(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
6 June 2013 (06.06.2013)

WIPO | PCT

(10) International Publication Number
WO 2013/079982 Al

(51) International Patent Classification:
H01M 10/44 (2006.01) *H02J 7/00* (2006.01)

(21) International Application Number:
PCT/HR20 11/000044

(22) International Filing Date:
2 December 201 1 (02.12.201 1)

(25) Filing Language: Croatian

(26) Publication Language: English

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(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, QA, RO, RS, RU, RW, 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, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, 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, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

— *of inventorship (Rule 4.17(iv))*

[Continued on next page]

(54) **Title:** BATTERY MANAGEMENT SYSTEM FOR STARTER 12/24V BATTERY CELLS, PARTICULARLY CELLS FROM NEW GENERATION OF LITHIUM-IONIC OR LITHIUM-FERROUS-PHOSPHATE BATTERIES

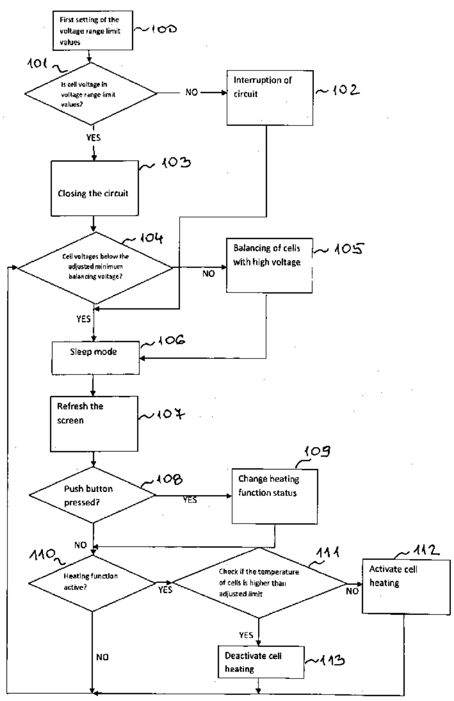


Fig. 1

(57) Abstract: The Invention concerns a management system and procedure for a starter battery pack containing more battery cells, mutually connected in series and parallel. The said system incorporates the unit (14) designed for voltage management and measurement of each individual battery cell (8) and for voltage balancing management, which unit (14) in real time generates the voltage signals of each of the battery cells (8) and detects at least one cell of more cells requiring balancing; and the unit (10) controlled by the unit (14). The unit (14) contains data on the predefined voltage range limit values (100), where the voltage range limit values (100) are defined by the lowest (10Γ) permissible voltage and the minimum balancing voltage (104), where the unit (14) in real time detects whether or not the generated voltage signals of each of the battery cells (8) lie within the voltage range limit values (100). The unit (14) is configured as follows: if the voltage of each individual cell cells (8) lies within the voltage range limit values (100), the unit (10) will close the circuit towards the consumer and/or the charger. Furthermore, if the voltage of at least one of more cells drops to the lowest value (10Γ) of the voltage range (100), or exceeds the maximum permissible voltage, the unit (10) will interrupt the circuit, and if the voltage of at least one or more cells (8) lies above the adjusted minimum balancing voltage (104), balancing will be activated in the way that the cells with voltage higher than the minimum balancing voltage (104) connect in parallel with the resistor on the unit (14), or outside of it, and thus get discharged to the minimum balancing voltage (104).

WO 2013/079982 A1

Published:

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

BATTERY MANAGEMENT SYSTEM FOR STARTER 12/24V BATTERY CELLS, PARTICULARY CELLS FROM NEW GENERATION OF LITHIUM-ION, LITHIUM-FERROUS-PHOSPHATE BATTERIES

Technical field

The subject of present Invention is the battery management system of the 12/24 V starter battery cells, especially those of the new generation of lithium-ion, lithium-iron-phosphate batteries. The system and procedure according to the present Invention maintain optimum conditions for the operation of the 12/24V starter battery pack.

Technical problem

Lead batteries used in automobiles weigh between 12 and 25 kg or more, depending on the model. By replacing lead batteries with a new generation of lithium batteries the weight would be greatly reduced and an improved product image obtained in terms of environmental protection.

Due to its large mass and toxic ingredients, the lead batteries are not considered a long-term solution for starting automobiles, trucks, other vehicles and products from similar areas of application. The subject of this Invention is the application of the new generation of 12/24 V batteries with systems which maintain optimum conditions for battery operation, featuring many advantages over the conventional lead battery, able to largely eliminate the shortcomings of the conventional battery in respect of bulky mass and toxic ingredients.

Lithium-iron-phosphate is a compound thinly applied to the anode and cathode layers of lithium-iron-phosphate battery cells. Such cells have proved to be the best choice for the new generation of 12V battery owing to a high degree of safety compared with other technologies (e.g., lithium-polymer or lithium-ion), long life (over 2000 charge/discharge cycles up to 80% capacity) and a relatively low price per unit of stored energy.

The value that customers care most when buying a conventional battery is the ampere-hour (Ah) value, but that figure has not much impact the battery's performance, because the stored energy itself is not crucial for a conventional car. To start the car you need 5-15 Wh energy. A 12V battery with declared capacity of 70 Ah would theoretically need to make about 200 of such starts without recharging. In practice this data is lower for lead batteries due to a major influence of the Peukert effect during high discharge currents with the conventional batteries. With the LiFeP04 (lithium-iron-phosphate) and other lithium technologies of battery cells the Peukert effect is negligible, so that a battery with the same nominal capacity has a higher usable capacity. Besides, a lithium battery will need a much lower capacity to reach discharge currents equal to a lead battery. For example, the LiFeP04 battery pack, where we use 12 cylindrical lOAh LiFeP04 cells (4 in series, 3 in parallel), has the stored energy of 30Ah and nominal voltage of 12.8V. It is possible to extend the battery to get a much high capacity, but there is no need for it because a 30Ah pack can provide enough power to ignite virtually any car without a major voltage drop. In a 4s3p (4 series, 3 parallel cells) configuration, if using the lOAh LiFeP04 cells we get a pack with 30Ah capacity and 12.8V nominal voltage. With such a configuration, 900 Amperes is available at room temperature, which is sufficient to start almost any car engine. Lead batteries must have more than 90 Ah capacity to achieve so high discharge currents.

The nominal voltage of a lithium-iron-phosphate cell is 3,2 V. When four such cells are connected in series, a nominal voltage of 12,8V is achieved, which corresponds to the nominal voltage of the conventional lead batteries. This method works in the short run without additional cell voltage regulation and balancing mechanisms. After a certain amount of time the cells start to differentiate in voltage, to the effect that some cells will have a higher voltage, whereas in others voltage will be falling. This may go on up to the point where a low voltage cell will drop below 1 V or where a high voltage cell will rise above 4V. In both cases the affected cell will fail and the whole battery pack will be rendered useless. One of the basic characteristics of lithium cells is that they are very voltage-stable, so that it is almost impossible to determine the battery charge status through voltage. It is only at the very end of charging that the cells start surging and with every additional Watt hour (Wh)/Ampere hour (Ah) that difference is increasing. When the battery is nearly discharged, voltage starts falling rapidly. Under no circumstances may the cells go completely empty, otherwise they would remain permanently damaged. To avoid such a failure of battery cells, voltage in them is monitored and, if required, regulated, i.e., the voltage of all cells is balanced at a reference value.

The technical problem being solved with the present Invention is to protect individual cells and thereby the whole battery pack from failure in the following way: in case of voltage drop or rise in at least one cell beyond the preset voltage range, the battery pack is either shut off by a switch or the circuit opened towards a consumer/charger respectively.

Prior art

Based on previous practice, it is known that the battery packs for motor vehicles contain a lot of series-connected battery cells which together provide voltage potential for the electric drive of motor vehicles. The document US 2011/0181248 (Porsche Aktiengesellshaft DE) discloses a lithium-based battery management apparatus which keeps the voltage of series-connected battery cells at approximately the same level. According to the said document, voltage balancing takes place in a way that the determined voltages of all cells are compared and if the voltage of at least one cell is greater than a first limit value, and, furthermore, if the cell voltage of at least one battery cell differs from the cell voltage of ever}' other battery cell by more than a defined second limit value, the battery management apparatus uses the lowest cell voltage of the battery cells as the reference voltage, and it discharges all other battery cells with a higher cell voltage in order to balance the voltage between the battery cells at the reference voltage.

Unlike the invention revealed in the document US 2011/0181248, voltage balancing according to the subject Invention is more efficient because it spends less energy, i.e., voltage is not balanced at the reference voltage, which is the lowest voltage of at least one battery cell. Another difference concerns a system that keeps the cells from pre-discharging and hence from failure of the battery pack. Likewise, the system according to the subject Invention keeps the battery pack from pre-charging by opening the circuit towards the consumer/charger.

Furthermore, Porsche is the only car manufacturer to launch the 12V Li-ion starter battery and offer its own Li-ion battery as a very easy alternative to the conventional lead battery, with a note that it operates only above zero (0 G). This battery now serves as racing equipment, for roadtrack races, anyway not for everyday use. With the Li-ion battery the manufacturer also supplies the conventional lead battery for everyday use.

The to-date e 12V Li-Ion starter batteries do not provide cell protection if the battery is completely discharged, for example, if the car lights are left burning all night, in which case the battery is irreversibly damaged and must be replaced.

Disclosure of the Invention

The Battery Management System (BMS) of the new generation of the lithium-Ion, lithium-iron-phosphate batteries measures the voltage of each cell individually and its basic function is the balancing and protection of battery cells from failure caused by voltage drop. Balancing is necessary because the cells themselves vary as a result of production tolerances, so over time they tend to show increasing differences in voltage.

Brief description of drawings

The Invention will be described below in detail with reference to the following drawings:

Fig. 1 - BMS software - operating diagram,

Fig. 2 - appearance of a completed battery pack with a casing,

Fig. 3 - battery pack - cross-section showing the main components inside the casing,

Fig. 4 - view of the battery pack cover and the parts arranged on the upper side,

Fig. 5 - front view of the battery pack,

Fig. 6 - front view with a transparent casing to show the components inside,

Fig. 7 - 3D-view of the main components of the battery pack without the casing,

Fig. 8 - side view of the battery pack with a transparent casing,

Fig. 9 - battery pack cross-section with all the components inside,

Fig. 10 - characteristic of lithium-iron-phosphate batteries (ratio between voltage and charge status),

Fig. 11 - screen, and

Fig. 12 - example of a battery pack with flat cells

One of the basic characteristics of lithium cells is that they have high voltage stability, as shown in the graph of **Fig. 10,** so that it is virtually impossible to determine the cell charge status through voltage. It is only at the very end of charging that the voltage **41** of the cells starts rising rapidly, see the respective part of the curve **38,** and with every additional Watt hour (Wh)/Ampere hour (Ah) **42** of energy that difference is increasing. As the alternator is continuously charging the battery in driving and keeps it at high voltage **38,** it is extremely important that the battery management system (BMS) ensures quality regulation of cell voltage. Voltage regulation takes place via resistors being activated for an individual cell if it oversteps a certain preset limit. 3, 65 V has proved to be an ideal voltage for removing excess power in an overcharged cell, since the car alternator usually keeps voltage at around 14,4 V, which yields a voltage of 3.6 V per cell. Resistors are very weak in power and are rarely activated in practice if in the installation of a battery pack the cells are selected with the same initial charge status (for example: all cells 50% full) and are subjected to good quality control in the factory (very close internal resistance). In a relatively high voltage increase there is not much energy around, so with very little spent energy through the resistors the cell voltage will drop to the level of other cells, if voltage has risen for a short duration, so that the balancing function does not essentially impair the efficiency of the whole system.

When the battery is at the end of its charge status, i.e., nearly empty, voltage 41 starts falling rapidly, as indicated by 40 in Fig. 10. Under no circumstances may the cells go completely empty, otherwise they would be rendered permanently damaged.

By monitoring voltage over time, the system detects when the cells are about to get discharged. The BMS tolerates a voltage drop for a shorter period of time, because it is a normal occurrence while massive currents are drawn at start. However, if low voltage on one or more cells lasts longer than 5 seconds, the BMS preventively interrupts the circuit. If voltage is restored to normal level, the circuit is re-closed. Therefore, if the BMS separates the battery cells from the circuit of the consumer/motorcar, the circuit will be re-closed if the charger or another source of energy is connected to the terminals, i.e., once the voltage of all cells is returned within the given levels.

If the ignition process is much prolonged due to a defect in the automobile, with a result that the BMS has mistakenly interrupted the circuit (the battery was not empty), the voltage of the cells will rise as soon as the load has ceased and the circuit will be re-closed immediately.

Once voltage starts dropping without a load, the battery pack will have been almost completely empty and thus would not have enough power for car ignition. If a battery discharge has occurred because, for example, the car lights have been left burning all night, the remaining power would very soon dissipate, so the cell protection system would have no influence on product functionality, but would serve instead solely to save the battery cells from failure.

For circuit opening/closing it is possible to use a relay, MOSFETs, transistors or the like, depending on application and amperage.

Figures 2 through 9 show the battery pack elements. The casing (1) and the cover (2) contain all the essential components of a battery pack. Visible on the outside are the casing handles (6), the terminals (3, 4), the terminal threads (5, 13, 17, 18, 20, 21), the push-button (34) and the screen (12).

The casing shown in Figures 2, 4 and 5 corresponds in height and width to standard casings for lead batteries, which allows a broad application of the battery pack without a need for any car modifications. The terminals (3, 4) can be connected from either side of the battery pack to required places, so that the battery could be used in automobiles with differently positioned battery clamps.

The butt (7) at the bottom of the casing serves to receive the battery pack in the car to hold faster in place.

Within the casing (1) are the battery cells (8). Depending on the cell type, capacity and area of application, there can be more or less of the cells. The more cells are series-connected, the higher voltage is obtained, the more of them are parallel-connected, the higher capacity is obtained. Figures 3, 6, 7, 8 and 9 show an example where the cylindrical cells in a configuration 4 series-, 3 parallel-connected are used. Physically they are held in place by the holders (35) inside the casing, the metal plates (22, 19, 31, 33), which also serve for electrical connection, and extra holders. When four battery cells (8) of this type are series-connected, the voltage obtained is similar to that of the conventional 12V lead batteries. For a 24V battery (e.g., in a truck), it would be necessary to series-connect eight instead of four cells (8). In that case, the BMS with 8 instead of 4 channels is monitoring cell voltages. The shown examples use metal plates (9) for mutual connection in series or parallel. Fig. 12 shows an example with flat cells (47) inside the casing (46). For the flat cells different terminal connection methods are used.

The number of cells in parallel can be added as needed - if more current is required more cells will beaded in parallel connection. In terms of monitoring and management, more cells in parallel are treated as one separate cell.

The battery cells (8) are mutually connected in parallel by metal plates (22, 19, 31, 33) and screws (32) or in series or parallel by other means. For example, the metal plate (22) connects simultaneously three positive terminals (30) and three negative terminals (23) and thus at once connects cells in both series and parallel. The metal plates in the shown examples have relief holes (23, 24, 25). Through the metal plates (16, 19, 22) current flows from the battery cells (8) to the consumers, and vice versa in case of charging. To each of the cells (8) a positive (29) and a negative (23) terminal are connected leading to the BMS. In that way the BMS monitors the voltage of each cell.

The graph in Fig. 10 shows the voltage characteristic of the cells which are suitable for this application - the lithium-iron-phosphate (LiFeP04) cells. The main characteristic of such a cell is that voltage is stable for a very long time, as shown by the curve (39), regardless of the charge status. It is hence impossible alone on the basis of voltage measurement to tell how full the battery is; 3.2V may mean that the cell is 80% full, but also just 20%. It is only when the cell is nearly empty that voltage starts to drop (40). When voltage starts to drop, it is not necessary to take much power from the cell to discharge it completely. Already below 2.5 V the critical area takes over that can permanently damage the cell. When the cell reaches 0 V, it is irreversibly damaged and must be replaced. For a case like this the battery pack has a built-in unit (10) which prevents the cell from discharging to the point of no return. The unit (10) may be a relay, a MOSFET, transistor, an IGBT-module or the like.

Present Invention concerns a management system for a starter battery pack containing more battery cells (8) of the new generation of lithium-ion; lithium-iron-phosphate batteries, mutually connected in series and parallel, with the series-connected cells being treated as one separate cell, where the said system contains a unit (14) designed for voltage management and measurement of each individual battery cell (8) and for management of voltage balancing operations. The unit (14) generates in real time voltage signals of each of the battery cells (8) and detects cells that need balancing; and the unit (10) controlled by the unit (14). The unit (14) contains data on the predefined maximum permissible voltage (104') of the cells (8), the voltage range limit values (100) of the cells (8), where the voltage range limit values (100) are defined by the lowest (101') voltage and minimum balancing voltage (104), where the unit (14) detects in real time if the generated voltage signals of each of the battery cells (8) are within the voltage range limit values (100). The unit (14) is configured as follows:

(i) if the voltage of each individual cell (8) lies within the voltage range limit values (100), the unit (10) will close the circuit;

(ii) if the voltage of at least one of more cells drops to the lowest level (101') of the voltage range (100), the unit (10) will interrupt the circuit; and

(iii) if the voltage of at least one or more battery cells (8) lies above the adjusted minimum balancing voltage (104), balancing will be activated in the way that the cells with voltage higher than the minimum balancing voltage (104) will connect in parallel with the resistor on the unit (14), or outside of it, and thus become discharged to the minimum balancing voltage (104).

The system provides that the control unit (14), for a predefined time interval in which the voltage of at least one of more cells drops to the lowest level (101') of the voltage range (100) or below, does not interrupt the circuit through the unit (10). Furthermore, the system provides that the control unit (14) interrupts the circuit through the unit (10) for a predefined time interval in which the voltage of at least one of more cells rises above the maximum permissible level (104').

The example shows the relay unit (10) which is fixed by the holder (11) to the box (2). The relay (10) is connected by a terminal (27) to the metal plate which in turn is connected to the cells and by another terminal (26) to one of the battery pack terminals (16, 4). Therefore, complete current from the cells must pass through it. Its purpose is to interrupt the circuit if one or more battery cells drop to the critical level of 2V, or to another preset voltage limit voltage that depends on the chemical composition of the used cells.

The unit (10) is controlled by the unit (14) that monitors the voltage of each individual cell. The BMS program involves predefined voltage range limit values (100), where the voltage range limit values (100) are defined by the lowest (101) voltage and the minimum balancing voltage (104), temperature, etc. At any moment it is monitored if voltage is within the given range (100) - for example, not below 2.0V and not above 3.8V. If the values are outside the given values, in step (102) the relay shuts down and thereby interrupts the connection of the battery pack to the rest of the circuit of a consumer, an automobile for example. As it is possible that during major discharge currents the battery voltage drops below 2V for a short while, although the battery is not emptied, it is desirable that for a predefined time interval the BMS logic permits a voltage drop below the predefined lowest voltage level (101) - for example, three seconds, so as to prevent the deactivation of the unit (10) during automobile ignition.

If voltage is within the given values, the unit (10) closes the circuit and switches on the relay, respectively. In normal use the circuit should be permanently closed. Using a relay that independently keeps the status saves energy.

A special function of the BMS is balancing (114). If the voltages of all cells lie below the minimum balancing voltage (104), the balancing of cells with high voltage (105) is not active. If the voltage of one or more cells lies above the adjusted minimum balancing voltage (104), balancing (105) will be activated. Balancing is performed in a way that a cell with excessive voltage is connected in parallel with the resistor on the plate of the unit (14), or outside of it, and is thus getting discharged. With the discharging of that cell, voltage is falling and approximates that of the rest. Since the balancing process requires energy, it is desirable that it is switched on as rarely as possible, which can be achieved by good initial balancing of the cells while assembling the battery pack.

Once all voltage values lie within the given ones, the BMS can go to sleep mode (106) for a while to save energy. The screen (12) is also periodically refreshed (107). The LCD screen (12) spends very little electricity and thus does not generate a significant cost that can shorten the battery's life. It displays data such as cell temperature (43), total voltage or the voltage of individual cells (44), heating status (45) (ON/OFF), etc

The procedure shown in Fig. 1, management of the starter battery pack with more battery cells (8) of the new generation of lithium-ion-phosphate batteries, mutually connected in series and parallel, where the series-connected cells are treated as one separate cell, involves the following steps:

- input of predefined voltage range limit values (100), where data on the voltage range limit values (100) are defined by the lowest (101') voltage and the minimum balancing voltage (104);
- measuring the voltage of each individual battery cell (8), generating the voltage signals of each individual battery cell (8) and transmitting the signals to the unit (14);
- checking (101) if the voltage of each of the battery cells(8) lies within the given voltage range (100); and
- detecting at least one of more cells (8), in real time, above the minimum balancing voltage (104) or with the voltage of the lowest value (10Γ) of the voltage range (100).

If the voltage of each of more battery cells (8) is within the voltage range (100), in step (103) the unit (10) is switched on to close the circuit. If the voltages of all battery cells (8) lie below the minimum balancing voltage (104), balancing (105) of the cells (8) will be inactive. If the voltage of one or more battery cells battery cells (8) lies above the adjusted minimum balancing voltage (104), balancing (105) becomes activated in a way that the detected battery cells (8) with excessive voltage connect in parallel with the resistor on the unit (14), or outside of it, and thus get discharged. Furthermore, if the voltage of one of more battery cells (8) is not within the given voltage range (100), where the measured voltage of one of more battery cells (8) equals the lowest value (101') of the voltage range (100), in step (102) by means of the unit (10) the circuit will be interrupted, and that will interrupt the connection of the battery pack cells (8) to the rest of the consumer's circuit. The said procedure tolerates a brief voltage drop to or below the lowest value (101') of the voltage range (100), meaning that for a predefined time interval the unit (14) will not interrupt the connection of the battery pack cells (8) to the rest of the consumer's circuit.

CLAIMS

1. The starter battery pack management system containing more battery cells (8), mutually connected in series and parallel, where the series-connected cells are treated as one separate cell, where the said system incorporates the unit (14) designed for voltage management and measurement of each individual battery cell (8) and for voltage balancing management, which unit (14) generates in real time the voltage signals of each of the battery cells (8) and detects the cells that require balancing; and the unit (10) controlled by the unit (14), **characterized in that** the unit (14) contains data on the predefined maximum permissible voltage (104') of the cells (8), the limit values (100) of the voltage range of the cells (8), where the voltage range limit values (100) are defined by the lowest permissible voltage value (101') and the minimum balancing voltage (104), where the unit (14) detects in real time if the generated voltage signals of each of the battery cells (8) lie within the voltage range limit values (100), where the unit (14) is configured as follows:

   (i) if the voltage of each individual cell (8) lies within the voltage range limit values (100), the unit (10) will close the circuit;

   (ii) if the voltage of at least one of more cells drops to the lowest value (10Γ) of the voltage range (100), the unit (10) will interrupt the circuit; and

   (iii) if the voltage of at least one or more battery cells (8) lies above the adjusted minimum balancing voltage (104), balancing will be activated in a way that the cells with voltage higher than the minimum balancing voltage (104) will connect in parallel with the resistor on the unit (14), or outside of it, and thus become discharged to the minimum balancing voltage (104).

2. The system according to claim 1, **characterized in that** the control unit (14) does not interrupt the circuit through the unit (10) for a predefined time interval in which the voltage of at least one cell drops to the lowest level (101') of the voltage range (100) or below.

3. The system according to claim 1, **characterized in that** the control unit (14) interrupts the circuit through the unit (10) for a predefined time interval in which the voltage of at least one cell rise above the maximum permissible level (104').

4. The system according to the previous claims, **characterized in that** unit (10) can be a relay, a MOSFET, a transistor, or an IGBT-module.

5. Balancing of the starter battery pack for the system as defined in the claims 1 - 4, **characterized in that** it involves the following steps:

    - input of predefined voltage range limit values (100), where the data on the voltage range limit values (100) are defined by the lowest (10Γ) voltage and the minimum balancing voltage (104);

    - measuring the voltage of each individual battery cell (8), generating the voltage signals of each individual battery cell (8) and transmitting the signals to the unit (14);

    - checking (101) if the voltage of each of the battery cells (8) lies within the given voltage range (100); and

    - detecting one or more cells (8), in real time, with voltage lying above the minimum balancing voltage (104) or with the voltage equal to or lower than the value (101') of the voltage range (100).

6. Procedure according to claim 5, **characterized in that** if the voltage of each of more battery cells (8) lies within the voltage range (100), in step (103) the unit (10) will be switched on closing the circuit.

7. Procedure according to claim 5, **characterized in that** if the voltages of all battery cells (8) lie below the minimum balancing voltage (104), the balancing (105) of the cells (8) is inactive.

8. Procedure according to claim 5, **characterized in that** if the voltage of one or more battery cells (8) exceeds the adjusted minimum balancing voltage (104), balancing (105) will be activated in the way that the detected battery cells (8) connect in parallel with the resistor on the unit (14), or outside of it, and thus get discharged.

9. Procedure according to claim 5, **characterized in that** if the measured voltage of at least one battery cell (8) is equal to or lower than the lowest permissible value (101') of the voltage range (100), in step (102) the circuit will be interrupted by the unit (10), whereby the connection of the battery pack cells (8) to the consumer will be interrupted.

10. Procedure according to claim 9, characterized in that for a predefined time interval in which the voltage of one of more battery cells (8) is equal to or lower than the lowest permissible voltage value (101') or below, the unit (14) does not interrupt the connection of the battery pack cells (8) to the rest of the consumer's circuit.

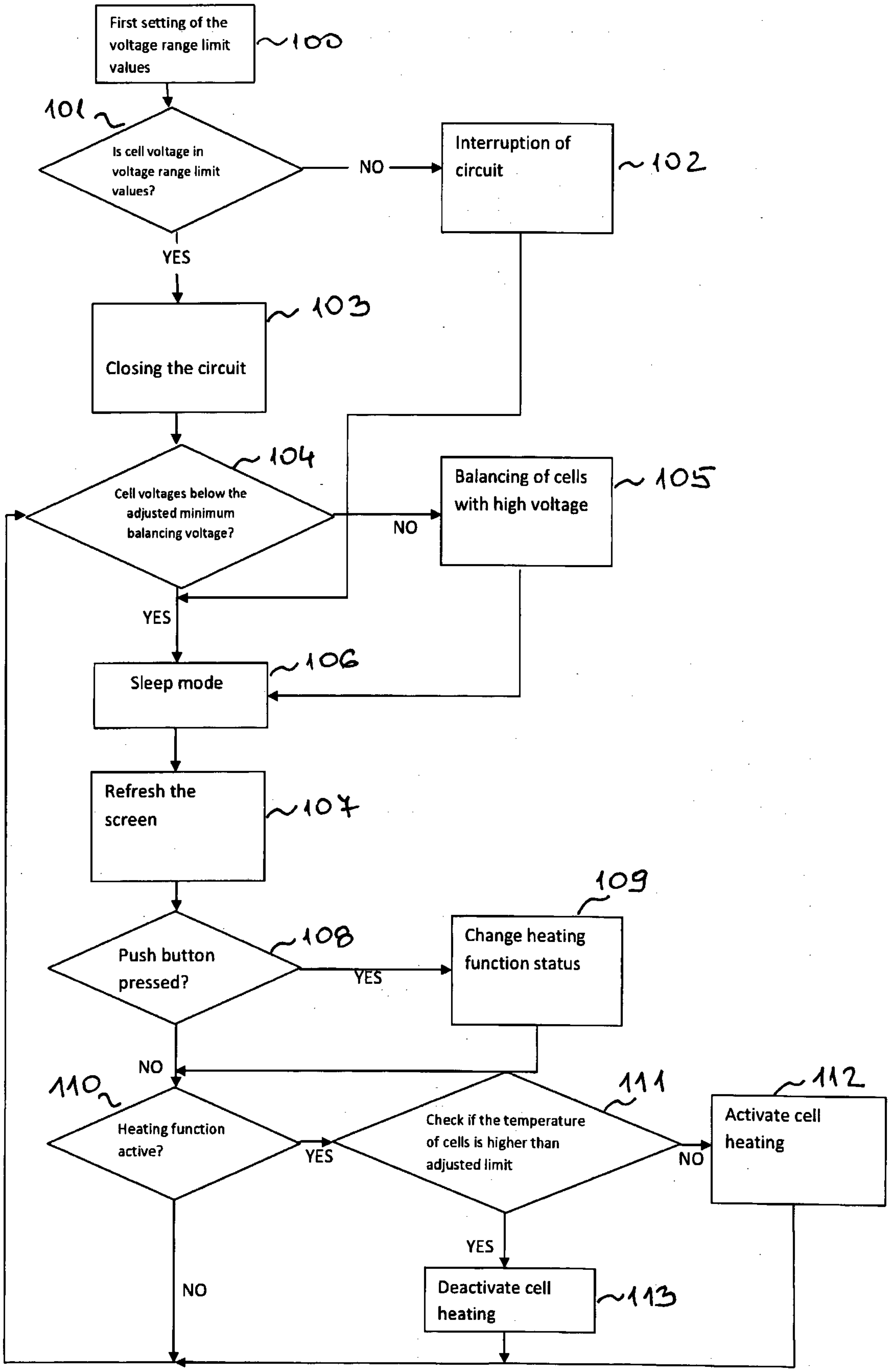

First setting of the voltage range limit values
100
101
Is cell voltage in voltage range limit values?
NO
Interruption of circuit
102
YES
Closing the circuit
103
104
Cell voltages below the adjusted minimum balancing voltage?
NO
Balancing of cells with high voltage
105
YES
Sleep mode
106
Refresh the screen
107
109
Push button pressed?
108
YES
Change heating function status
NO
110
Heating function active?
YES
111
Check if the temperature of cells is higher than adjusted limit
NO
Activate cell heating
112
YES
NO
Deactivate cell heating
113

Fig. 1

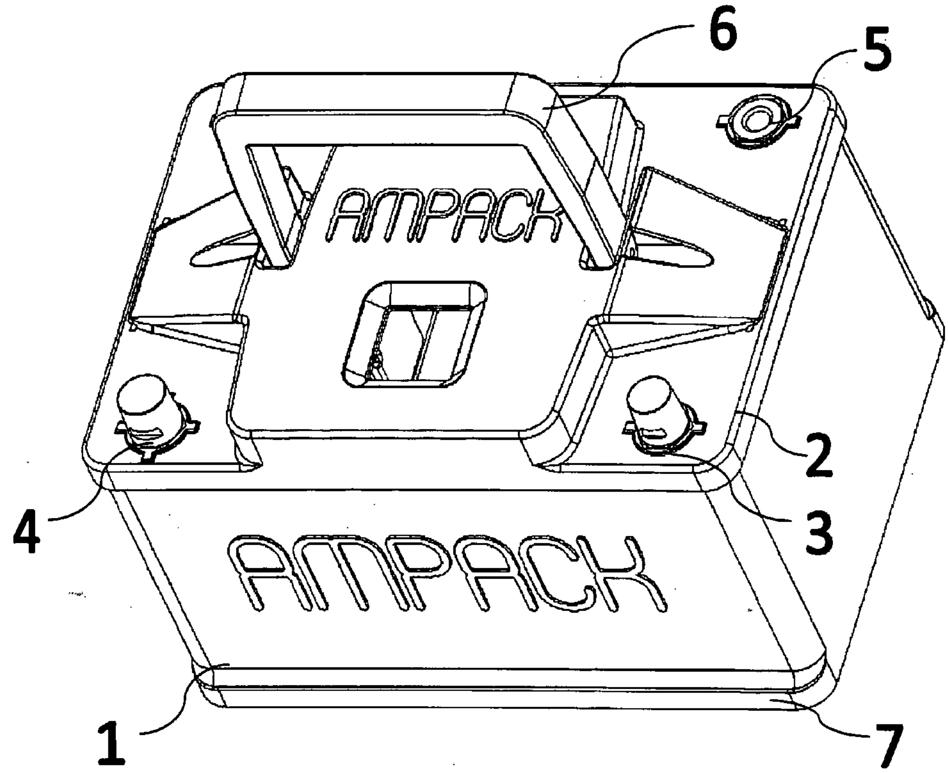


Fig. 2

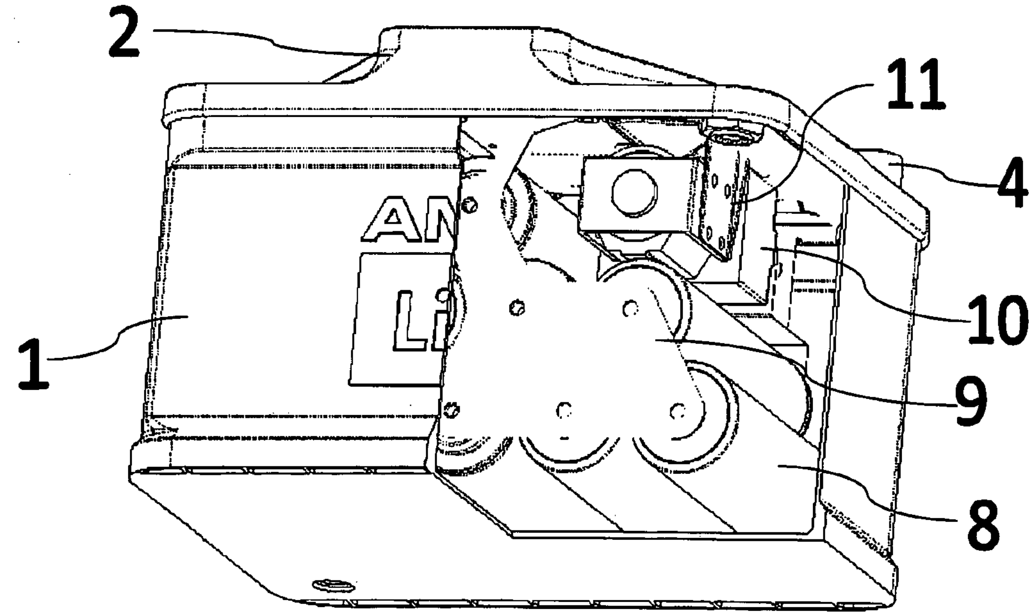


Fig. 3

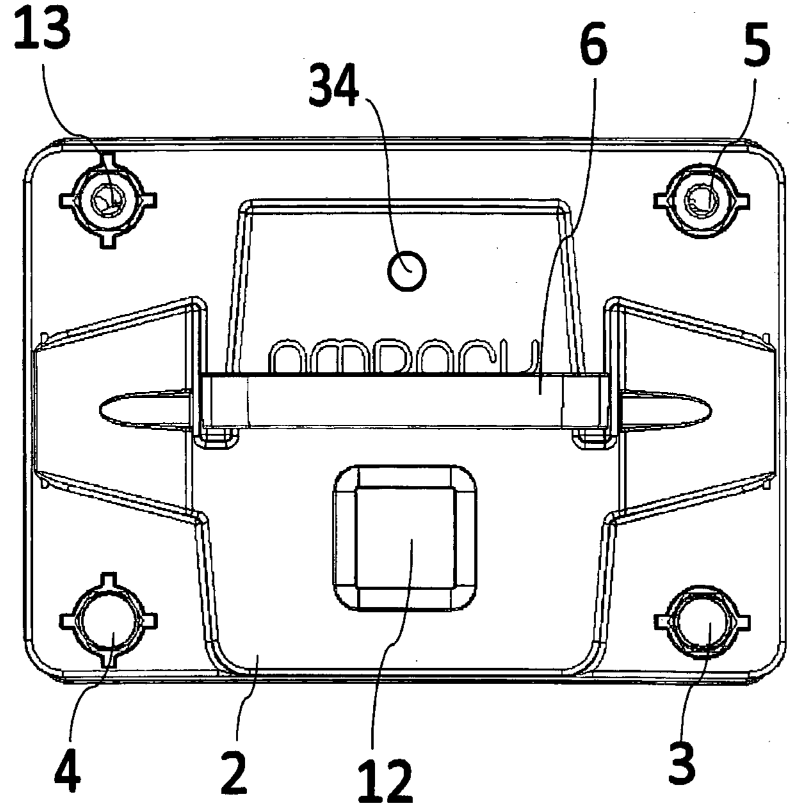
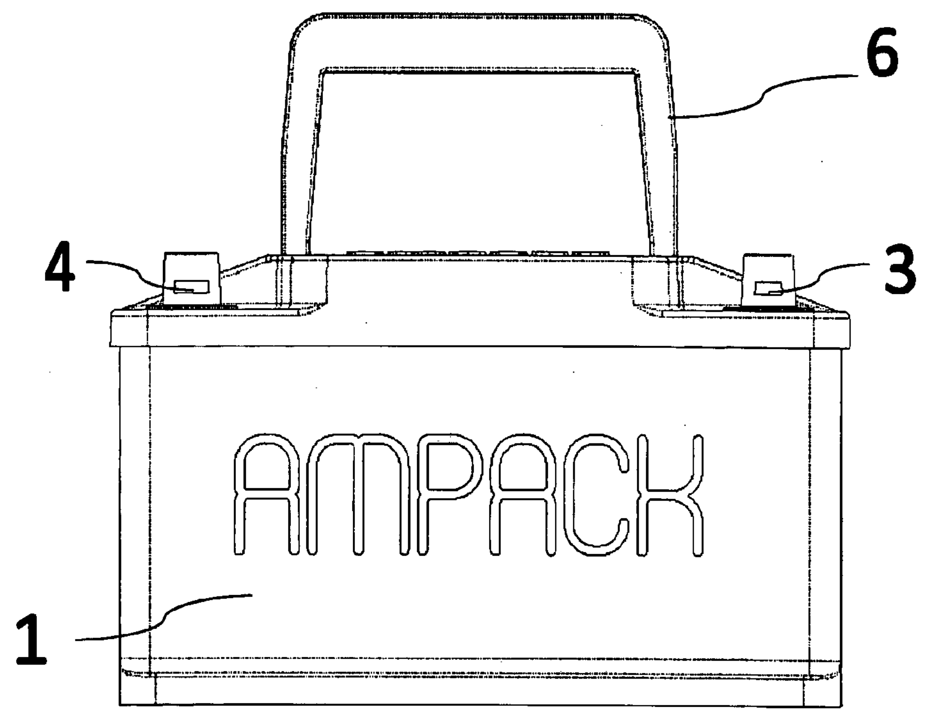


Fig. 4



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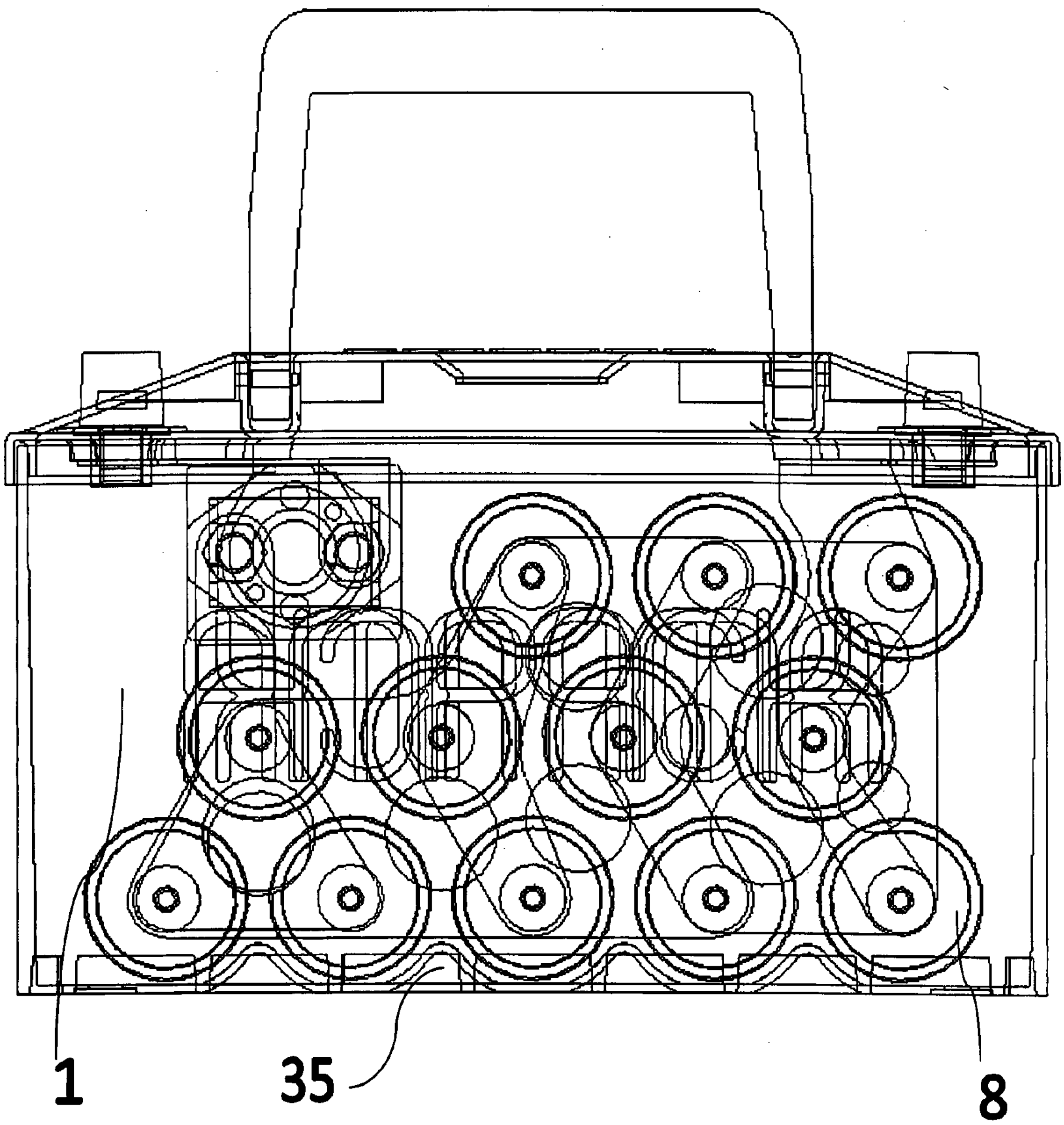


Fig. 6

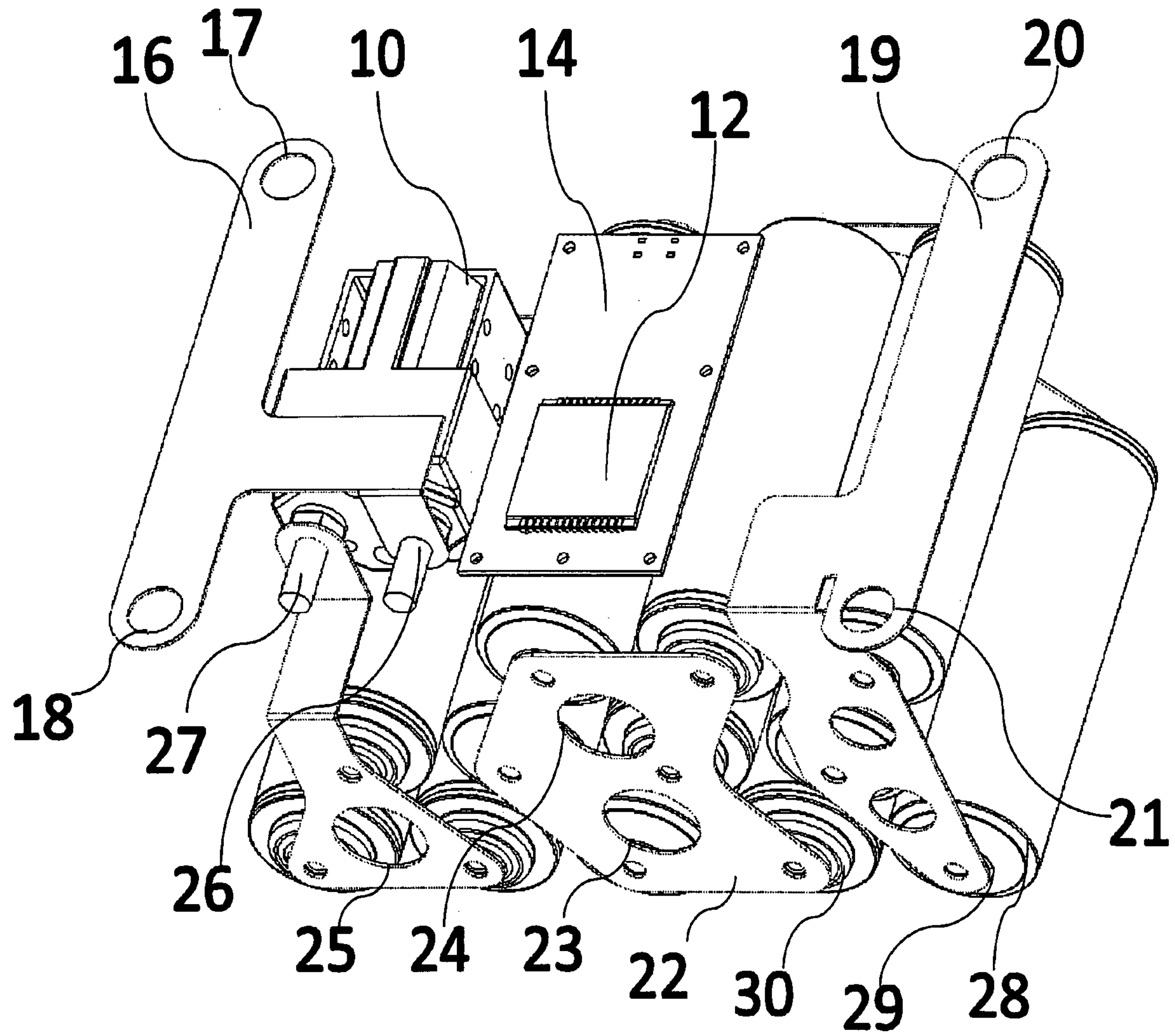


Fig. 7

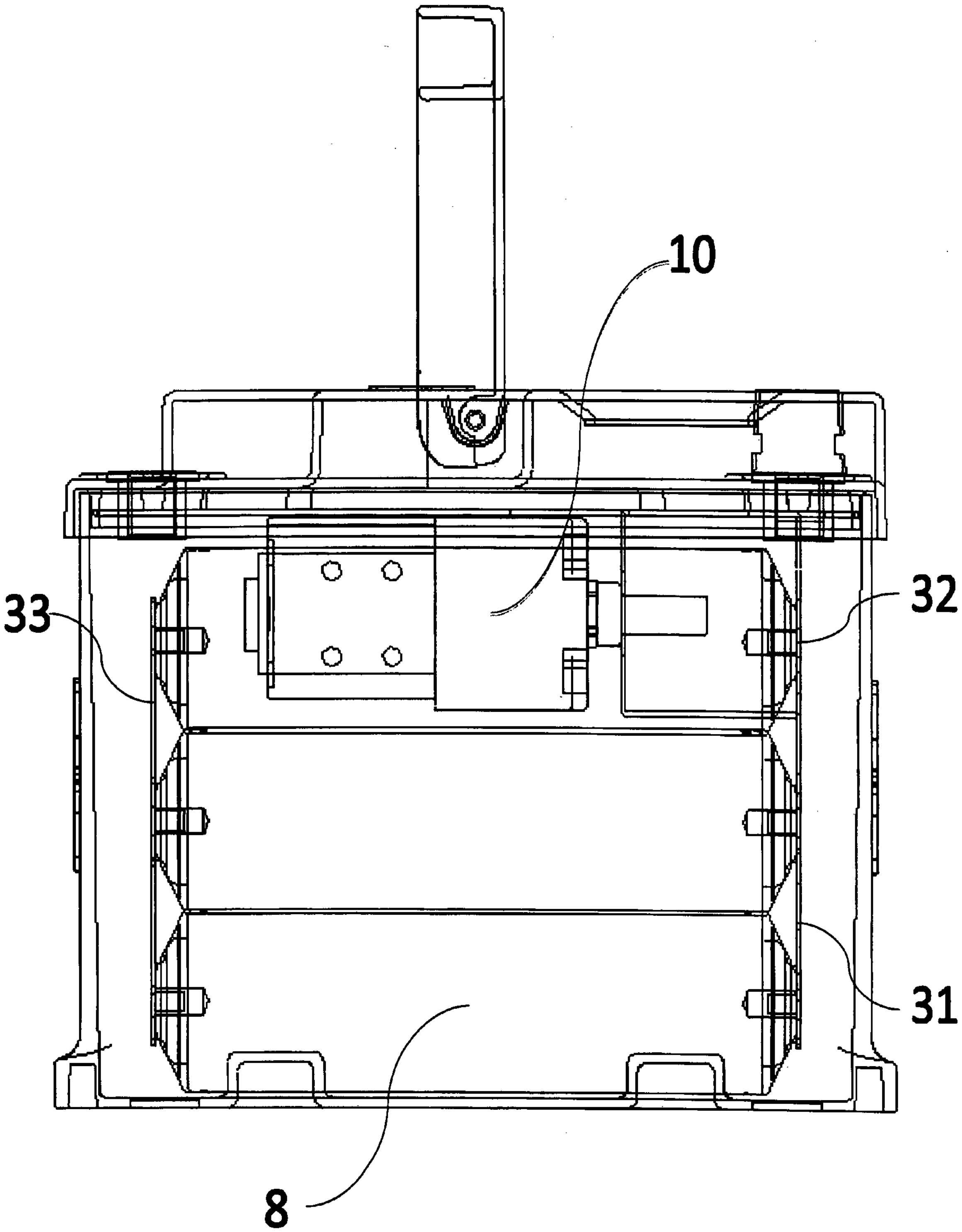


Fig. 8

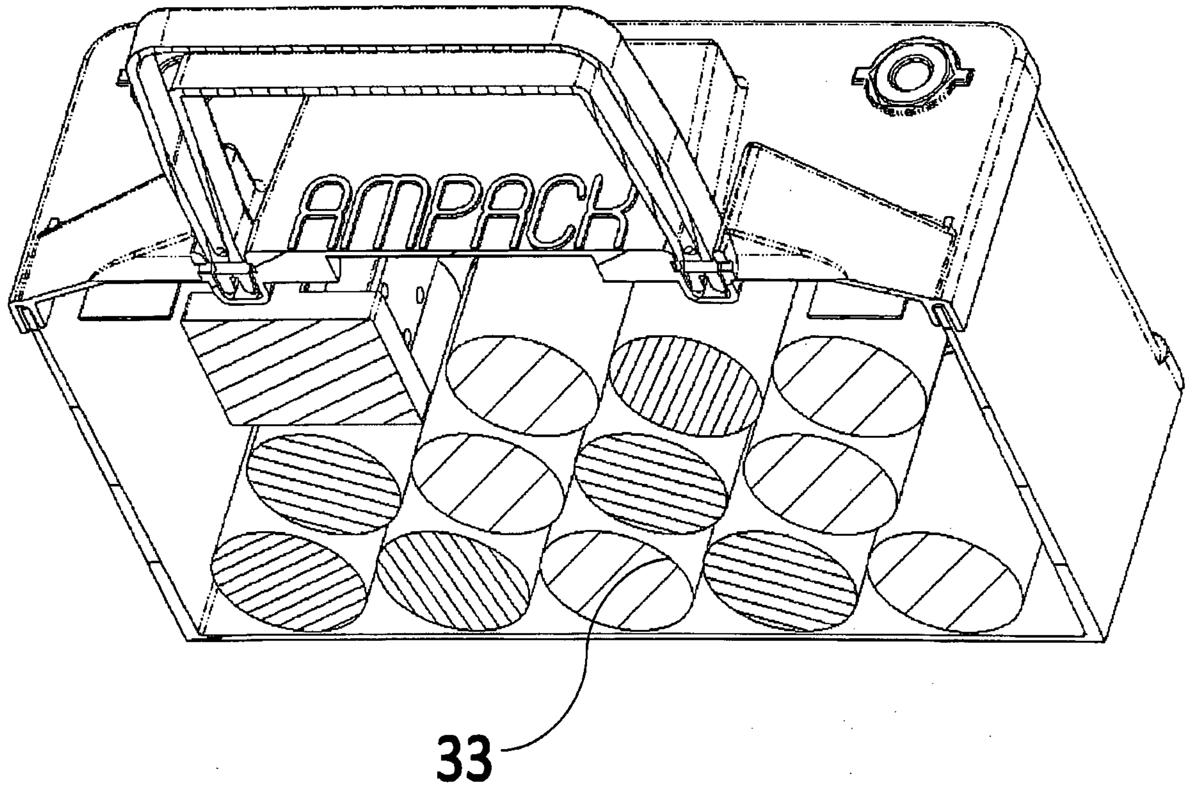
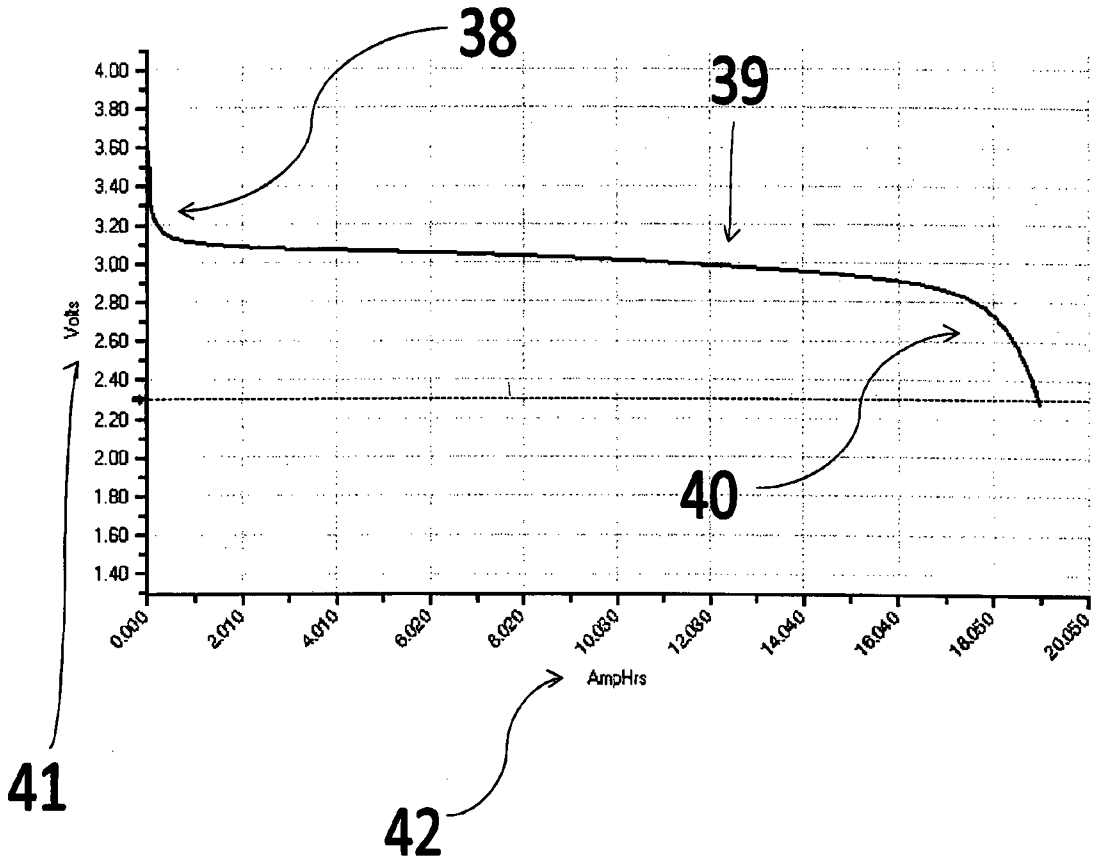


Fig. 9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1.60
1.40
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Fig. 10

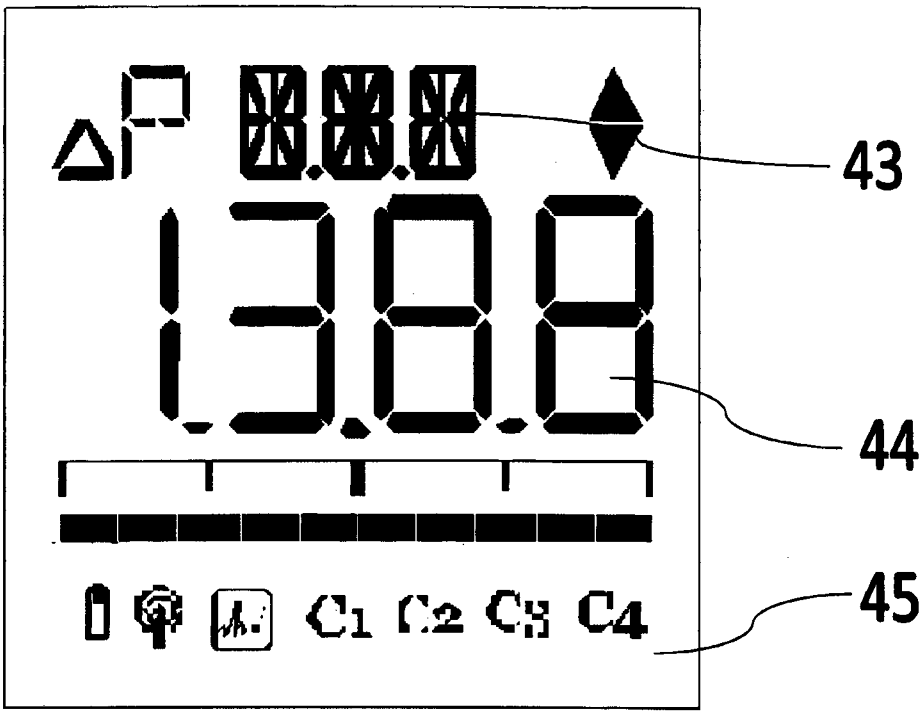

Fig. 11

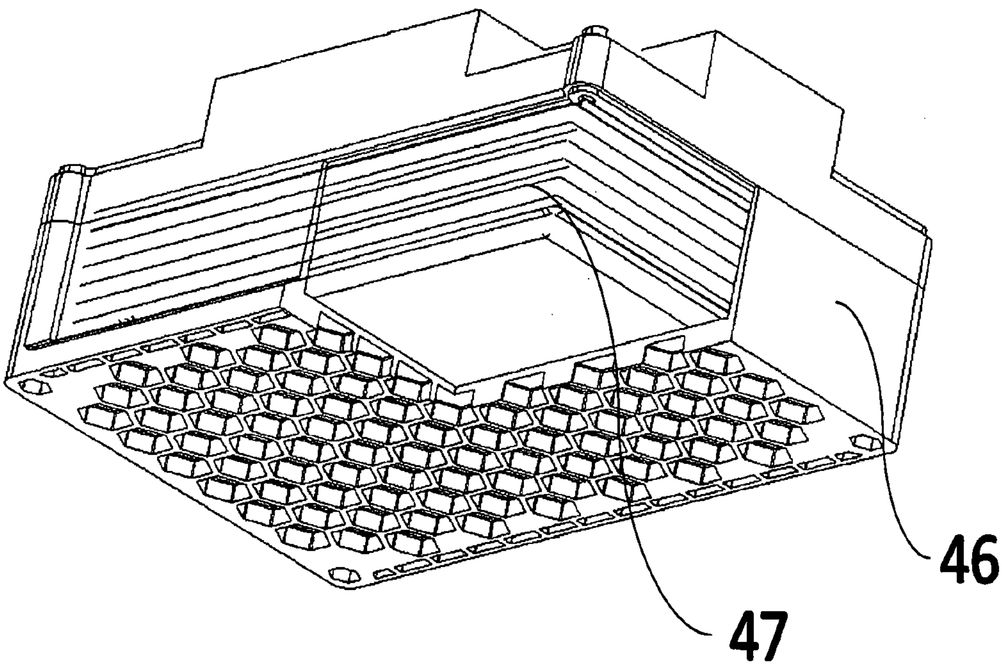

Fig. 12

INTERNATIONAL SEARCH REPORT

International application No
PCT/HR2011/000044

A. CLASSIFICATION OF SUBJECT MATTER
INV. H01M10/44 H02J7/00
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)
H01M H02J

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 practical, search terms used)

EPO-Internal , WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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Y	paragraphs [0033] - [0038], [0100] - [0116], [0132] - [0137], [0156]	2,10
X	US 2010/217552 A1 (HSU HUNG-AN [TW] ET AL) 26 August 2010 (2010-08-26)	1,3-9
Y	paragraphs [0027] - [0031]	2,3,10
X	US 6 114 835 A (PRICE BURT L [US]) 5 September 2000 (2000-09-05) column 1, lines 32-58	1,5
X	US 2011/133690 A1 (CRANE J0LY0N M [GB]) 9 June 2011 (2011-06-09) paragraphs [0066] - [0095]	1,5

-/--

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

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"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
18 April 2012	27/04/2012

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	Baur, Christoph

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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Y	US 2009/167249 A1 (WANG LIGONG [US] ET AL) 2 July 2009 (2009-07-02) paragraph [0005]	3
A	US 2002/195994 A1 (CIT ALCATEL [FR] SAFT FINANCE S A R L [LU]) 26 December 2002 (2002-12-26) paragraph [0007]	1-10

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Information on patent family members

International application No
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