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[Continued on next page]

(54) **Title**: BATTERY MODULE AND CONTROL CIRCUIT THEREFOR

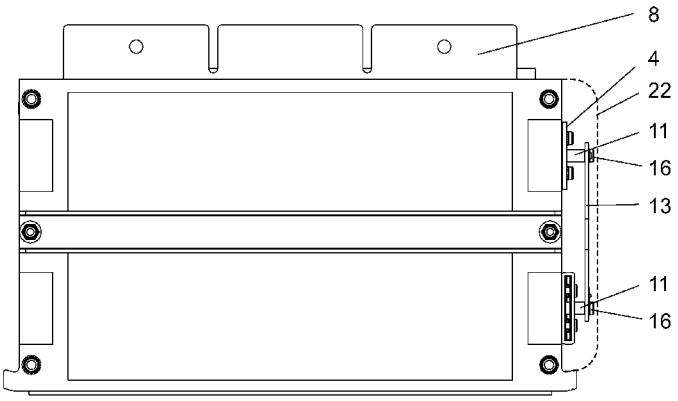


Figure 6

(57) **Abstract**: A battery module is provided comprising a plurality of cell stacks each composed of multiple cells with the cells interconnected in a predetermined arrangement by means of bus bars secured to terminals of the individual cells on one side of the battery module. A control circuit board is attached to each of the bus bars by way of a thermally conductive support element selected to substantially adopt the temperature of its associated bus bar. A temperature sensor is included on the control circuit board in the vicinity of each thermally conductive support element to sense the temperature of the support element with the temperature sensors being included in electronic circuitry on the control circuit board. The support elements may be thermally conductive cylindrical elements press-fitted or otherwise secured in thermal contact with the associated bus bar to extend at right angles thereto. Communications contacts may be provided for communicating with a battery management system that controls a plurality of battery modules of a particular battery assembly or pack. A control circuit board is also provided.

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— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))*

BATTERY MODULE AND CONTROL CIRCUIT THEREFOR

FIELD OF THE INVENTION

This invention relates to a battery module having a control circuit whereby the temperature of bus bars that interconnect multiple cells of a battery module can be monitored with a view to appropriate action being taken in the event that the temperature of a bus bar rises above a predetermined level, at least when compared to ambient temperature or normal operating temperature.

The invention also relates to a control circuit board for use in a battery module according to the invention.

BACKGROUND TO THE INVENTION

Battery modules generally include multiple individual cells such as lithium ion cells that are typically arranged in cell stacks in which the cells of each stack are connected in parallel with each other and the cell stacks are connected in series with each other in order to make up a battery module. Multiple modules are inter-connected in order to make up a complete battery assembly or pack, for example for powering electric vehicles.

In one arrangement of interest to applicant, five individual cells are arranged in a stack and six stacks are interconnected to form a battery module that can be handled as a single entity. Fifteen of such modules are interconnected to form a complete battery assembly or pack and a single battery management unit applies overall management to the entire battery assembly whilst a control circuit associated with each battery module supplies inputs to the battery management unit.

The interconnection of the cells within each module is made using bus bars that are connected to the positive and negative terminals of each cell, usually using bolts or clamps but also optionally the bus bars may be welded to the cell terminals. The bus bars usually take the form of electrically conductive strips, typically copper strips of an appropriate thickness. A single bus bar is in electrical contact with the positive or negative terminals of the cells of one stack in order to connect the cells of that stack in parallel and with the terminals of opposite polarity of the cells of the next adjacent stack in order to connect the cell stacks in series. The bolts or clamps are designed to maximize the jointing efficiency and to minimize the formation of hot spots or "hot connections".

However, due to vehicle vibration the bolts or clamps may become lose or show signs of wear with time. This may cause an increase in localized resistance between a cell and the bus bar which may lead to an increase in dissipated heat that leads to the creation of a hot spot.

Hot spots in batteries may be problematic for a number of reasons including uneven battery discharge or charge; localized side reactions in the cells; and, most importantly, it may present a safety concern in that in a catastrophic failure situation in which a battery may overheat and catch fire.

US Patent No 5,319,356 to Takeo YOSHINO describes an apparatus for the surveillance of bus-bar temperature. This apparatus includes at least one electrically insulating holder that is made of ceramics or other highly heat conductive material for holding a bus-bar. A temperature sensor that is typically a thermistor contacts the insulating holder and is connected to a remote control device that compares an output signal of the temperature sensor with a predetermined reference value, or data of a characteristic curve, thereby judging whether or not an abnormal temperature rise has occurred or is likely to occur in the near future. This arrangement results in a large number of wired-in components which add to the size of the battery

module as well as to the cost of both components and labour in connecting a battery assembly.

International Patent Publication Number WO/2007/046587 describes a bus bar that simultaneously performs the electrical connection between a plurality of unit cells and, by way of vertically bent parts of the strip-shaped bus bar, supports a circuit board incorporating a battery management system. The battery management system detects the voltages of the unit cells in the battery module. It also receives temperature signals from remote thermistors that measure the temperatures of the unit cells. No specific mention is made of monitoring the temperatures of the bus bars themselves.

There is a need to provide a battery module having a suitable temperature management system in which the occurrence of hot spots in the battery bus bars can be detected.

There is also a need to provide a control circuit on a suitable circuit board, typically a printed circuit board, for incorporation in a battery module for the aforesaid purpose.

SUMMARY OF THE INVENTION

In accordance with a first aspect of this invention there is provided a battery module comprising a plurality of cell stacks each composed of multiple cells wherein the cells are interconnected in a predetermined arrangement by means of bus bars secured to terminals of the individual cells on one side of the battery module and a control circuit board is attached to each of the bus bars, the battery module being characterized in that the attachment of the control circuit board to each bus bar is by way of a thermally conductive support element selected to substantially adopt the temperature of its associated bus bar and in that a temperature sensor is included on the control circuit board in the vicinity of each thermally conductive support

element to sense the temperature of the support element with the temperature sensors being included in electronic circuitry on the control circuit board.

Further features of this aspect of the invention provide for the support elements to be thermally conductive cylindrical elements press-fitted or otherwise secured in thermal contact to the associated bus bar to extend at right angles thereto; for the control circuit board to be a printed circuit board; for the control circuit board to have thermally and electrically conductive zones associated with a plurality of apertures through the circuit board for receiving fasteners passing through the circuit board and into each of the associated support elements to achieve thermal contact with the associated support element; for there to be additional and separate temperature sensors for sensing the temperatures of the cells in a cell stack, such separate temperature sensors also being connected into the electronic circuit of the control circuit board; and for the control circuit board to have communications contacts for communicating and interacting with a battery management system that controls a plurality of battery modules and typically all of the battery modules of a particular battery assembly or pack.

For the purpose of exercising the invention, it is preferred that the bus bars be arranged horizontally as short strips secured to each of the relevant cell terminals at one side of the battery module, that is to say, at one end of generally vertically orientated cells that are typically lithium ion pouch cells.

Each full-size bus bar will preferably serve to connect the electrodes of the same polarity of each of the cells constituting a cell stack with the electrodes of opposite polarity of the cells constituting the next adjacent cell stack.

In this particular instance the battery module comprises cell trays that each accommodate a single cell and have a heat sink panel permanently attached

to a surrounding plastic frame on one side of the panel. The heat sink panel has an extension along its top edge to form a heat dissipating fin.

The plastic frame is provided with terminal accommodating recesses at both of its operatively vertical edges so that a cell can be located in the plastic frame with its terminals at either end of the frame. In the one instance the negative terminal will thus be uppermost, and in the other instance the negative terminal will be lowermost. The cell tray and cell can be rotated through 180° about a vertical axis to locate all of the terminals at the same side of the battery module. The terminals can then be interconnected by a single bus bar that serves to interconnect, in parallel, the terminals of like polarity of one cell stack in series with the terminals of opposite polarity of the cells of an adjacent cell stack.

In accordance with a second aspect of this invention there is provided a control circuit board having battery control circuitry associated therewith and multiple connection facilities for connecting the control circuit board directly to support elements carried by multiple bus bars that serve to interconnect the cells of a battery module, the control circuit board being characterized in that each of the connection facilities has associated therewith a temperature sensor for sensing the temperature, in use, of the associated support element, the temperature sensors being connected into electronic circuitry forming a part of the control circuit board.

It will be understood that by utilizing a control circuit board according to the invention, no wiring is required to connect temperature sensors with a control circuit as the necessary circuits are formed as a part of the circuit board itself. This results from the close proximity between the control circuit board and the bus bars and the fact that they are connected by means of a thermally conductive support element. The temperature monitoring circuitry is thus located on the control circuit board which is connected to the main battery management system.

The temperature of each bus bar can therefore be monitored and if a hotspot is detected corrective action can be taken before it becomes a safety concern.

In order that the above and other features of the invention may be more fully understood, one embodiment thereof will now be described with reference to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings:-

Figure 1 is an isometric view of a battery module showing the bus bars inter-connecting the individual cells and the cell stacks of the battery module;

Figure 2 is an elevation of a cell tray from the cell receiving side thereof;

Figure 3 is a similar elevation of the cell tray with a pouch cell located therein in one orientation;

Figure 4 is a similar elevation of the cell tray with a pouch cell located therein in the alternative orientation;

Figure 5 is an isometric view similar to Figure 1 and showing the control circuit board in position;

Figure 6 is a side elevation of the battery module;

Figure 7 is an isometric detail of one temperature sensor in the immediate vicinity of an aperture for receiving a fastener

attaching the control circuit board to the support elements carried by the bus bars; and,

Figure 8 is a plan view of an entire battery pack made up of modules of the general type illustrated in Figures 1 and 5.

DETAILED DESCRIPTION WITH REFERENCE TO THE DRAWINGS

In the embodiment of the invention illustrated in the drawings, a battery module (1) comprises six cell stacks each composed of five pouch lithium ion cells (3) with the cells of each cell stack having their terminals of like polarity interconnected with each other in order to connect them in parallel and to the terminals of the other polarity of the next adjacent cell stack to create a series connection with the cells of that cell stack.

These connections are effected by means of bus bars (4) secured to the relevant terminals of the individual cells. Each bus bar, other than the two bus bars at the ends of the battery module, thus connects ten cells, namely the five terminals of the same polarity of the cells of one cell stack and the five terminals of the other polarity of the cells of the next adjacent cell stack. All of the bus bars are located on the same side of the battery module. The bus bars at the ends of the battery module are connected to corresponding bus bars on adjacent battery modules typically using flexible, woven or plaited conductors (not shown). It is preferred that the bus bars are arranged horizontally as short strips secured to each of the relevant cell terminals, as illustrated clearly in Figure 1.

In the instance that the battery module comprises cell trays (5) for accommodating and locating each of the cells relative to the others, each cell tray has, in this embodiment of the invention and as illustrated in Figure 2, a heat sink panel (6) permanently attached to a surrounding plastic frame (7) on one side of the panel. The heat sink panel has an extension along its top

edge to form a heat dissipating fin (8). The plastic frame has terminal accommodating recesses (9) at both of its operatively vertical edges so that a cell can be located in the plastic frame with its terminals at either end of the frame.

In the instance of the terminals (10) being located at one end of the frame, the negative terminal may be uppermost, as illustrated in Figure 3, and in the instance of the terminals being located at the other end of the cell tray, the negative terminal will be lowermost, as illustrated in Figure 4. The latter cell tray and cell assembly can be rotated through 180° about a vertical axis to locate all of the terminals at the same side of the battery module and locate the terminals correctly for connecting the cells of each cell stack in parallel with each other and each cell stack in series with adjacent cell stacks using the generally horizontal bus bars. Two empty halve-trays (12) are fitted in between adjacent cell stacks to act as a spacer, thereby preventing a short circuit of the cells.

Each of the bus bars has a heat conductive cylindrical support element (11) press-fitted to it so that it is in thermal contact with the associated bus bar and extends at right angles thereto. Standard press fitted standoff connectors can be employed for this purpose. The arrangement is, in any event, such that the support element substantially adopts the temperature of its associated bus bar. An alternative embodiment would be to form a mounting protrusion in the copper bus bar using cold forging. The protrusion should have a threaded hole to accommodate a fastener.

A control circuit board in the form of a printed circuit board (13) is secured to the support elements so that thermally and electrically conductive zones (14) associated with a plurality of apertures (15) through the printed circuit board (see Figure 7) receive screw threaded fasteners (16) that extend into each of the associated support elements (see Figure 6). The arrangement ensures that the zones (14) of the printed circuit board also achieve substantially the

temperature of the support elements and therefore the temperature of the relevant bus bar.

A temperature sensor (18) is included on the control circuit board in the vicinity of each thermally conductive support element to sense the temperature of the support element with the temperature sensors being included in electronic circuitry on the printed circuit board.

It should be noted that in this specific application these temperature sensors are additional and separate from temperature sensors (not shown) for sensing the temperatures of the cells in a cell stack for the purpose of overall battery management. Nevertheless, such separate temperature sensors are also connected into the electronic circuit of the printed circuit board. In some applications the temperature sensors on the printed circuit board may be adequate to infer the cell temperature, in which case separate cell sensors may not be required. This depends on the design of the battery module.

Each of the printed circuit boards has a set of communications contacts (not shown) for communicating and interacting with a battery management unit (20) (see Figure 8) that controls a plurality of battery modules and typically all of the battery modules of a particular battery assembly or battery pack as they are generally termed.

As shown in Figure 6 the printed circuit boards are preferably covered by a releasable, electrically insulating cover, indicated by dotted lines (22).

It will be understood that by utilizing a printed circuit board according to the invention, no wiring is required to connect it to the module or the temperature sensors as the necessary circuits are formed as a part of the mechanical fastening of the board onto the support elements in the bus bar. This results from the close proximity between the control circuit board and the bus bars and the fact that they are connected by means of a thermally and electrically

conductive support element. The temperature monitoring circuitry is thus located on the control circuit board which is connected to the main battery management system.

The temperature of each bus bar can therefore be monitored and if a hotspot is detected, corrective action can be taken before it becomes a safety concern.

It will therefore be appreciated that use of the invention may be employed to eliminate significant amounts of wiring to the control circuit board; it simplifies the components used; it may result in a more compact battery; it renders the battery simpler and more cost-effective to assemble and install; the mounting of the printed circuit board is robust; and there is improved safety of the battery.

Numerous variations may be made to the embodiment of the invention described above without departing from the scope hereof.

CLAIMS:

1. A battery module comprising a plurality of cell stacks each composed of multiple cells wherein the cells are interconnected in a predetermined arrangement by means of bus bars secured to terminals of the individual cells on one side of the battery module and a control circuit board is attached to each of the bus bars, the battery module being characterized in that the attachment of the control circuit board to each bus bar is by way of a thermally conductive support element selected to substantially adopt the temperature of its associated bus bar and in that a temperature sensor is included on the control circuit board in the vicinity of each thermally conductive support element to sense the temperature of the support element with the temperature sensors being included in electronic circuitry on the control circuit board.

2. A battery module as claimed in claim 1 in which the support elements are thermally conductive cylindrical elements press-fitted or otherwise secured in thermal contact with the associated bus bar to extend at right angles thereto.

3. A battery module as claimed in either one of claims 1 or 2 in which the control circuit board is a printed circuit board.

4. A battery module as claimed in any one of the preceding claims in which the control circuit board has thermally and electrically conductive zones associated with a plurality of apertures through the circuit board for receiving fasteners passing through the circuit board and into an associated support element to achieve thermal contact with the associated support element.

5. A battery module as claimed in any one of the preceding claims in which additional and separate temperature sensors are provided for sensing the temperatures of the cells in a cell stack with such separate temperature sensors being connected into the electronic circuit of the control circuit board.

6. A battery module as claimed in any one of the preceding claims in which the control circuit board has communications contacts for communicating and interacting with a battery management system that controls a plurality of battery modules of a particular battery assembly or pack.

7. A battery module as claimed in any one of the preceding claims in which the bus bars are arranged horizontally as short strips secured to each of the relevant cell terminals at one side of the battery module and the bus bars serve to connect the electrodes of the same polarity of each of the cells constituting a cell stack with the electrodes of opposite polarity of the cells constituting the next adjacent cell stack.

8. A battery module as claimed in any one of the preceding claims in which the battery module comprises cell trays that each accommodate a single cell and that have a heat sink panel permanently attached to a surrounding plastic frame on one side of the panel with the heat sink panel having an extension along one edge to form a heat dissipating fin.

9. A battery module as claimed in claim 8 in which the plastic frame is provided with terminal accommodating recesses at both of its operatively vertical edges so that a cell can be located in the plastic frame with its terminals at either end of the frame and a cell tray and cell can be rotated through 180° about a vertical axis to locate all of the terminals at the same side of the battery module.

10. A control circuit board having battery control circuitry associated therewith and multiple connection facilities for connecting the control circuit board directly to support elements carried by multiple bus bars that serve to interconnect the cells of a battery module, the control circuit board being characterized in that at least selected connection facilities have associated therewith a temperature sensor for sensing the temperature, in use, of the associated support element, the temperature sensors being connected into electronic circuitry forming a part of the control circuit board.

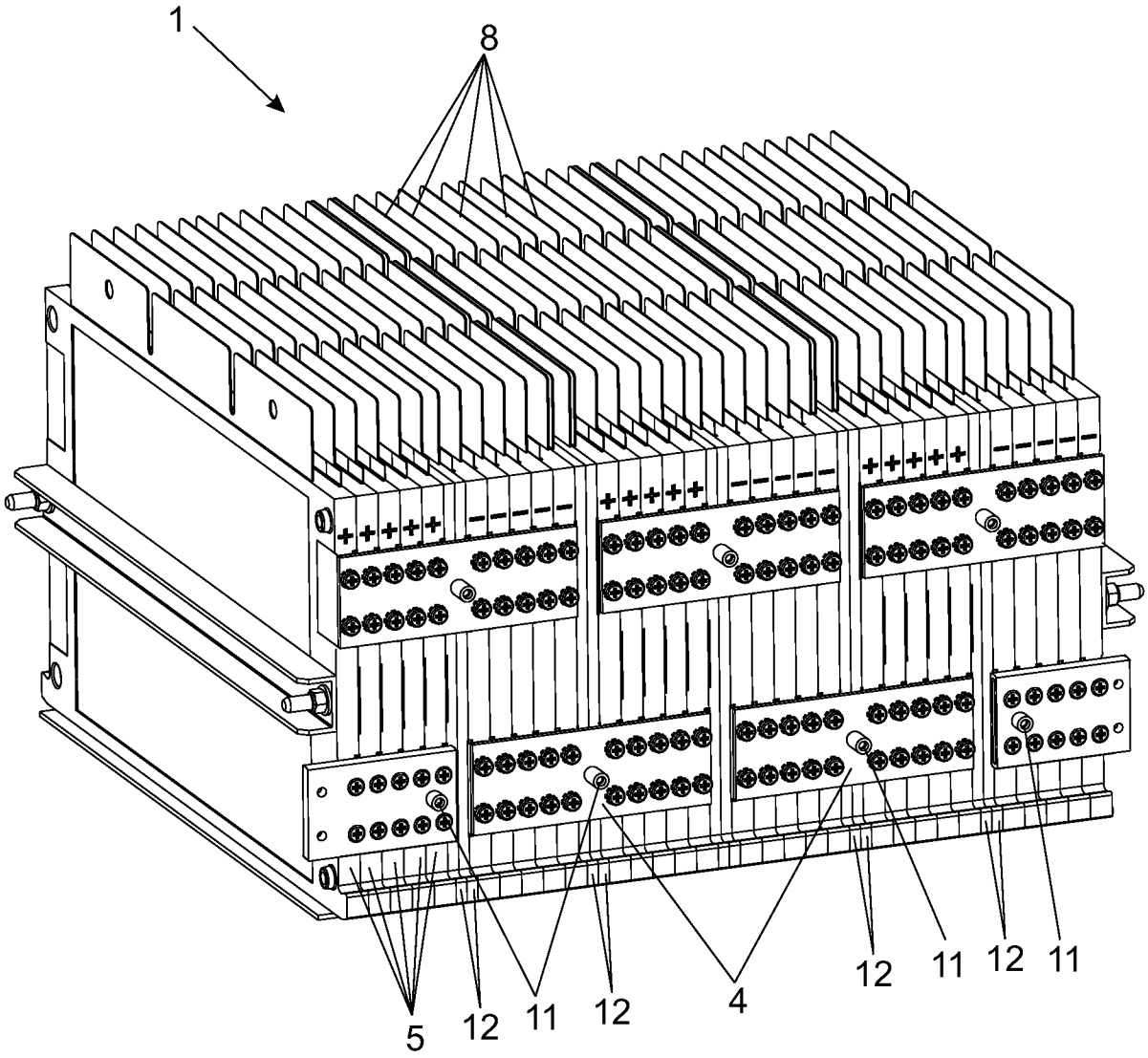


Figure 1

Figure 2

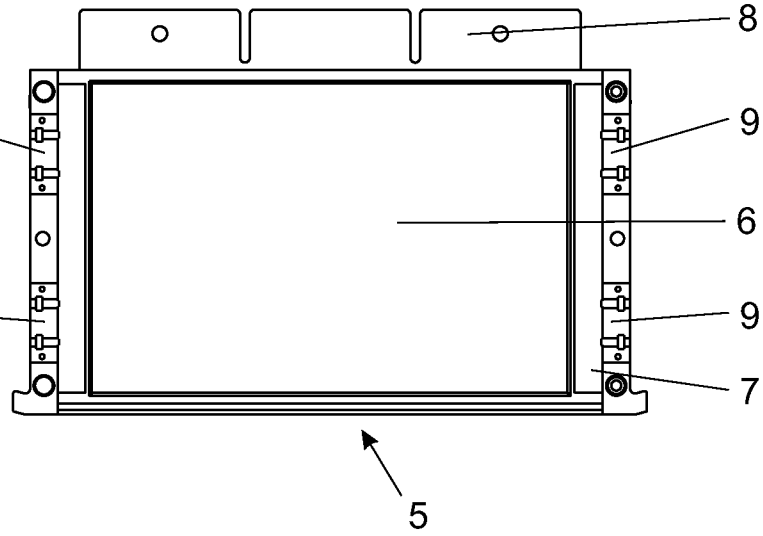


Figure 3

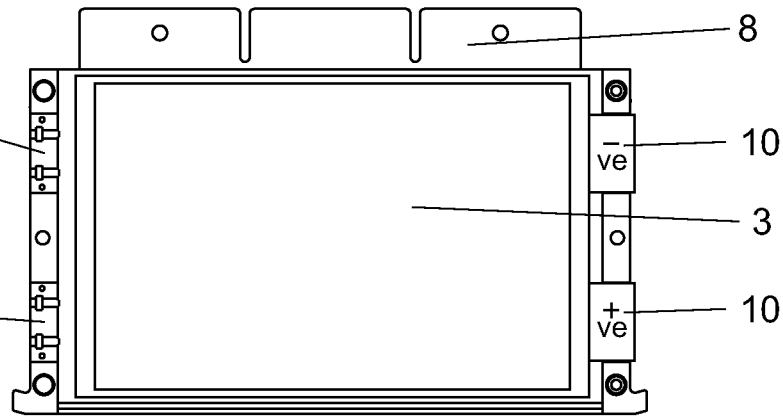
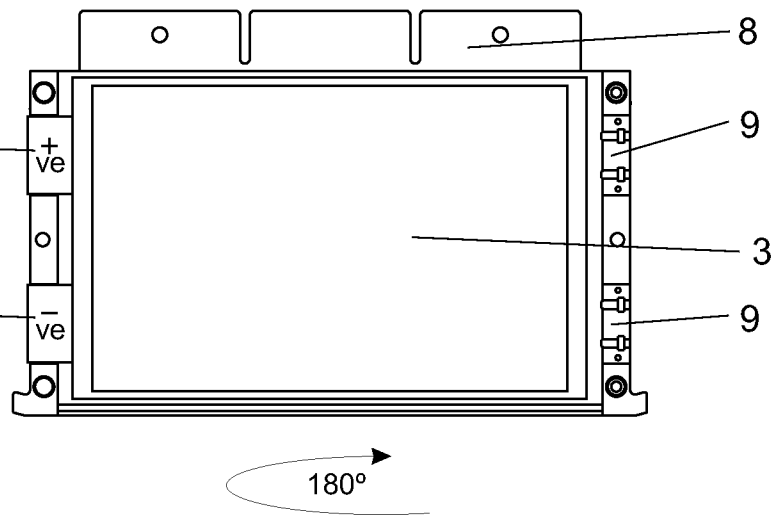


Figure 4



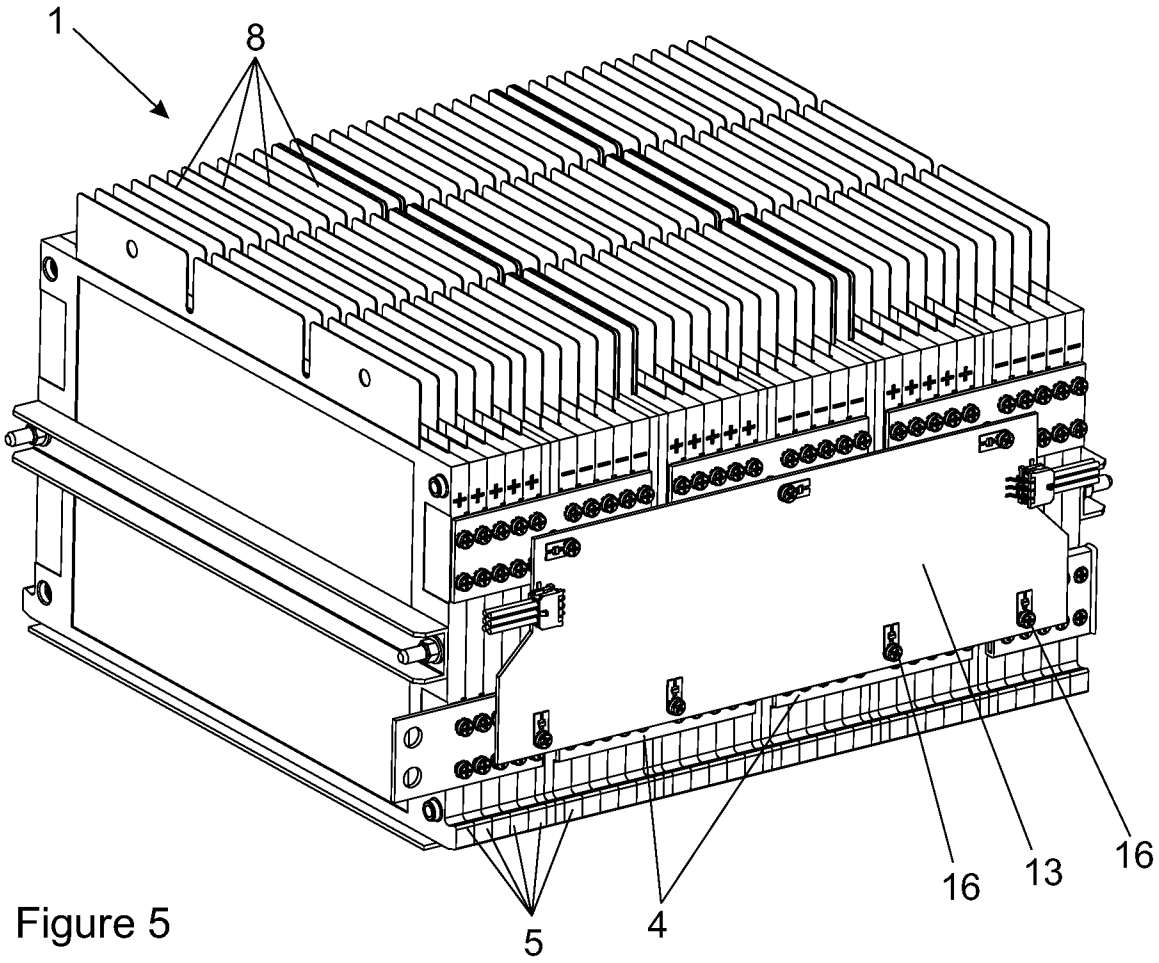


Figure 5

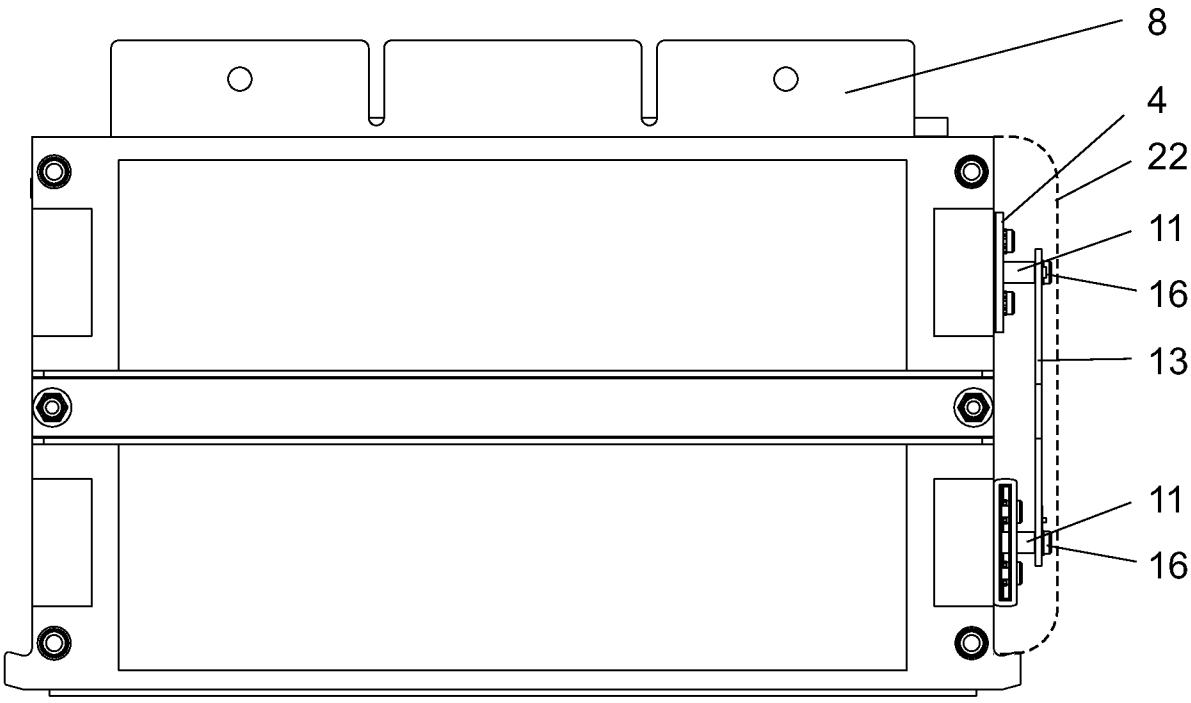


Figure 6

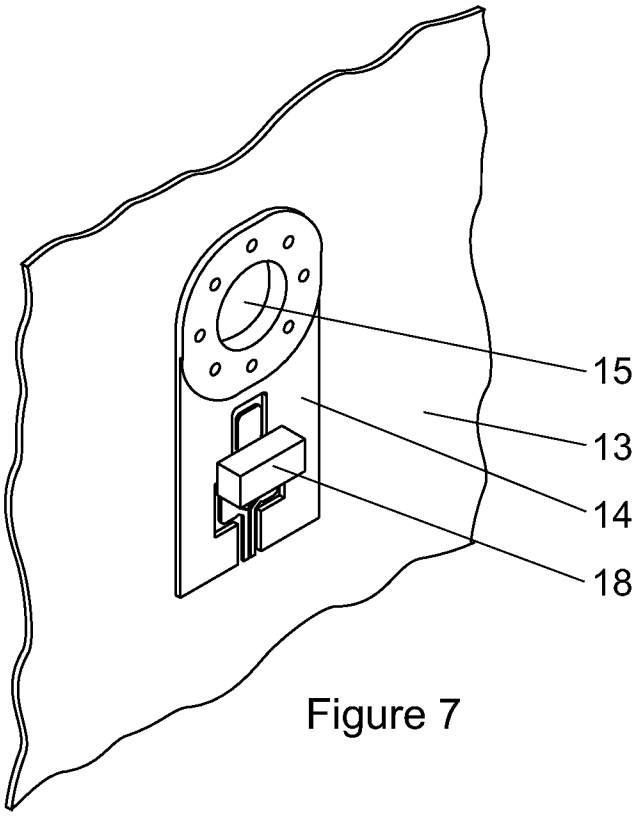


Figure 7

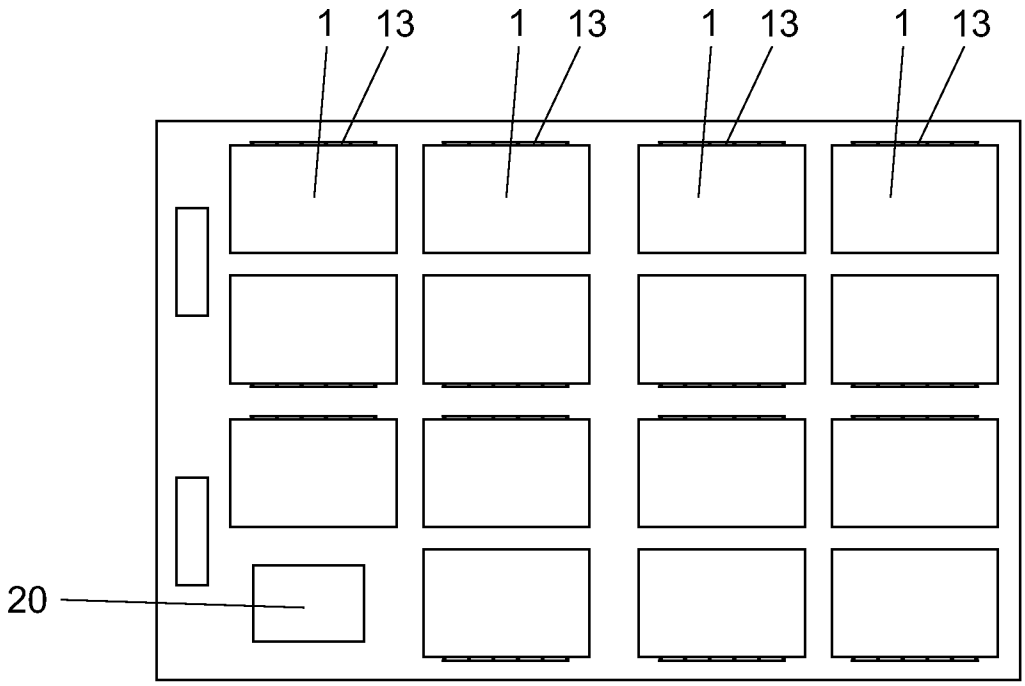


Figure 8

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2012/052211

A. CLASSIFICATION OF SUBJECT MATTER
INV. H01M2/10 H01M2/20 H01M10/48
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

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, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 2 259 365 A1 (MITSUBISHI MOTORS CORP [JP]; MITSUBISHI MOTOR ENG [JP]) 8 December 2010 (2010-12-08) paragraph [0024] - paragraph [0030] paragraph [0033] paragraph [0037] - paragraph [0041] figures 1,2,3	1,3,6,7, 10
A	US 5 319 356 A (YOSHINO TAKEO [JP]) 7 June 1994 (1994-06-07) cited in the application the whole document	1-10
A	WO 2010/019503 A2 (JOHNSON CONTROLS SAFT ADVANCED [US]; MASSON OLIVIER [FR]; TEYSSONNIER) 18 February 2010 (2010-02-18) the whole document	1-10

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

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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
27 September 2012	09/10/2012

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	Horváth, László

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Form PCT/ISA/210 (second sheet) (April 2005)

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
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