



(51) International Patent Classification:

H02J 7/00 (2006.01) *H01M 10/42* (2006.01)

(21) International Application Number:

PCT/US2018/032718

(22) International Filing Date:

15 May 2018 (15.05.2018)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

201710491797.3 20 June 2017 (20.06.2017) CN

(71) Applicant: GENERAL ELECTRIC COMPANY
[US/US]; 1 River Road, Schenectady, NY 12345 (US).(72) Inventors: MAO, Saijun; 1800 Cai Lun Road, Zhangjiang
High-tech Park, Pudong, Shanghai, 201203 (CN). LIAO,
Yi; General Electric Company Global Research, One Research
Circle, Niskayuna, NY 12309 (US). BRAZIL, Ste-wart Blake; General Electric Company Global Research,
One Research Circle, Niskayuna, NY 12309 (US). CHEN,
Yuzheng; 1800 Cailun Road, Zhangjiang High-tech Park,
Pudong, Shanghai, 201203 (CN). HAN, Xinhong; 1800
Cailun Road, Zhangjiang High-tech Park, Pudong, Shang-
hai, 201203 (CN).(74) Agent: POLLANDER, Laura L. et al.; General Electric
Company, Global Patent Operation, 901 Main Avenue, 3rd
Floor, Norwalk, CT 06851 (US).(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, BN, BR, BW, BY, BZ,
CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO,
DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN,
HR, HU, ID, IL, IN, IR, IS, JO, JP, KE, KG, KH, KN, KP,
KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME,
MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ,
OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA,

(54) Title: BATTERY MANAGEMENT SYSTEM

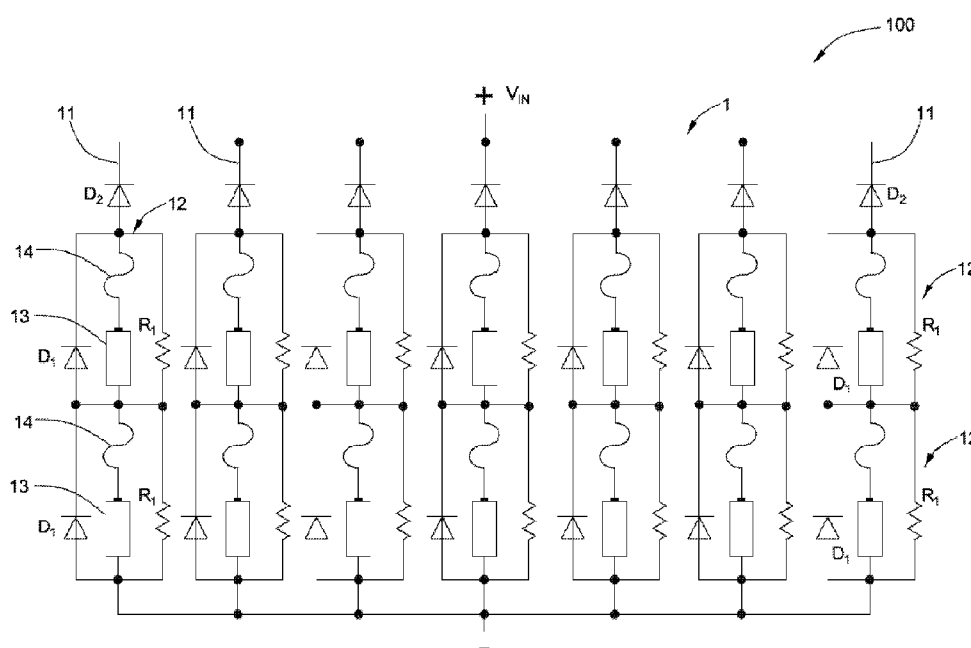


FIG. 1

(57) **Abstract:** A battery management system is disclosed, which includes a battery module having a positive output terminal and a negative output terminal. The battery module includes at least two branch circuits which are connected in parallel between the positive output terminal and the negative output terminal. Each of the at least two branch circuits includes at least two battery cells which are connected in series between the positive output terminal and the negative output terminal. Each battery cell includes a battery, a current limiting device for preventing the battery from over-discharging, and a bypass device for bypassing the battery when a fault occurs in the battery.



SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, 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, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, 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, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

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

BATTERY MANAGEMENT SYSTEM

BACKGROUND

[0001] This disclosure relates generally to the field of battery management, and more particularly to battery management systems.

[0002] Batteries are used in many applications to provide energy to loads. A typical conventional battery usually consists of multiple cells connected in series to form a battery module. Cells are used cumulatively in the battery to provide a desired output voltage. Depending upon the power requirements and available internal spaces of the loads, multiple batteries are sometimes used.

[0003] However, conventional battery deployments have some operating disadvantages. For example, the current drawn from the batteries may exceed the battery's designed current limit, and over-discharging of the battery is caused, which would no doubt reduce operation lifetime of the battery.

[0004] Therefore, in the view of the foregoing, it is desirable to provide an improved battery management system to solve at least one of problems above-mentioned.

BRIEF DESCRIPTION

[0005] In one aspect of embodiments of the present disclosure, a battery management system is provided. The battery management system comprises a battery module having a positive output terminal and a negative output terminal. The battery module comprises at least two branch circuits which are connected in parallel between the positive output terminal and the negative output terminal. Each of the at least two branch circuits comprises at least two battery cells which are connected in series between the positive output terminal and the negative output terminal. Each battery cell comprises a battery, a current limiting device for preventing the battery from over-discharging, and a bypass device for bypassing the battery when a fault occurs in the battery.

[0006] In another aspect of embodiments of the present disclosure, a battery management system is provided. The battery management system comprises a plurality of battery cells. Each of the plurality of battery cells comprises a battery, a current limiting device for preventing the battery from over-discharging, and a bypass device for bypassing the battery when a fault occurs in the battery.

DRAWINGS

[0007] These and other features, aspects, and advantages of the present disclosure will become better understood when the following detailed description is read with reference to the accompanying drawings in which like characters represent like parts throughout the drawings, wherein:

[0008] FIG. 1 is a schematic diagram of a battery management system in accordance with an embodiment of the present disclosure; and

[0009] FIG. 2 is a schematic diagram of a battery management system in accordance with another embodiment of the present disclosure.

DETAILED DESCRIPTION

[0010] Embodiments of the present disclosure will be described hereinbelow with reference to the accompanying drawings. In the following description, well-known functions or constructions are not described in detail to avoid obscuring the disclosure in unnecessary detail.

[0011] Unless defined otherwise, technical and scientific terms used herein have the same meaning as is commonly understood by one of ordinary skill in the art to which this disclosure belongs. The terms “first”, “second”, and the like, as used herein do not denote any order, quantity, or importance, but rather are used to distinguish one element from another. Also, the terms “a” and “an” do not denote a limitation of quantity, but rather denote the presence of at least one of the referenced items. The term “or” is meant to be inclusive and mean either or all of the listed items. The use of “including,” “comprising”

or “having” and variations thereof herein are meant to encompass the items listed thereafter and equivalents thereof as well as additional items. The terms “connected” and “coupled” are not restricted to physical or mechanical connections or couplings, and can include electrical connections or couplings, whether direct or indirect. In addition, Terms indicating specific locations, such as “top”, “bottom”, “left”, and “right”, are descriptions with reference to specific accompanying drawings. Embodiments disclosed in the present disclosure may be placed in a manner different from that shown in the figures. Therefore, the location terms used herein should not be limited to locations described in specific embodiments.

[0012] FIG. 1 illustrates a schematic diagram of a battery management system 100 in accordance with an embodiment of the present disclosure. As shown in FIG. 1, the battery management system 100 in accordance with an embodiment of the present disclosure may include a battery module 1. The battery module 1 has a positive output terminal “+” and a negative output terminal “-”.

[0013] In one implementation, the battery module 1 may include at least two branch circuits 11. The at least two branch circuits 11 are connected in parallel between the positive output terminal “+” and the negative output terminal “-”. The seven branch circuits 11 are shown as an illustrative example in FIG. 1.

[0014] Each of the at least two branch circuits 11 may include at least two battery cells 12. The at least two battery cells 12 are connected in series between the positive output terminal “+” and the negative output terminal “-”. In this embodiment, the number of the battery cells 12 in each branch circuit 11 are shown to be two in FIG. 1, but the number of the battery cells 12 of the present disclosure should be not limited herein.

[0015] Each battery cell 12 includes a battery 13, a current limiting device 14 and a bypass device. The current limiting device 14 can prevent the battery 13 from over-discharging. For example, the current limiting device 14 may include a fuse 14 connected in series with the battery 13. The bypass device can bypass the battery 13 when the battery 13 is in a fault condition. The bypass device may for example include a first diode D₁.

The first diode D_1 is connected in parallel with the fuse 14 and the battery 13. For example, when one battery 13 gets open-circuit failures, the impedance of open-circuit battery 13 becomes quite large. In this condition, the first diode D_1 is triggered to bypass the open-circuit battery 13. The current will flow through the first diode D_1 and the open-circuit battery 13 is bypassed. Each battery cell 12 may further include a first resistor R_1 . The first resistor R_1 is connected in parallel with the fuse 14 and the battery 13 and is configured for cell voltage balancing.

[0016] The current limiting device including the fuse 14 and the bypass device including the first diode D_1 can guarantee the continuity and redundancy of battery operation under different fault conditions of the battery 13. The first resistor R_1 can ensure voltage balancing for the battery cells 12 connected in series.

[0017] In addition, each branch circuit 11 may further include a second diode D_2 . In each branch circuit 11, the second diode D_2 is connected in series with the at least two battery cells 12. The second diode D_2 can prevent reverse connection of the corresponding branch circuit 11.

[0018] With continued reference to FIG. 1, in another implementation, the battery module 1 of the battery management system 100 may include a plurality of battery cells 12. Each of the plurality of battery cells 12 includes a battery 13, a current limiting device 14 for preventing the battery 13 from over-discharging, and a bypass device for bypassing the battery 13 when a fault occurs in the battery 13. The current limiting device 14 may for example include a fuse 14 connected in series with the battery 13. The bypass device may for example include a first diode D_1 connected in parallel with the fuse 14 and the battery 13.

[0019] The plurality of battery cells 12 comprises at least two battery cells 12 which are connected in parallel and at least two battery cells 12 which are connected in series.

[0020] Each battery cell 12 may further include a first resistor R_1 . The first resistor R_1 is connected in parallel with the fuse 14 and the battery 13. The first resistor R_1 of each

battery cells 12 can ensure voltage balancing for the at least two battery cells 12 which are connected in series.

[0021] The battery management system 100 may further include at least two second diodes D_2 for preventing reverse connection of the at least two battery cells 12 which are connected in parallel.

[0022] FIG. 2 illustrates a schematic diagram of a battery management system 200 in accordance with another embodiment of the present disclosure. As shown in FIG. 2, the battery management system 200 in accordance with another embodiment of the present disclosure may include the battery module 1 as shown in FIG. 1, and may further include a self-driven matching circuit 2. The battery module 1 is coupled to a discharge circuit 3 via the self-driven matching circuit 2. The discharge circuit 3 is for example a boost converter in this embodiment. However, the discharge circuit 3 should be not limited to the boost converter, and may also include a buck converter, a buck-boost converter and other converters. The self-driven matching circuit 2 may be used for over-discharging control of the battery module 1. When the battery module 1 is in a normal operation, a discharge current from the battery module 1 flows through the self-driven matching circuit 2 to the discharge circuit 3, and when the battery module 1 is in an over-discharging condition, the self-driven matching circuit 2 is open circuit and no current flows through the self-driven matching circuit 2 from the battery module 1.

[0023] The self-driven matching circuit 2 may include a second resistor R_2 , a third resistor R_3 , a fourth resistor R_4 , a first transistor Q_1 and a second transistor Q_2 . The second resistor R_2 and the third resistor R_3 are connected in series between the positive output terminal “+” and the negative output terminal “-”. The first transistor Q_1 is a NPN type transistor and has a body diode D_3 . For example, the first transistor Q_1 is a N-channel Metal-Oxide-Semiconductor Field-Effect Transistor (simply called as NMOS). A gate electrode g of the first transistor Q_1 is connected with a connection point of the second resistor R_2 and the third resistor R_3 . A source electrode s of the first transistor Q_1 is connected to the negative output terminal “-”, and the source electrode s of the first transistor Q_1 is grounded. The fourth resistor R_4 is coupled between the positive output

terminal “+” and a drain electrode d of the first transistor Q_1 . The second transistor Q_2 is a PNP type transistor and has a body diode D_4 . For example, the second transistor Q_2 is a P-channel Metal-Oxide-Semiconductor Field-Effect Transistor (simply called as PMOS). A gate electrode g of the second transistor Q_2 is connected with the drain electrode d of the first transistor Q_1 , a source electrode s of the second transistor Q_2 is connected with the positive output terminal “+” and a drain electrode d of the second transistor Q_2 is connected to the discharge circuit 3. The types of the first transistor Q_1 and the second transistor Q_2 should be not limited herein. In another embodiment, the first transistor Q_1 and the second transistor Q_2 can be both silicon type, gallium nitride or silicon carbide type N-channel Metal-Oxide-Semiconductor Field-Effect Transistor (MOSFET) and P-channel Metal-Oxide-Semiconductor Field-Effect Transistor (MOSFET).

[0024] Hereinafter, how the self-driven matching circuit 2 of the present disclosure realizes the over-discharging protection for the battery module 1 will be explained in detail in combination with FIG. 2.

[0025] With continued reference to FIG. 2, the first transistor Q_1 is NMOS and the second transistor Q_2 is PMOS, the second resistor R_2 and the third resistor R_3 make up a voltage divider. When a voltage provided by the battery module 1 (called as a battery voltage V_{IN}) drops, the voltage at point A1, i.e. a gate voltage V_{G1} of the first transistor Q_1 , will reduce. With further reduction of the battery voltage V_{IN} , when the gate voltage V_{G1} of the first transistor Q_1 will drop to be less than a threshold voltage $V_{GS(th)1}$ of the first transistor Q_1 , the first transistor is turned off. The voltage at point A2, i.e. a gate voltage V_{G2} of the second transistor Q_2 will increase step by step through the fourth resistor R_4 . When a voltage difference between the gate voltage V_{G2} of the second transistor Q_2 and the battery voltage V_{IN} is larger than a threshold voltage $V_{GS(th)2}$ of the second transistor Q_2 , that is, $(V_{G2} - V_{IN}) > V_{GS(th)2}$, the second transistor Q_2 is turned off.

[0026] Thus, when the battery voltage V_{IN} is under a protect voltage V_{UCP} of the battery module 1, both the first transistor Q_1 and the second transistor Q_2 are turned off. The battery module 1 is disconnected from the boost converter 3. The battery module 1 can't output the battery voltage V_{IN} .

[0027] Therefore, the self-driven matching circuit 2 can prevent the battery 13 from over current discharging or provide under voltage protection. By selecting proper control parameters, the battery 13 can work in a health and durable condition.

[0028] The current limiting device 14 including the fuse and the self-driven matching circuit 2 of the present disclosure can realize an effective over-discharging protection for the battery module 1.

[0029] The battery management system 100, 200 can use a robust mechanical package, and such the robust mechanical package design can allow the battery management system 100, 200 to survive in a harsh environment like high temperature, high pressure and high vibration.

[0030] The battery management system 100, 200 of the present disclosure enables an effective, robust and long lifetime operation of the battery 13, particularly in the harsh environments. The battery management system 100, 200 of the present disclosure can have high efficiency, robust structure, simple circuit, low power consumption, and compact size.

[0031] While the disclosure has been illustrated and described in typical embodiments, it is not intended to be limited to the details shown, since various modifications and substitutions can be made without departing in any way from the spirit of the present disclosure. As such, further modifications and equivalents of the disclosure herein disclosed may occur to persons skilled in the art using no more than routine experimentation, and all such modifications and equivalents are believed to be within the spirit and scope of the disclosure as defined by the following claims.

WHAT IS CLAIMED IS:

1. A battery management system, comprising:
a battery module having a positive output terminal and a negative output terminal, and comprising:
at least two branch circuits which are connected in parallel between the positive output terminal and the negative output terminal, wherein each of the at least two branch circuits comprises at least two battery cells which are connected in series between the positive output terminal and the negative output terminal, and each battery cell comprises:
a battery;
a current limiting device for preventing the battery from over-discharging; and
a bypass device for bypassing the battery when a fault occurs in the battery .
2. The battery management system of claim 1, wherein the current limiting device comprises a fuse connected in series with the battery, and the bypass device comprises a first diode connected in parallel with the fuse and the battery.
3. The battery management system of claim 2, wherein each battery cell further comprises a first resistor connected in parallel with the fuse and the battery and configured for cell voltage balancing.
4. The battery management system of claim 1, wherein each branch circuit further comprises a second diode connected in series with the at least two battery cells.
5. The battery management system of claim 1, further comprising:
a self-driven matching circuit for over-discharging control of the battery module, wherein the battery module is coupled to a discharge circuit via the self-driven matching circuit, when the battery module is in a normal operation, a discharge current from the battery module flows through the self-driven matching circuit to the discharge circuit, and when the battery module is in an over-discharging condition, the self-driven matching circuit is open circuit and no current flows through the self-driven matching circuit from the battery module.

6. The battery management system of claim 5, wherein the self-driven matching circuit comprises:

- a second resistor and a third resistor which are connected in series between the positive output terminal and the negative output terminal;

- a first transistor which is a NPN type transistor, wherein a gate electrode of the first transistor is connected with a connection point of the second resistor and the third resistor and a source electrode of the first transistor is connected to the negative output terminal;

- a fourth resistor coupled between the positive output terminal and a drain electrode of the first transistor; and

- a second transistor which is a PNP type transistor, wherein a gate electrode of the second transistor is connected with the drain electrode of the first transistor, a source electrode of the second transistor is connected with the positive output terminal and a drain electrode of the second transistor is connected to the discharge circuit.

7. The battery management system of claim 6, wherein the source electrode of the first transistor is grounded.

8. A battery management system, comprising:

- a plurality of battery cells, each of which comprises:

- a battery;

- a current limiting device for preventing the battery from over-discharging; and

- a bypass device for bypassing the battery when a fault occurs in the battery.

9. The battery management system of claim 8, wherein the current limiting device comprises a fuse connected in series with the battery, and the bypass device comprises a first diode connected in parallel with the fuse and the battery.

10. The battery management system of claim 9, wherein each battery cell further comprises a first resistor connected in parallel with the fuse and the battery and configured for cell balancing.

11. The battery management system of claim 8, wherein the plurality of battery cells comprises at least two battery cells which are connected in parallel and at least two battery cells which are connected in series.

12. The battery management system of claim 11, further comprising:
at least two second diodes for preventing reverse connection of the at least two battery cells which are connected in parallel.

13. The battery management system of claim 8, further comprising:
a self-driven matching circuit coupled between the battery module and a discharge circuit, wherein when the battery module is in a normal operation, a discharge current from the battery module flows through the self-driven matching circuit to the discharge circuit, and when the battery module is in an over-discharging condition, the self-driven matching circuit is open circuit and no current flows through the self-driven matching circuit from the battery module.

14. The battery management system of claim 13, wherein the self-driven matching circuit comprises:

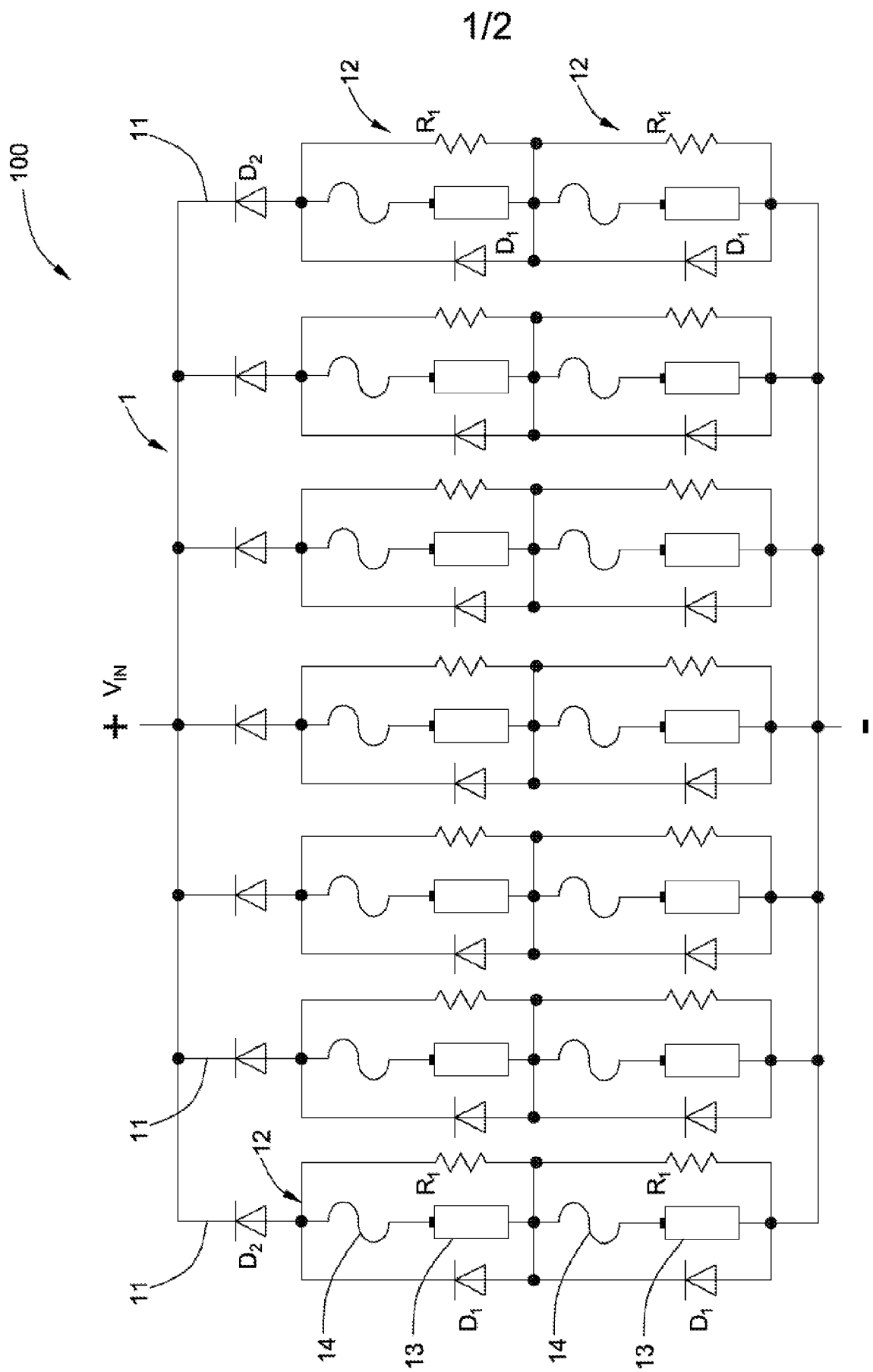
a second resistor and a third resistor which are connected in series between the positive output terminal and the negative output terminal;

a first transistor which is a NPN type transistor, wherein a gate electrode of the first transistor is connected with a connection point of the second resistor and the third resistor and a source electrode of the first transistor is connected to the negative output terminal;

a fourth resistor coupled between the positive output terminal and a drain electrode of the first transistor; and

a second transistor which is a PNP type transistor, wherein a gate electrode of the second transistor is connected with the drain electrode of the first transistor, a source electrode of the second transistor is connected with the positive output terminal and a drain electrode of the second transistor is connected to the discharge circuit.

15. The battery management system of claim 14, wherein the source electrode of the first transistor is grounded.



७६

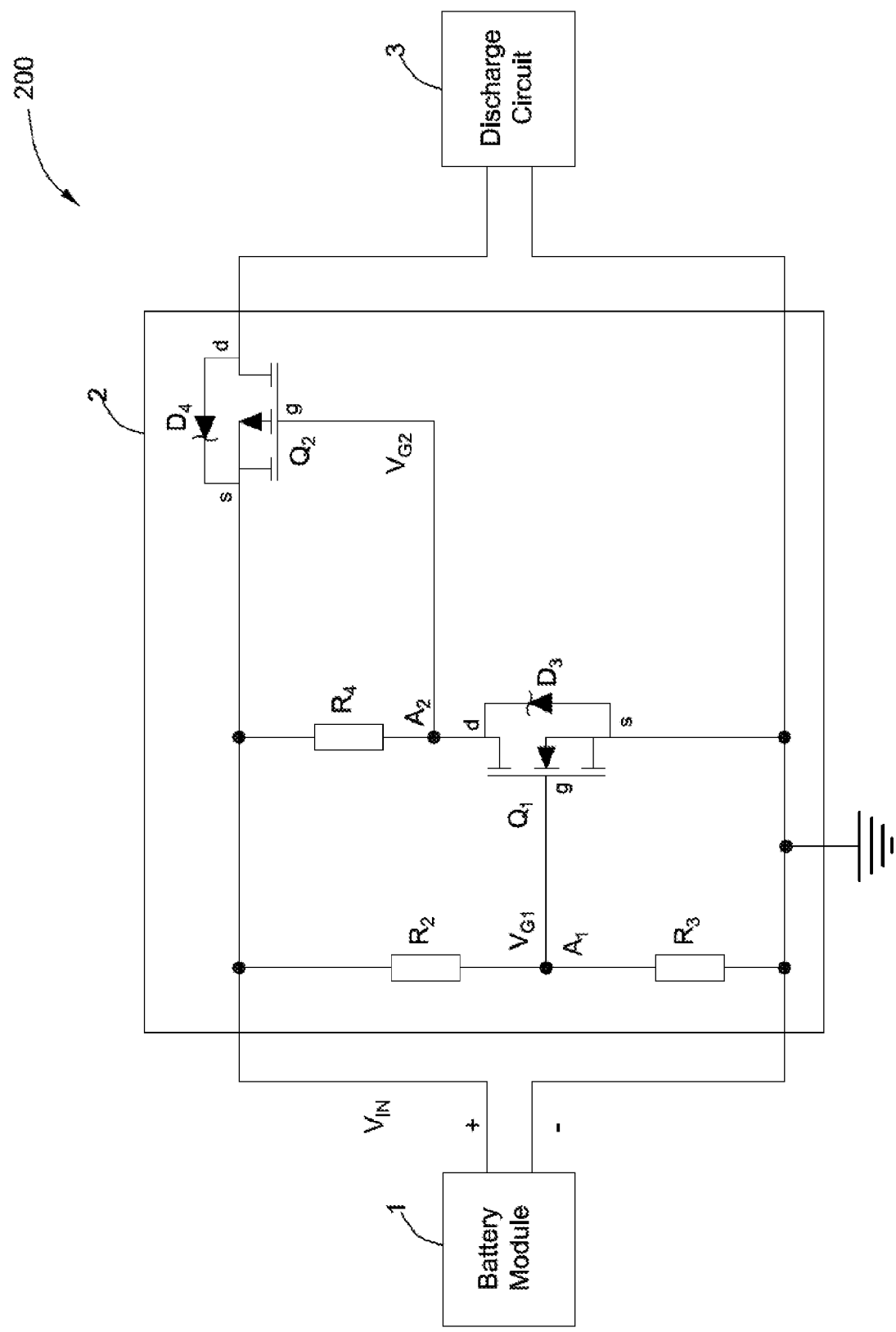


FIG. 2

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2018/032718**A. CLASSIFICATION OF SUBJECT MATTER****H02J 7/00(2006.01)i, H01M 10/42(2006.01)i**

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)

H02J 7/00; G05F 3/02; H02H 7/18; H01M 10/44; G01R 31/36; H01M 10/42

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

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

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

eKOMPASS(KIPO internal) & Keywords: battery, management, over-discharging, current limiting, bypass

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	WO 2012-023707 A2 (EUN-EY JUNG) 23 February 2012 See paragraphs 3, 30-31, 42, 48; claim 1; and figures 2, 6.	1-15
Y	CN 202696124 U (TIANJIN TECHNIX ELECTRONIC SCIENCE & TECHNOLOGY CO., LTD.) 23 January 2013 See paragraphs 15-16; and figure 1.	1-15
Y	CN 102684165 A (BYD CO., LTD.) 19 September 2012 See paragraphs 15, 26-27; claim 4; and figures 2-3.	5-7, 13-15
A	US 2013-0119967 A1 (RENESAS ELECTRONICS CORPORATION) 16 May 2013 See the entire document.	1-15
A	US 2003-0030413 A1 (MITSUO SAEKI et al.) 13 February 2003 See the entire document.	1-15



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

27 August 2018 (27.08.2018)

Date of mailing of the international search report

27 August 2018 (27.08.2018)

Name and mailing address of the ISA/KR

International Application Division

Korean Intellectual Property Office

189 Cheongsa-ro, Seo-gu, Daejeon, 35208, Republic of Korea

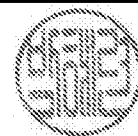


Facsimile No. +82-42-481-8578

Authorized officer

PARK, Hye Lyun

Telephone No. +82-42-481-3463



INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2018/032718

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2012-023707 A2	23/02/2012	KR 10-1249972 B1 WO 2012-023707 A3	03/04/2013 31/05/2012
CN 202696124 U	23/01/2013	None	
CN 102684165 A	19/09/2012	CN 102684165 B	22/07/2015
US 2013-0119967 A1	16/05/2013	CN 103116380 A CN 103116380 B EP 2595028 A2 EP 2595028 A3 JP 2013-105451 A JP 5839953 B2 US 2016-0282895 A1 US 2018-0113485 A1 US 9367077 B2 US 9891647 B2	22/05/2013 16/03/2016 22/05/2013 01/11/2017 30/05/2013 06/01/2016 29/09/2016 26/04/2018 14/06/2016 13/02/2018
US 2003-0030413 A1	13/02/2003	CN 101267126 A CN 101267126 B CN 1267927 A CN 1267927 B DE 10009618 A1 DE 10009618 B4 DE 10066259 B4 JP 2000-270485 A JP 3380766 B2 KR 10-0688135 B1 KR 10-2000-0076890 A TW 451508 B US 2002-0190694 A1 US 2006-0049804 A1 US 6492791 B1 US 6885168 B2 US 6989652 B2 US 7276881 B2	17/09/2008 02/05/2012 27/09/2000 28/11/2012 28/09/2000 17/01/2013 03/06/2015 29/09/2000 24/02/2003 08/03/2007 26/12/2000 21/08/2001 19/12/2002 09/03/2006 10/12/2002 26/04/2005 24/01/2006 02/10/2007