include a single four cell high discharge rate battery (4S, 1P) for charging the capacitor 22 plus one or more eight or twelve cell high capacity batteries (4S and either 2P or 3P) for battery 16 to power other device functions. An eight or twelve cell high discharge rate battery (4S and either 2P or 3P) (battery 12) may be employed for powering all device functions plus an AC or DC battery charger for power source 16. A single four, eight or twelve cell high discharge rate battery (4S and either 1P or 2P or 3P) (battery 12) may be employed to power the device plus one or more ten cell batteries (5S, 2P) (battery 16) to charge the high discharge rate batteries (12).

In accordance with the present principles, the defibrillator 10 provides pulsed currents of 30C to 40C with just four serial lithium ion cells optimized for discharge rate and can discharge at a maximum current of about 30 amps using the battery 12. Control of the pulses may be provided by the delivery circuitry 20 or other circuits in the defibrillator 10. This is sufficient power to charge a defibrillator capacitor for a 200J shock in about a second. Since the defibrillator 10 includes a second power source 16 that may include a higher capacity battery. This battery 16 can provide over 6.0 amp-hours capacity and is sufficient to charge the first battery 12 and/or the capacitors 22.

Referring to FIG. 3, a block/flow diagram shows a method for charging a defibrillator in accordance with the present principles. In block 102, a dual source defibrillator is provided having a first battery configured to provide a discharge rate to a capacitor suitable for generating a defibrillator shock, a power source having a larger capacity than the first battery, and a power control module coupled to the first battery and the power source. The power control module is configured to selectively enable connections between the first battery and the power source and from each of the first battery and the power source to a capacitor. In block 104, the power source may include a second battery, a direct current source or an alternating current source configured to charge the first battery in accordance with the power control module.

In block 106, the capacitor is charged in accordance with the power control module to reduce charge time of the capacitor and/or increase a recovery rate after a discharge of the capacitor. In block 108, connections between the first battery and the power source and between each of the first battery and the power source to the capacitor are selectively enabled or disabled to improve a charging rate of the capacitor. In block 110, feedback is received from the capacitor and /or batteries at the power control module to adjust (e.g., optimize) a configuration of energy sources (batteries, etc.) to increase a charge rate of the capacitor. In block 112, one or more additional batteries are controlled by the power control module. Optimization decisions may be made by the power control module or may be preprogrammed in memory and made in accordance with current conditions.

In block 114, a shock is delivered by discharging the capacitor through a shock delivery device. Subsequent shocks may be administered at a rate of about every 1-4 seconds in block 116.

In interpreting the appended claims, it should be understood that:

a) the word "comprising" does not exclude the presence of other elements or acts than those listed in a given claim;

b) the word "a" or "an" preceding an element does not exclude the presence of a plurality of such elements;

c) any reference signs in the claims do not limit their scope;

d) several "means" may be represented by the same item or hardware or software implemented structure or function; and

e) no specific sequence of acts is intended to be required unless specifically indicated.

Having described preferred embodiments for dual battery fast charging defibrillator (which are intended to be illustrative and not limiting), it is noted that modifications and variations can be made by persons skilled in the art in light of the above teachings. It is therefore to be understood that changes may be made in the particular embodiments of the disclosure disclosed which are within the scope of the embodiments disclosed herein as outlined by the appended claims. Having thus described the details and particularity required by the patent laws, what is claimed and desired protected by Letters Patent is set forth in the appended claims.

CLAIMS:

1. A defibrillator, comprising:

a first battery (12) configured to provide a discharge rate to a capacitor suitable for generating a defibrillator shock;

a power source (16) having a larger capacity than the first battery; and

a power control module (14) coupled to the first battery and the power source and configured to selectively enable connections between the first battery and the power source and from each of the first battery and the power source to the capacitor based on feedback from at least one of the first battery and the power source to reduce charge time.

2. The defibrillator as recited in claim 1, wherein the power source (16) includes a second battery.

3. The defibrillator as recited in claim 1, wherein the power source (16) includes one of a direct current source and an alternating current source.

4. The defibrillator as recited in claim 1, wherein the power control module (14) includes a controller (30) configured to selectively enable or disable connections (32, 34, 36) between the first battery and the power source and between each of the first battery and the power source to the capacitor.

5. The defibrillator as recited in claim 1, wherein the power control module (30) receives feedback from the first battery (12) and the power source (16) to adjust a configuration of energy sources to increase a charge rate of the capacitor.

6. The defibrillator as recited in claim 1, wherein the power source (16) is configured to charge the first battery (12).

7. The defibrillator as recited in claim 1, further comprising one or more additional batteries controlled by the power control module.

8. The defibrillator as recited in claim 1, wherein the power control module (30) receives feedback from the capacitor to selectively enable the connections.

9. A defibrillator, comprising:

a first battery (12) configured to provide a discharge rate to a capacitor suitable for generating a defibrillator shock;

a second battery (16) having a larger capacity than the first battery;

a power control module (14) coupled between the first battery and the second battery and configured to selectively enable connections between the first battery and the second battery and from each of the first battery and the second battery to the capacitor to reduce charge time and increase a recovery rate after a discharge; and

a delivery circuit (20) coupled to the power control module and the capacitor and configured to enable discharge of the capacitor to a shock delivery device, the delivery circuit providing feedback to the power control module for a state of the capacitor.

10. The defibrillator as recited in claim 9, wherein the power control module (14) includes a controller (30) configured to selectively enable or disable connections (32, 34, 36) between the first battery and the second battery and between each of the first battery and the second battery to the capacitor.

11. The defibrillator as recited in claim 9, wherein the power control module (14) receives feedback from the capacitor (22) through the delivery circuit (20) to adjust a configuration of energy sources to increase a charge rate of the capacitor.

12. The defibrillator as recited in claim 9, wherein the power control module (14) receives feedback from the first and second batteries through the delivery circuit (20) to adjust a configuration of energy sources to increase a charge rate of the capacitor.

13. The defibrillator as recited in claim 9, wherein the second battery (16) is configured to charge the first battery (12).

14. The defibrillator as recited in claim 9, further comprising one or more additional batteries controlled by the power control module.

15. A method for charging a defibrillator, comprising:

providing (120) a first battery configured to provide a discharge rate to a capacitor suitable for generating a defibrillator shock, a power source having a larger capacity than the first battery, and a power control module coupled to the first battery and the power source and configured to selectively enable connections between the first battery and the power source and from each of the first battery and the power source to the capacitor; and

charging (106) the capacitor in accordance with the power control module which selectively enables the connections in accordance with feedback from at least one of the first battery and the power source to reduce charge time of the capacitor.

16. The method as recited in claim 14, wherein the power source includes a second battery configured to charge the first battery in accordance with the power control module.

17. The method as recited in claim 14, wherein the power source includes one of a direct current source and an alternating current source.

18. The method as recited in claim 14, further comprising selectively enabling or disabling (108) connections between the first battery and the power source and between each of the first battery and the power source to the capacitor to improve a charging rate of the capacitor.

19. The method as recited in claim 14, further comprising receiving (110) feedback from at least one of the capacitor, the first battery and the power source at the power control module to adjust a configuration of energy sources to increase a charge rate of the capacitor.

20. The method as recited in claim 14, further comprising at least one of
(i) controlling (112) one or more additional batteries by the power control module, or
(ii) delivering (114) a shock by discharging the capacitor through a shock delivery device.

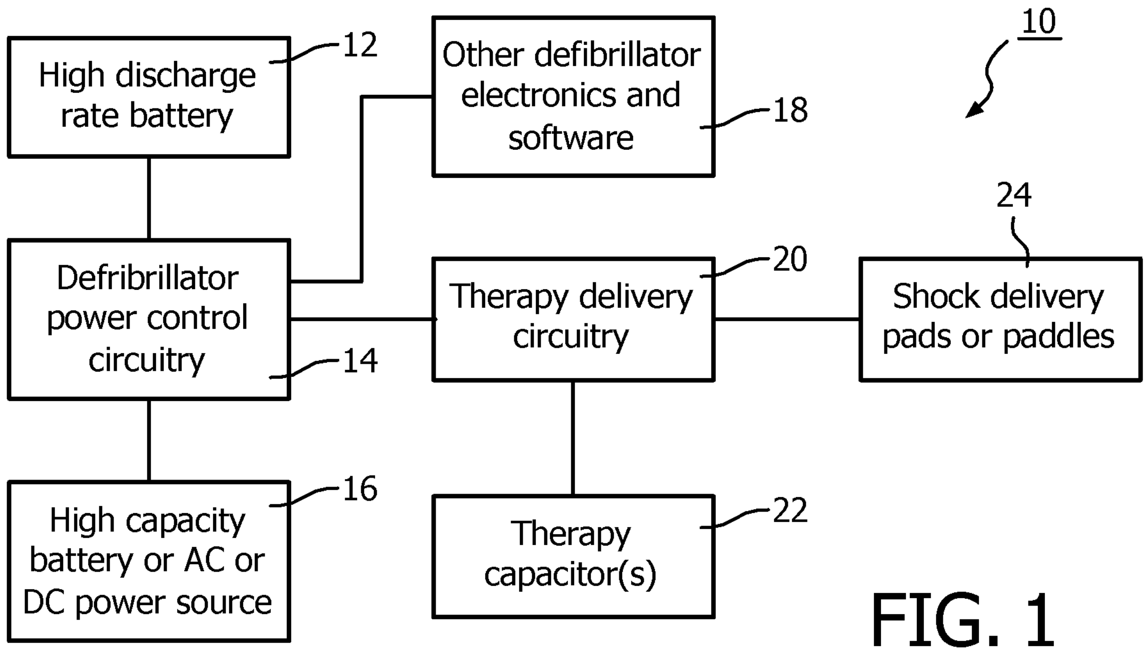
High discharge rate battery
12
Other defibrillator electronics and software
18
10
Defribrillator power control circuitry
14
Therapy delivery circuitry
20
24
Shock delivery pads or paddles
High capacity battery or AC or DC power source
16
Therapy capacitor(s)
22

FIG. 1

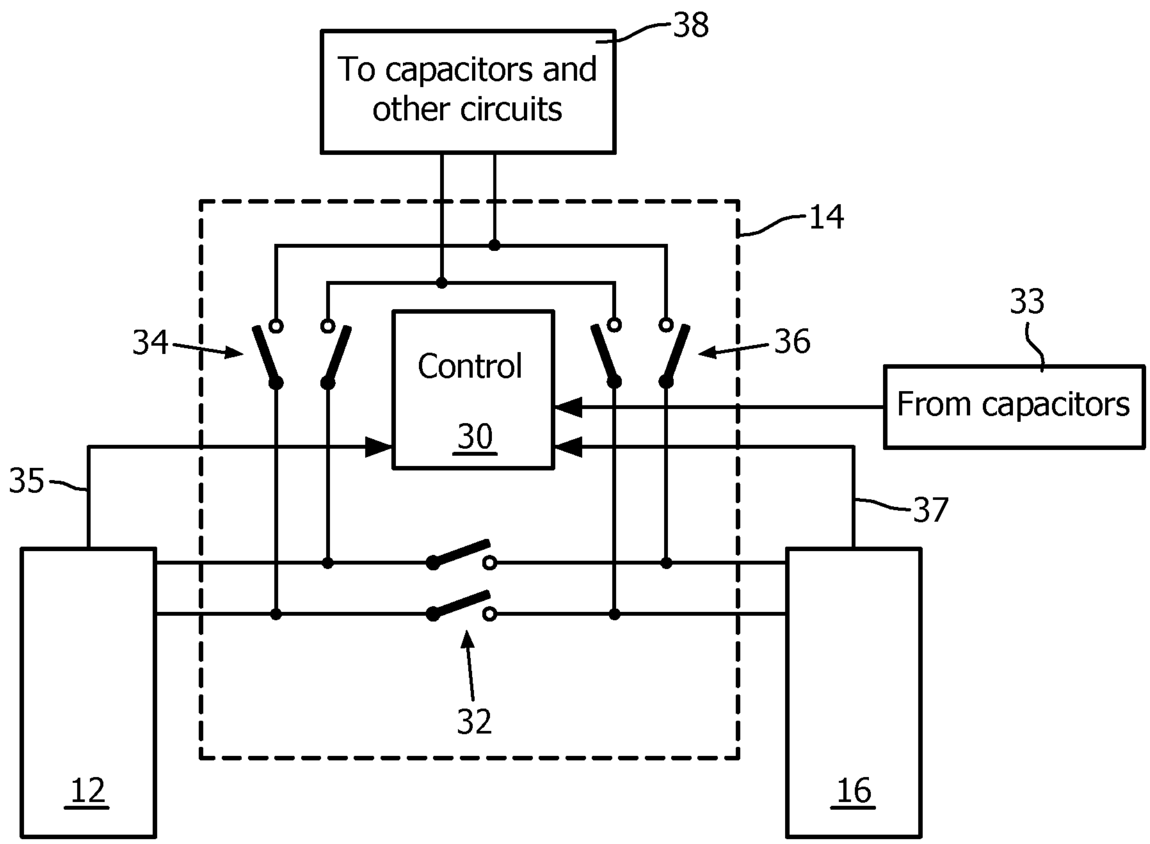
To capacitors and other circuits
38
14
33
34
Control
30
36
From capacitors
35
37
32
12
16

FIG. 2

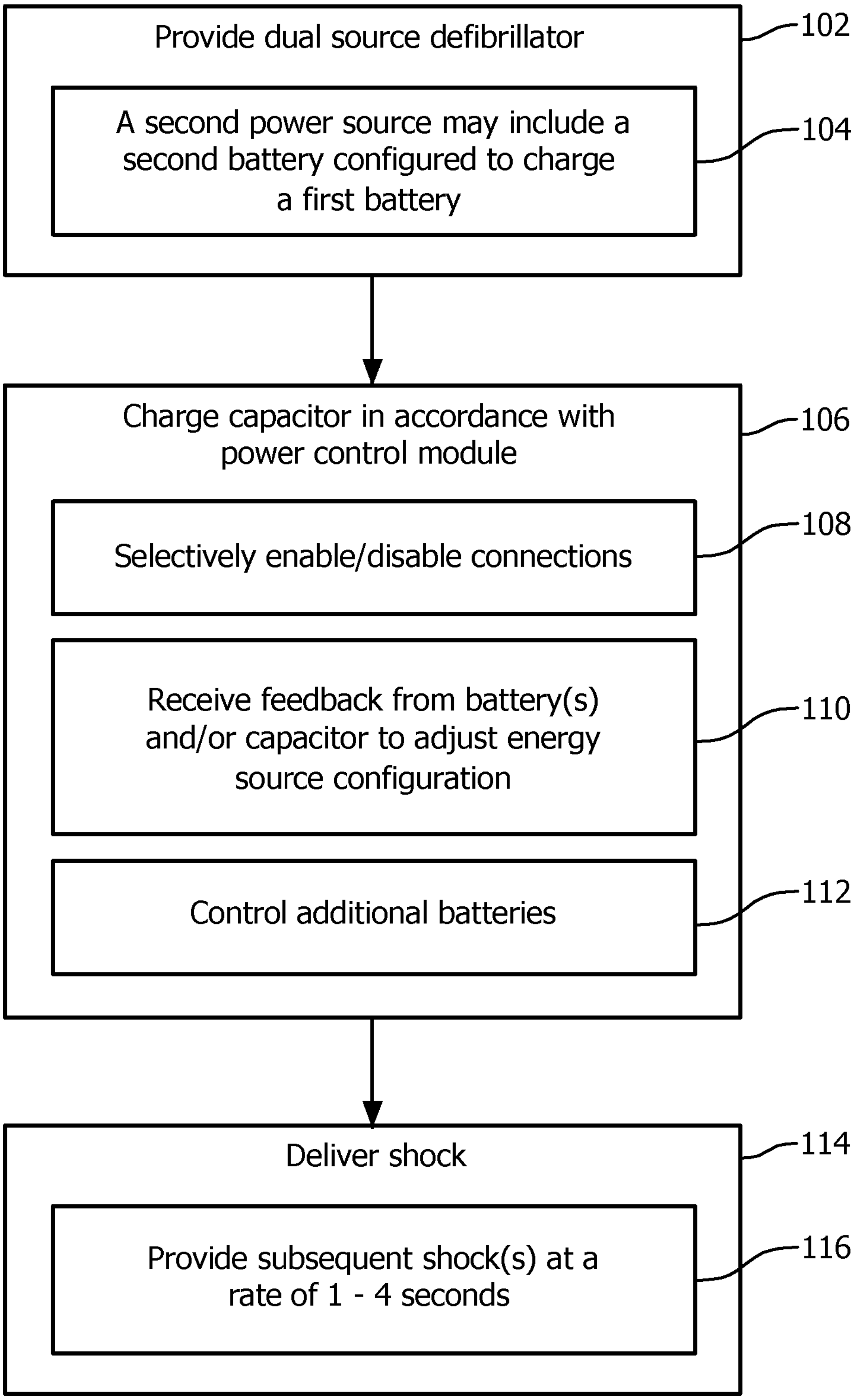
Provide dual source defibrillator
102
A second power source may include a second battery configured to charge a first battery
104
Charge capacitor in accordance with power control module
106
Selectively enable/disable connections
108
Receive feedback from battery(s) and/or capacitor to adjust energy source configuration
110
Control additional batteries
112
Deliver shock
114
Provide subsequent shock(s) at a rate of 1 - 4 seconds
116

FIG. 3

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2014/061707

A. CLASSIFICATION OF SUBJECT MATTER
INV. A61N1/39
ADD.

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)
A61N

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

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

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2009/018535 A1 (CAMERON HEALTH INC [US]; SIGNOFF DAVID M [US]; JULIAN MARCUS F [US]) 5 February 2009 (2009-02-05) abstract; figures 2-4C, 8 paragraph [0001] paragraph [0007] - paragraph [0009] paragraph [0021] - paragraph [0040] -----	1-20
A	US 2003/193245 A1 (POWERS DANIEL J [US]) 16 October 2003 (2003-10-16) the whole document -----	1-20
A	US 2010/114235 A1 (JIANG NAIXIONG [US] ET AL) 6 May 2010 (2010-05-06) the whole document -----	1-20
A	US 4 323 075 A (LANGER ALOIS A) 6 April 1982 (1982-04-06) the whole document -----	1-20

☐ 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

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
29 July 2014	07/08/2014

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Molina Silvestre, A

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/IB2014/061707

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