POWER SUPPLY DEVICE, ELECTRONIC APPARATUS AND POWER SUPPLY CONTROL METHOD

CROSS-REFERENCE TO RELATED APPLICATION

This application is based upon and claims the benefit of priority of the prior Japanese Patent Application No. 2014-253173, filed on December 15, 2014, the entire contents of which are incorporated herein by reference.

FIELD

**[0001]** The embodiments discussed herein are related to a power supply device, an electronic apparatus, and a power supply control method.

BACKGROUND

**[0002]** Nowadays, an electricity storage member is widely used. For example, a lithium ion capacitor or a lithium ion battery is used as the electricity storage member. The electricity storage member can be used as a power supply of a cellular phone, a personal computer (PC), an electric car, or the like.

**[0003]** There is a case in which a maximum value of a voltage that is stored at the time of charging, or a minimum value of a voltage at the time of discharging is set for an electricity storage member, such as a lithium ion capacitor or a lithium ion battery. If a voltage that exceeds the maximum value is stored, or if discharging of a voltage that is lower than the minimum value is performed, the electricity storage member is degraded. That is, the electricity storage member such as a lithium ion capacitor or a lithium ion battery has features that are weak in an overcurrent or overcharging. Thus, a technology is proposed, in which a plurality of a lithium ion batteries is connected in series, if a voltage of at least one cell is increased to a value equal to or higher than a predetermined value during charging, the charging is stopped, the voltage of the cell which is increased to a value equal to or higher than the predetermined value is discharged, and if a voltage of at least one cell is decreased to a value equal to or lower than a predetermined value during discharging, the discharging is stopped, as an example of coping with a case in which an overcurrent or overcharging is generated,.

**[0004]** In addition, a lithium ion secondary battery system which includes two fuses connected in series so as to connect a charging and discharging connection terminal to a positive electrode of a secondary battery, a switching element disposed so as to connect a wire between the respective fuses to a negative electrode of the secondary battery, and a detection circuit that controls on or off of the switching element, is proposed as a protection circuit of a lithium ion secondary battery.

**[0005]** Related arts are Japanese Unexamined Patent Application Publication No. 2002-58170 and Japanese Unexamined Patent Application Publication No. 2010-212166.

PROBLEMS

**[0006]** However, there is a method of connecting a plurality of electricity storage members in series to each other, as a method of ensuring a high discharging voltage. If the plurality of electricity storage members connected in series is charged, a both-terminal voltage between a positive electrode of an electricity storage member on a positive electrode side and a negative electrode of an electricity storage member on a negative electrode side is set so as to not exceed a value (threshold value) which is obtained by multiplying a maximum value of the voltage of the electricity storage member by the number of electricity storage members.

**[0007]** Here, if an electricity storage member, such as a lithium ion capacitor or a lithium ion battery is used, natural discharging or an internal degradation degree becomes different, and thereby voltages stored in each of a plurality of electricity storage members may be unequal. If charging is made in a state in which voltages are unequal, a both-terminal voltage exceeds a threshold value, or only a part of the electricity storage members may be overcharged. In addition, in the same manner as a case of charging, also in a case of discharging, if discharging is made in a state in which voltages are unequal, a both-terminal voltage does not become a voltage lower than the minimum threshold value, or only a part of the electricity storage members may be over-discharged.

**[0008]** In this way, if overcharging or over-discharging is repeated, degradation of the electricity storage member is advanced, and failure probability of the electricity storage member is increased. In a case in which a plurality of electricity storage members is connected in series, if at least one electricity storage member fails, it is impossible to perform charging and discharging that uses the plurality of electricity storage members.

**[0009]** According to one aspect, an object of the embodiments is to provide a power supply device, an electronic apparatus, and a power supply control method in which failure resistance of charging and discharging operations is increased.

SUMMARY

According to an aspect of the invention, an apparatus includes

The object and advantages of the invention will be realized and attained by means of the elements and combinations particularly pointed out in the claims.

It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory and are not restrictive of the invention, as claimed.

BRIEF DESCRIPTION OF DRAWINGS

**[0014]** FIG. 1 is a diagram illustrating a configuration example and an operation example of a power supply device according to a first embodiment;

**[0015]** FIG. 2 is a comparison example of a case in which a plurality of electricity storage members is connected in series and is charged;

**[0016]** FIG. 3 is a comparison example of a case in which a plurality of electricity storage units is coupled in series and is discharged;

**[0017]** FIG. 4 is a diagram illustrating a hardware example of a storage device according to a second embodiment;

**[0018]** FIG. 5 is a diagram illustrating a hardware example of a power supply circuit;

**[0019]** FIG. 6 is a diagram illustrating an internal configuration example of an LIC unit;

**[0020]** FIG. 7 is a diagram illustrating a connection state of the LIC at the time of charging and at the time of discharging;

**[0021]** FIG. 8 is a diagram illustrating a specific example of a case in which the LIC fails;

**[0022]** FIG. 9 is a flowchart illustrating a processing example (part 1) of a controller;

**[0023]** FIG. 10 is a flowchart illustrating another processing example (part 1) of a controller; and

**[0024]** FIG. 11 is a flowchart illustrating still another processing example (part 1) of a controller.

DESCRIPTION OF EMBODIMENTS

**[0025]** Hereinafter, the present embodiments will be described with reference to the drawings.

First Embodiment

**[0026]** FIG. 1 is a diagram illustrating a configuration example and an operation example of a power supply device according to a first embodiment. Electricity storage members 11a to 11f can store charges, and can be charged by an external charging voltage. The electricity storage members 11a to 11f are, for example, lithium ion capacitors. In addition, the electricity storage members 11a to 11f may be members (for example, lithium ion batteries) having the same features as the lithium ion capacitors.

**[0027]** A power supply device 1 includes an electricity storage circuit 2 including the electricity storage members 11a to 11f, and a control circuit 3. The electricity storage members 11a to 11f in the electricity storage circuit 2 are grouped by electricity storage member groups 12a to 12c that respectively have two or more electricity storage members which are connected in parallel. In the example of FIG. 1, the electricity storage member group 12a includes the electricity storage members 11a and 11b which are connected in parallel, the electricity storage member group 12b includes the electricity storage members 11c and 11d which are connected in parallel, and the electricity storage member group 12c includes the electricity storage members 11e and 11f which are connected in parallel. Thus, the electricity storage member groups 12a to 12c are connected in series.

**[0028]** A connection point of the electricity storage members 11a and 11b which are on an upper side of FIG. 1 configures a positive electrode of the electricity storage circuit 2, and a connection point of the electricity storage members 11e and 11f which are on a lower side of FIG. 1 configures a negative electrode of the electricity storage circuit 2. Thus, when the electricity storage circuit 2 is charged, a charging voltage from a charging circuit is applied to the connection point on the upper side of the electricity storage members 11a and 11b. In addition, when the electricity storage circuit 2 is discharged, a load is connected to the connection point on the upper side of the electricity storage members 11a and 11b.

**[0029]** As described above, the electricity storage members are configured to be connected by three serial-stages, and thereby the electricity storage circuit 2 can output the discharging voltage that is triple that of one electricity storage member to the load. The number of the electricity storage member groups which are connected in series in the electricity storage circuit 2 can be an arbitrary number equal to or higher than 2 depending on a necessary discharging voltage. In addition, the number of electricity storage members which are connected in parallel in the respective electricity storage member groups can be an arbitrary number equal to or higher than 2.

**[0030]** In addition, the electricity storage circuit 2 includes disconnecting circuits 13a to 13f. The disconnecting circuits 13a to 13f correspond to the electricity storage members of the electricity storage circuit 2 one to one. When a corresponding electricity storage member fails, each of the disconnecting circuits 13a to 13f disconnects the electricity storage member from the electricity storage circuit 2 in such a manner that a current does not flow through the electricity storage member.

**[0031]** In the example of FIG. 1, the disconnecting circuits 13a, 13b, 13c, 13d, 13e, and 13f are respectively connected to the positive electrodes of the electricity storage members 11a, 11b, 11c, 11d, 11e, and 11f. When the electricity storage members 11a to 11f fail thereby being shorted, the disconnecting circuits 13a to 13f can use a circuit that disconnects a power supply line connected to the positive electrode of a corresponding electricity storage member, if a current equal to or greater than a predetermined value flows. Fuses can be used as the disconnecting circuits 13a to 13f. The disconnecting circuits 13a, 13b, 13c, 13d, 13e, and 13f may be respectively inserted into a power supply line connected to a negative electrode of a corresponding electricity storage member.

**[0032]** In addition, for example, the disconnecting circuits 13a to 13f may respectively include a switch that disconnects the power supply line connected to the positive electrode or the negative electrode of a corresponding electricity storage member. In this case, for example, if a current that flows through a certain electricity storage member has a value equal to or higher than a predetermined value, a switch corresponding to the electricity storage member may be switched off by processing of the control circuit 3.

**[0033]** The control circuit 3 controls whether to continue a charging operation of the electricity storage circuit 2 or not , based on a connection position of a failed electricity storage member among the electricity storage members 11a to 11f. For example, if one or more electricity storage members that do not fail are included in all the electricity storage member groups 12a to 12c, the control circuit 3 continues to perform a charging and discharging operation of the electricity storage circuit 2. In addition, if all the electricity storage members included in at least one of the electricity storage member groups 12a to 12c fail, the control circuit 3 stops the charging and discharging operation of the electricity storage circuit 2.

**[0034]** Here, an example of a case in which a plurality of electricity storage members are connected in series to a power supply device and are disposed will be described by using FIGS. 2 and 3. FIG. 2 is a comparison example of a case in which a plurality of electricity storage members is connected in series and is charged.

**[0035]** FIG. 2 illustrates a state in which electricity storage members 5a, 5b, and 5c in a power supply device are connected in series. If there is a variation in the features of the electricity storage members 5a, 5b, and 5c, a voltage is equally stored in each of the electricity storage members 5a, 5b, and 5c. However, in the example on the left hand side of FIG. 2, a voltage of 2.375 V is stored in both the electricity storage members 5a and 5b, while a voltage of 2.75 V is stored in the electricity storage member 5c. This is due to a difference of natural discharging or internal degradation for each electricity storage member.

**[0036]** In a case of charging, the power supply device controls a both-terminal voltage between the positive electrode of the electricity storage member 5a and the negative electrode of the electricity storage member 5c, in such a manner that the both-terminal voltage does not exceed a value (11.4 V=3.8 V´3) that is obtained by multiplying a maximum value (for example, 3.8 V) of the voltage of the electricity storage member by the number (three) of the electricity storage members. As illustrated in FIG. 2, if charging is made in a state in which voltages are unequal, there is a case in which only the electricity storage member 5c is overcharged, even if the both-terminal voltage (11.078 V) does not exceed 11.4 V.

**[0037]** FIG. 3 is a comparison example of a case in which a plurality of electricity storage units is coupled in series and is discharged. In the same manner as at the time of charging, also at the time of discharging, if there is a variation in the features of the electricity storage members 5a, 5b, and 5c, the respective voltages of the electricity storage members 5a, 5b, and 5c become equal to each other. However, in the example on the left hand side of FIG. 3, a voltage of 3.69 V is stored in both the electricity storage members 5a and 5b, while a voltage of 3.42 V is stored in the electricity storage member 5c. This is due to a difference of natural discharging or internal degradation for each electricity storage member.

**[0038]** In a case of discharging, the power supply device controls the both-terminal voltage, in such a manner that the both-terminal voltage does not have a value less than a value (6.6 V=2.2 V´3) that is obtained by multiplying a minimum value (for example, 2.2 V) of the voltage of the electricity storage member by the number (three) of the electricity storage members. As illustrated in FIG. 3, if discharging is made in a state in which voltages are unequal, there is a case in which only the electricity storage member 5c is over-discharged, even if the both-terminal voltage (6.6 V) does not have a value less than 6.6 V.

**[0039]** As described in the examples of FIGS. 2 and 3, if it is controlled in such a manner that the plurality of electricity storage members is connected in series and overcharging and over-discharging are prevented based on the both-terminal voltage, the overcharging and the over-discharging of a part of the electricity storage members can be repeated by a variation of the features of each electricity storage member. In this way, the electricity storage member in which the overcharging and the over-discharging is repeated can be degraded or can fail. As illustrated in FIGS. 2 and 3, if one of electricity storage members connected in series fails, charging and discharging may not be made. For example, as the failed electricity storage member is shorted, a predetermined discharging voltage may not be overall obtained, and correct charging and discharging may not be made.

**[0040]** In contrast to this, according to the power supply device 1 illustrated in FIG. 1, even if a part of the electricity storage members fails, the charging and discharging operation can be continuously performed. Hereinafter, description returns to FIG. 1.

**[0041]** For example, like a state 1 illustrated on the lower left hand side of FIG. 1, it is assumed that the electricity storage member 11c fails. In this case, the electricity storage member 11c is disconnected by the disconnecting circuit 13c. According to this, a state is eliminated in which a connection is made between the positive electrode and the negative electrode of the electricity storage member 11d that is connected in parallel to the electricity storage member 11c, and a current flows through the electricity storage member 11d.

**[0042]** In this state, while a state in which the electricity storage member 11a or the electricity storage member 11b, the electricity storage member 11d, and the electricity storage member 11e or the electricity storage member 11f are connected in series is maintained, a charging and discharging operation of the electricity storage circuit 2 can be continuously performed. Thus, if it is detected that only the electricity storage member 11c fails, the control circuit 3 determines that a continuous charging and discharging operation of the electricity storage circuit 2 is possible, and continuously performs the charging and discharging operation. According to this, even if there is a failed electricity storage circuit, it is possible to continuously perform the charging and discharging operation. In addition, it is possible to obtain a discharging voltage of an amount of three electricity storage members, at the time of discharging.

**[0043]** Meanwhile, like a state 2 illustrated on the lower right hand side of FIG. 1, it is assumed that the electricity storage member 11d fails further from a state of the state 1. In this case, the electricity storage member 11d is disconnected by the disconnecting circuit 13d. In this state, a disconnection is made between the electricity storage member group 12a and the electricity storage member group 12c, and it is impossible to continuously perform the charging and discharging operation of the electricity storage circuit 2. Thus, if it is detected that the electricity storage members 11c and 11d fail, the control circuit 3 determines that the continuous charging and discharging operation of the electricity storage circuit 2 is impossible, and stops the charging and discharging operation.

**[0044]** For example, the installation detection unit 3 determines whether to continuously perform the charging and discharging of the electricity storage circuit 2 or not, depending on the following determination conditions. If one or more electricity storage members that do not fail are included in all of the electricity storage member groups 12a to 12c, the control circuit 3 continuously performs the charging and discharging operation. In addition, even if all the electricity storage members included in at least one of the electricity storage member groups 12a to 12c fail, the control circuit 3 stops the charging and discharging operation.

**[0045]** According to the first embodiment described above, it is possible to continuously perform the charging and discharging of the electricity storage circuit 2, even if the electricity storage member fails. According to this, it is possible to increase failure-resistance of the charging and discharging operation, and to increase reliability of the power supply device 1.

Second Embodiment

**[0046]** Next, an example in which the power supply device 1 of the first embodiment is applied to a storage device will be described as the second embodiment. In addition, a power supply device in the following storage device has a function in which variation does not occur in a voltage that is stored in each electricity storage member at the time of charging, in addition to a function in which a failed electricity storage member is disconnected and a charging and discharging operation is continuously performed.

**[0047]** In the second embodiment, a lithium ion capacitor is used as the electricity storage member, but, for example, a lithium ion battery can also be used. Hereinafter, each lithium ion capacitor is referred to as an LIC.

**[0048]** FIG. 4 is a diagram illustrating a hardware example of a storage device according to a second embodiment. The storage device 100 includes a controller module (CM) 101, hard disk drives (HDD) 102 and 102a, and light emitting diodes (LED) 103a and 103b. The storage device 100 may have a plurality of CMs, and may have one HDD or three or more HDDs. A host device 300 is connected to the CM 101. Communication between the CM 101 and the host device 300 is performed through, for example, a storage area network (SAN).

**[0049]** The CM 101 includes a processor 104, a random access memory (RAM) 105, a solid state drive (SSD) 106, a drive interface (DI) 107, and a channel adapter (CA) 108. Each unit is connected to a bus. In addition, the CM 101 includes a power supply circuit 200.

**[0050]** The processor 104 controls information processing of the CM 101. The processor 104 is, for example, a central processing unit (CPU), a digital signal processor (DSP), an application specific integrated circuit (ASIC), a field programmable gate array (FPGA), or the like. The processor 104 may also be a multi-processor. The processor 104 may be a combination of two or more elements of the CPU, the DSP, the ASIC, the FPGA, or the like.

**[0051]** The RAM 105 is a main memory device of the CM 101. The RAM 105 temporarily stores at least a part of a program or an application program of an operating system (OS) that is executed by the processor 104. In addition, the RAM 105 stores various types of data that is used for processing which is performed by the processor 104.

**[0052]** The SSD 106 is an auxiliary memory device of the CM 101. The SSD 106 is a non-volatile semiconductor memory. A program of an OS, an application program, and various types of data are stored in the SSD 106. The CM 101 may include an HDD instead of the SSD 106, as an auxiliary memory device.

**[0053]** The DI 107 is an interface for communicating with the HDDs 102 and 102a. The CA 108 is an interface for communicating with the host device 300.

**[0054]** The power supply circuit 200 generates a drive voltage based on a direct current (DC) voltage that is input from an external power supply outside the storage device 100, and supplies the drive voltage to each unit inside the CM 101. In addition, in order to prevent cache data stored in the RAM 105 from being erased at the time of a power outage, the power supply circuit 200 has a function of supplying a drive voltage to the RAM 105 using the LIC. In addition, the power supply circuit 200 charges the LIC using a DC power supply from outside, at the time of non-power outage.

**[0055]** The LEDs 103a and 103b are lit, if the LIC included in the power supply circuit 200 fails. As will be described later, in a case in which, even if a part of the LICs in the power supply circuit 200 fails, a charging and discharging operation can be continuously performed by using the other LICs, the LED 103a is lit. In addition, if the charging and discharging operation may not be continuously performed by the failure of the LIC in the power supply circuit 200, the LED 103b is lit. Reporting of the failure state may be performed by displaying on a liquid crystal display, or may be performed by an audio output. In addition, the above two states may be distinguished by blinking and lighting of one LED.

**[0056]** FIG. 5 is a diagram illustrating a hardware example of a power supply circuit. Fig. 5 illustrates only a configuration related to power supplying to the RAM 105, among the configurations of the power supply circuit 200. The power supply circuit 200 includes a butt circuit 201, diodes 202 and 203, a controller 210, a power supplying circuit 220, a charging circuit 230, a discharging field effect transistor (FET) 240, and an LIC unit 250.

**[0057]** The controller 210 includes a CPU 211, a RAM 212, a flash memory 213, a voltage monitor 214, and an interface (I/F) circuit 215. The controller 210 is an example of the control circuit 3 of FIG. 1.

**[0058]** The CPU 211 controls the entire controller 210. The CPU 211 may be a multi-processor.

**[0059]** The RAM 212 is a main memory device of the controller 210. The RAM 212 temporarily stores at least a part of a plurality of application programs. In addition, the RAM 212 stores various types of data that is used for processing which is performed by the CPU 211.

**[0060]** The flash memory 213 is an auxiliary memory device of the controller 210. The flash memory 213 is a non-volatile semiconductor memory. An application program and various types of data are stored in the flash memory 213.

**[0061]** The voltage monitor 214 detects a voltage value of the LIC included in the LIC unit 250.

**[0062]** The interface circuit 215 outputs a control signal to each of the charging circuit 230, the discharging FET 240, the LIC unit 250, and the LEDs 103a and 103b, based on a command from the CPU 211.

**[0063]** If a DC voltage from an external power supply is input, the butt circuit 201 outputs the input voltage, and if the DC voltage is not input, the butt circuit 201 outputs a voltage that is input from the LIC unit 250 through the discharging FET 240. The output voltage of the butt circuit 201 is supplied to the RAM 105 and the charging circuit 230. The output voltage of the butt circuit 201 may be converted into a drive voltage of the RAM 105 by a voltage converting circuit that is not illustrated, and the converted drive voltage may be supplied to the RAM 105.

**[0064]** The diode 202 limits a direction of a current flowing through a wire between the butt circuit 201 and the power supplying circuit 220 to a direction from the butt circuit 201 to the power supplying circuit 220. The diode 203 limits a direction of a current flowing through a wire between the discharging FET 240 and the power supplying circuit 220 to a direction from the discharging FET 240 to the power supplying circuit 220.

**[0065]** The power supplying circuit 220 supplies a constant drive voltage to the controller 210. In a case of non-power outage, the power supplying circuit 220 converts a voltage that is supplied from an external power supply through the butt circuit 201 into a drive voltage, and supplies the drive voltage to the controller 210. Meanwhile, in a case of a power outage, the power supplying circuit 220 converts a voltage that is supplied from the LIC unit 250 through the discharging FET 240 into a drive voltage, and supplies the drive voltage to the controller 210.

**[0066]** In a case of receiving a charging start command with respect to the LIC unit 250 from the controller 210, the charging circuit 230 converts a voltage that is supplied from an external power supply into a predetermined voltage for charging, and supplies the predetermined voltage to the LIC unit 250.

**[0067]** The discharging FET 240 is a control element for charging a voltage stored in the LIC unit 250. For example, the discharging FET 240 is a metal oxide semiconductor (MOS)-FET. The discharging FET 240 is turned on or off according to the command of the controller 210, and controls conduction or cut-off of a current that is output to the butt circuit 201 and the diode 203 from the LIC unit 250. The discharging FET 240 is controlled so as to be turned off (cut-off state) at the time of charging, and to be turned on (conduction state) at the time of non-charging.

**[0068]** The LIC unit 250 is a circuit for storing a voltage for being supplied to the RAM 105 at the time of a power outage, and includes a plurality of LICs. The LIC unit 250 is an example of the electricity storage circuit 2 of FIG. 1.

**[0069]** FIG. 6 is a diagram illustrating an internal configuration example of the LIC unit. FIG. 6 also illustrates a connection relationship between the LIC unit and the charging circuit 230, and the discharging FET 240 and the controller 210.

**[0070]** The LIC unit 250 includes cells 251 to 254, fuses 254a to 254f, and switching circuits 255a to 255f.

**[0071]** In the second embodiment, two LICs that are connected in parallel are referred to as a “cell”. The cell 251 includes LICs 251a and 251b. The cell 252 includes LICs 252a and 252b. The cell 253 includes LICs 253a and 253b. A connection point of wires on each positive electrode side of the LICs 251a and 251b is connected to the charging circuit 230 and the discharging FET 240. A connection point of wires on each negative electrode side of the LICs 253a and 253b is connected to a ground (GND).

**[0072]** The fuses 254a, 254, 254c, 254d, 254e, and 254f are disposed so as to respectively correspond to each of the LICs 251a, 251b, 252a, 252b, 253a, and 253b. The fuses 254a to 254f are an example of the disconnecting circuits 13a to 13f of FIG. 1.

**[0073]** The fuses 254a to 254f are respectively inserted into a wire on the positive side of a corresponding LIC, and are burned out when a current having a value equal to or greater than a predetermined value flows through the wire, and thereby the wire is in an open state. According to this, the fuses 254a to 254f prevent a current from flowing through the LIC, when the corresponding LIC fails thereby being shorted. For example, when the LIC 251a fails thereby being shorted, the fuse 254a is cut, and thus a current is prevented from flowing through the failed LIC 251a. The fuses 254a to 254f may be respectively inserted into a wire on the negative electrode side of a corresponding LIC.

**[0074]** The switching circuits 255a to 255f are switching elements such as MOS-FETs, and switch conduction and cut-off of a wire into which each of the switching circuits 255a to 255f is inserted, based on a command of the controller 210. The switching circuit 255a is disposed between a connection point of wires of the respective negative electrodes of the LICs 251a and 251b, and a connection point of wires of the respective positive electrodes of the LICs 252a and 252b. The switching circuit 255b is disposed between a connection point of wires of the respective negative electrodes of the LICs 252a and 252b, and a connection point of wires of the respective positive electrodes of the LICs 253a and 253b.

**[0075]** The switching circuit 255c is disposed between a connection point of wires of the respective positive electrodes of the LICs 251a and 251b, and a connection point of wires of the respective negative electrodes of the LICs 252a and 252b. The switching circuit 255d is disposed between a connection point of wires of the respective negative electrodes of the LICs 252a and 252b, and a connection point of wires of the respective negative electrodes of the LICs 253a and 253b.

**[0076]** The switching circuit 255e is disposed between a connection point of wires of the respective positive electrodes of the LICs 251a and 251b, and a connection point of wires of the respective positive electrodes of the LICs 252a and 252b. The switching circuit 255f is disposed between a connection point of wires of the respective positive electrodes of the LICs 252a and 252b, and a connection point of wires of the respective positive electrodes of the LICs 253a and 253b.

**[0077]** A conduction state and a cut-off state of the switching circuits 255a to 255f is controlled by the controller 210, and thereby a connection state in which the cells 251 to 253 are connected in series, and a connection state in which the cells 251 to 253 are connected in parallel are switched.

**[0078]** The voltage monitor 214 detects a voltage value on the positive electrode side of each of the LICs 251a, 251b, 252a, 252b, 253a, and 253b. The CPU 211 of the controller 210 can calculate a voltage stored in each of the LICs 251a, 251b, 252a, 252b, 253a, and 253b, based on the voltage value detected by the voltage monitor 214.

**[0079]** FIG. 7 is a diagram illustrating a connection state of the LICs at the time of charging and at the time of discharging. In FIG. 7, the fuses 254a to 254f and the switching circuits 255a to 255f are not illustrated.

**[0080]** An upper portion of FIG. 7 illustrates a connection state of the LICs at the time of charging. By the control of the controller 210, the switching circuits 255a and 255b are turned off (cut-off state), the switching circuits 255c to 255f are turned on (conduction state), and thereby the cells 251 to 254 are connected in series. In this state, the number of stages of the LICs in a serial direction is one, the six LICs 251a, 251b, 252a, 252b, 253a, and 253b are in a state being connected in parallel, and thus, hereinafter, there is a case in which the connection state is referred to as “one-series six-parallel”.

**[0081]** Meanwhile, a lower portion of FIG. 7 illustrates a connection state of the LICs at the time of discharging. By the control of the controller 210, the switching circuits 255a and 255b are turned on, the switching circuits 255c to 255f are turned off, and thereby the cells 251 to 254 are connected in series. In this state, the cells respectively having two LICs connected in parallel are connected in series by three stages, and thus, hereinafter, there is a case in which the connection state is referred to as “three-series two-parallel”. In the state of three-series two-parallel, a discharging voltage that is triple a discharging voltage of one LIC is obtained.

**[0082]** Here, in a state of three-series two-parallel, if the charging is made such that a both-terminal voltage (a voltage between the positive electrode side of the cell 251 and the negative electrode side of the cell 253) does not exceed a predetermined threshold value, only a part of the LICs can be overcharged. For example, charging starts in a state in which voltages stored in the LIXs 251a, 251b, 252a, 252b, 2513, and 253b become unequal by a variation of features such as a processing method of natural discharging or a state of an internal degradation. Here, if the LIC 251a has a higher voltage than those of the other LICs at the time of start of charging, only the LIC 251a exceeds a predetermined maximum voltage thereby being able to be overcharged, even if the both-terminal voltage does not exceed the threshold value

**[0083]** In contrast to this, the controller 210 makes the connection state of the LICs become the state of one-series six-parallel, at the time of start of charging of the LIC unit 250. In this state, equal voltages are applied to all the LICs 251a, 251b, 252a, 252b, 253a, and 253b from the charging circuit 230. For this reason, even if there is a variation of features between the LICs 251a, 251b, 252a, 252b, 253a, and 253b, equal voltages are stored in the LICs 251a, 251b, 252a, 252b, 253a, and 253b. Thus, even if the charging operation is controlled such that the both-terminal voltage of the LIC unit 250 does not exceed the predetermined threshold value, a situation in which only a part of the LICs is overcharged is prevented from occurring. As a result, it is possible to reduce degradation of the LICs and to reduce failure probability.

**[0084]** Meanwhile, if the charging of the LIC unit 250 is completed, the controller 210 makes the connection state of the LICs become the state of three-series two-parallel. According to this, a discharging voltage that is triple that of one LIC can be supplied to the RAM 105 through the discharging FET 240.

**[0085]** The FIG. 8 is a diagram illustrating a specific example of a case in which the LIC fails. FIG. 8A illustrates a case in which the LIC 252a fails at the time of discharging. If the LIC 252a fails thereby being in a shorted state, a large current temporarily flows through the fuse 254c, and thereby the fuse 254c is cut. According to this, a state in which both terminals of the LIC 252b that is connected in parallel to the failed LIC 252a are shorted is avoided, and a state in which the LICs are connected in series by three stages is maintained. Thus, while the discharging voltage is maintained, the discharging operation can be continuously performed.

**[0086]** The controller 210 detects that the both-terminal voltage of the LIC 252a is rapidly decreased, and thereby determines that the LIC 252a fails. At this time, the controller 210 determines whether or not all the LICs 252a and 252b included in the cell 252 fail. The controller 210 determines that the LIC 252b does not fail. Since the LIC 252b does not fail, the controller 210 determines that the discharging operation can be continuously performed by using the LICs 251a, 251b, 252b, 253a, and 253b. In this case, the controller 210 maintains the discharging FET 240 in an on state, and in this state, the discharging operation is continuously performed.

**[0087]** In this way, by being in a connection state made by a combination of a serial connection and a parallel connection, the charging operation can be continuously performed, even if a part of the LICs fails. Thus, service life of a function of a backup power supply of the RAM 105 performed by the LIC unit 250 extends, and reliability of the operation can be increased.

**[0088]** Meanwhile, FIG. 8B illustrates a case in which the LIC 252b fails further from the state of FIG. 8A. If the LIC 252b fails thereby being shorted, the fuse 254d is cut. The controller 210 detects that the both-terminal voltage of the LIC 252b is rapidly decreased, and thereby determines that the LIC 252b fails. At this time, the controller 210 determines that all the LICs 252a and 252b included in the cell 252 fail. Since all the LICs 252a and 252b included in the cell 252 fail, the controller 210 determines that the discharging operation may not be continuously performed, turns off the discharging FET 240, and stops the discharging operation.

**[0089]** The second embodiment describes a configuration in which cells respectively having two LICs connected in parallel can be connected in series by three stages, but the number of LICs in the cell is not limited as long as it is multiple. In addition, the number of cells that can be connected in series is not limited as long as it is multiple.

**[0090]** In addition, FIG. 8 illustrates a case in which the LIC fails in a state in which the LIC is connected in three-series two-parallel. However, for example, even if the LIC fails in a case in which the LIC unit 250 is charging and the LICs are connected in one-series six-parallel, the controller 210 makes the charging circuit 230 continuously perform the charging operation, if one or more LICs that do not fail exist in all the cells.

**[0091]** However, the controller 210 is connected to the two LEDs 103a and 103b. As illustrated in the example of FIG. 8A, the controller 210 lights the LED 103a, if the charging operation can be continuously performed, although a part of the LICs in the LIC unit 250 fails. Meanwhile, as illustrated in the example of FIG. 8B, the controller 210 lights the LED 103b, if the charging operation may not be continuously performed by the failure of the LIC.

**[0092]** According to this, the controller 210 reports to a user separately a case in which the charging and discharging operations can be continuously performed although a part of the LICs fails, and a case in which the charging and discharging operations may not be continuously performed by the failure of the LIC. The user can separately recognize the states. Particularly, as the former state is reported, the user can recognize the failure of the LIC and can replace the failed LIC, before the charging and discharging operations may not be continuously performed.

**[0093]** Next, processing of the controller 210 will be described by using a flowchart. FIGS. 9 to 11 are flowcharts illustrating a processing example of the controller. Hereinafter, the processing illustrated in FIGS. 9 to 11 will be described in accordance with step numbers. The processing of FIG. 9 starts when DC power starts to be supplied to the power supply circuit 200 from an external power supply and thereby the controller 210 starts to operate.

**[0094]** (S11) The controller 210 turns on the discharging FET 240. According to this, discharging of the LIC unit 250 is blocked.

**[0095]** (S12) The controller 210 turns off the switching circuits 255a and 255b, turns on the switching circuits 255c to 255f, and thereby the connection state of the LICs is switched to a state of one-series six-parallel.

**[0096]** (S13) The controller 210 commands the charging circuit 230 to start charging. According to this, the output voltage of the charging circuit 230 is applied to the LICs 251a, 251b, 252a, 252b, 253a, and 253b.

**[0097]** Determination processing of the following steps S14 and S15 is repeatedly performed for each predetermined time.

**[0098]** (S14) The controller 210 determines whether or not the both-terminal voltage exceeds a predetermined maximum threshold value, based on a detected voltage obtained by the voltage monitor 214. The above-described both-terminal voltage is a voltage between the positive electrode and the negative electrode of each of the cells 251 to 253 that are connected in parallel. The maximum threshold value is, for example, 3.8 V. If the both-terminal voltage is equal to or lower than the maximum threshold value, the processing proceeds to step S15. If the both-terminal voltage exceeds the maximum threshold value, the processing proceeds to step S21 of FIG. 10.

**[0099]** (S15) The controller 210 determines whether or not the LIC fails. The failure of the LIC is detected when the both-terminal voltage of the LIC is rapidly decreased (or becomes 0 V). If the LIC fails, the processing proceeds to step S16. If the LIC does not fail, the processing proceeds to step S14.

**[0100]** (S16) The controller 210 alerts that the LED 103a is lit, the LIC fails, and the charging and discharging operations are continuously performed.

**[0101]** (S17) The controller 210 determines whether or not a cell in which all the LICs fail exists. If a cell in which all the LICs fail exists, the processing proceeds to step S18. If a cell in which all the LICs fail does not exist, the processing proceeds to step S14.

**[0102]** (S18) The controller 210 commands the charging circuit 230 to stop charging. In addition, the controller 210 maintains the discharging FET 240 in an off state. According to this, the charging and discharging operations of the LIC unit 250 are stopped.

**[0103]** (S19) The controller 210 alerts that the charging and discharging operations are stopped by the failure of the LIC by lighting the LED 103b. Thus, the processing is ended.

**[0104]** (S21) The controller 210 commands the charging circuit 230 to stop charging. According to this, the charging operation of the LIC unit 250 is stopped.

**[0105]** (S22) The controller 210 turns on the switching circuits 255a and 255b, and turns off the switching circuits 255c to 255f, and thereby the connection state of the LICs is switched to a state of three-series two-parallel.

**[0106]** (S23) The controller 210 turns on the discharging FET 240. According to this, at the time of a power outage, the discharging can be made any time (standby state).

**[0107]** (S24) The controller 210 determines whether or not a DC voltage is input from an external power supply, for each predetermined time. Thus, if the DC voltage is not input from the external power supply (that is, if a power outage is generated), the processing proceeds to step S31. In this case, the LIC unit 250 is changed to a discharging state, and power supply from the LIC unit 250 to the RAM 105 is started.

**[0108]** Determination processing of the following steps S31 to S33 is repeatedly performed for each predetermined time.

**[0109]** (S31) The controller 210 determines whether or not the DC voltage is input from the external power supply. If the DC voltage is input from the external power supply, the processing proceeds to step S32. If the DC voltage is input again from the external power supply, the processing proceeds to step S11 of FIG. 9.

**[0110]** (S32) The controller 210 determines whether or not the both-terminal voltage is less than a predetermined minimum threshold value, based on a detected voltage obtained by the voltage monitor 214. The above-described both-terminal voltage is a voltage between the positive electrode of the cell 251 and the negative electrode of the cell 253, among the cells that are connected in series. The minimum threshold value is, for example, 2.2 V. If the both-terminal voltage is equal to or higher than the minimum threshold value, the processing proceeds to step S33. If the both-terminal voltage is lower than the minimum threshold value, the processing proceeds to step S37. In a case of the latter, the charging operation is stopped.

**[0111]** (S33) The controller 210 determines whether or not the LIC fails. If the LIC fails, the processing proceeds to step S34. If the LIC does not fail, the processing proceeds to step S31.

**[0112]** (S34) The controller 210 alerts that the LED 103a is lit, the LIC fails, and the charging and discharging operations are continuously performed.

**[0113]** (S35) The controller 210 determines whether or not a cell in which all the LICs fail exists. If a cell in which all the LICs fail exists, the processing proceeds to step S36. If a cell in which all the LICs fail does not exist, the processing proceeds to step S31.

**[0114]** (S36) The controller 210 alerts that the charging and discharging operations are stopped by the failure of the LIC by lighting the LED 103b.

**[0115]** (S37) The controller 210 turns off the discharging FET 240 and stops the charging operation. Thus, processing is ended.

**[0116]** In FIG. 10, the controller 210 does not perform the determination processing in a standby state, but may perform the following determination processing. For example, in the standby state, the controller 210 regularly performs the determination processing of step S32 of FIG. 11, and, if it is determined that the both-terminal voltage is lower than the minimum threshold value, the processing may proceed to step S37. Furthermore, the controller 210 may regularly perform the determination processing of step S33, in the standby state. In this case, the controller 210 performs the processing of steps S34 and S35, in a case of detecting the failed LIC, and if it is determined that a cell in which all the LICs fail in step S35 exists, the processing proceeds to step S36.

**[0117]** In the second embodiment, the power supply circuit 200 is provided to supply a voltage to the RAM 105, but the power supply circuit 200 may be provided to supply a voltage to an arbitrary component included in an electronic apparatus including an information processing device such as a PC.

**[0118]** In addition, the respective embodiments can be executed by combining a plurality of embodiments in a range without contradiction.

**[0119]** All examples and conditional language recited herein are intended for pedagogical purposes to aid the reader in understanding the invention and the concepts contributed by the inventor to furthering the art, and are to be construed as being without limitation to such specifically recited examples and conditions, nor does the organization of such examples in the specification relate to a showing of the superiority and inferiority of the invention. Although the embodiments of the present invention have been described in detail, it should be understood that the various changes, substitutions, and alterations could be made hereto without departing from the spirit and scope of the invention.

CLAIMS

What is claimed is:

1. A power supply device that performs charging and discharging using a plurality of electricity storage members, the device comprising:

an electricity storage circuit which includes the plurality of electricity storage members, and a plurality of disconnecting circuits that corresponds to each of the plurality of electricity storage members and, if a corresponding electricity storage member fails, disconnects the electricity storage member such that a current does not flow through the electricity storage member, and in which the plurality of electricity storage members is grouped in a plurality of electricity storage member groups, each group having two or more electricity storage members connected in parallel, and the plurality of electricity storage members are connected in series; and

a control circuit which, based on a connection position of a failed electricity storage member among the plurality of electricity storage members, controls whether to continuously perform charging and discharging operations of the electricity storage member or not.

2. The power supply device according to claim 1, further comprising:

a switching circuit which switches a connection state of the plurality of electricity storage members to a first state in which the plurality of electricity storage member groups is connected in series, and to a second state in which the plurality of electricity storage member groups is connected in parallel,

wherein the control circuit switches the connection state to the second state when the electricity storage circuit starts the charging, and switches the connection state to the first state when the electricity storage circuit completes the charging.

3. The power supply device according to claim 1 or 2, wherein the control circuit stops the charging and discharging operations and outputs notification information to a notification device connected to the power supply device, if all electricity storage members that are included in at least one of the plurality of electricity storage member groups fail.

4. The power supply device according to claim 1 or 2,

wherein the control circuit continuously performs the charging and discharging operations and outputs first notification information to a notification device connected to the power supply device, if one or more electricity storage members that do not fail are included in all of the plurality of electricity storage member groups, and

wherein the control circuit stops the charging and discharging operations and outputs second notification information to the notification device, if all the electricity storage members that are included in at least one of the plurality of electricity storage members fail.

5. An electronic apparatus that includes a power supply device which performs charging and discharging using a plurality of electricity storage members, the apparatus comprising:

an electricity storage circuit which includes the plurality of electricity storage members, and a plurality of disconnecting circuits that corresponds to each of the plurality of electricity storage members and, if a corresponding electricity storage member fails, disconnects the electricity storage member such that a current does not flow through the electricity storage member, and in which the plurality of electricity storage members is grouped in a plurality of electricity storage member groups, each group having two or more electricity storage members connected in parallel, and the plurality of electricity storage members are connected in series; and

a control circuit which, based on a connection position of a failed electricity storage member among the plurality of electricity storage members, controls whether to continuously perform charging and discharging operations of the electricity storage member or not.

6. A power control method of a power supply device that performs charging and discharging using a plurality of electricity storage members, the method comprising:

disconnecting an electricity storage member such that a current does not flow through the electricity storage member, if at least one of a plurality of disconnecting circuits detects failure of a corresponding electricity storage member, in a state in which a plurality of electricity storage members is grouped in a plurality of electricity storage member groups, each group having two or more electricity storage members connected in parallel, the plurality of electricity storage member groups are connected in series, and the plurality of disconnecting circuits corresponding to each of the plurality of electricity storage members is disposed; and

causing a control circuit to control whether to continuously perform charging and discharging operations of the electricity storage member or not, based on a connection position of a failed electricity storage member among the plurality of electricity storage members.

ABSTRACT

Drawings

|  |  |
| --- | --- |
| FIG. 1 |  |
|  | CHARGING CIRCUIT AND LOAD |
| 2 | ELECTRICITY STORAGE CIRCUIT |
| 13a,13b,13c,13d,13e,13f | DISCONNECTING CIRCUIT |
| 11a,11b,11c,11d,11e,11f | ELECTRICITY STORAGE MEMBER |
| 3 | CONTROL CIRCUIT |
| 1 | POWER SUPPLY DEVICE |
|  | CHARGING AND DISCHARGING OPERATION CONNECTION |
|  | CHARGING AND DISCHARGING OPERATION STOP |
|  | STATE 1 |
|  | STATE 2 |
| FIG. 2 |  |
| 5a,5b,5c | ELECTRICITY STORAGE MEMBER |
|  | CHARGING |
| FIG. 3 |  |
| 5a,5b,5c | ELECTRICITY STORAGE MEMBER |
|  | CHARGING |
| FIG. 4 |  |
| 100 | STORAGE DEVICE |
| 200 | POWER SUPPLY CIRCUIT |
| 104 | PROCESSOR |
| 300 | HOST DEVICE |
| FIG. 5 |  |
|  | DC INPUT |
| 201 | BUTT CIRCUIT |
| 200 | POWER SUPPLY CIRCUIT |
| 230 | CHARGING CIRCUIT |
| 210 | CONTROLLER |
| 220 | POWER SUPPLYING CIRCUIT |
| 213 | FLASH MEMORY |
| 214 | VOLTAGE MONITOR |
| 215 | I/F CIRCUIT |
| 250 | LIC UNIT |
| 240 | DISCHARGING FET |
| FIG. 6 |  |
| 230 | CHARGING CIRCUIT |
| 210 | CONTROLLER |
| 214 | VOLTAGE MONITOR |
| 240 | DISCHARGING FET |
| 255a, 255b, 255c, 255d, 255e, 255f | SWITCHING CIRCUIT |
| 254a, 254b, 254c, 254d, 254e, 254f | FUSE |
| FIG. 7 |  |
| 230 | CHARGING CIRCUIT |
|  | SWITCHING |
| 240 | DISCHARGING FET |
| FIG. 8 |  |
| 240 | DISCHARGING FET |
|  | FAILURE |
|  | REPORT LIC FAILURE AND OPERATION CONTINUATION (LIGHT LED 103a) |
|  | REPORT LIC FAILURE AND OPERATION STOP (LIGHT LED 103b) |
| FIG. 9 |  |
|  | START |
| S11 | TURN OFF DISCHARGING FET |
| S12 | SWITCH TO ONE-SERIES SIX-PARALLEL |
| S13 | START CHARGING |
| S14 | DOES BOTH-TERMINAL VOLTAGEEXCEED MAXIMUM THRESHOLD VALUE ? |
| S15 | IS LIC FAILURE DETECTED ? |
| S16 | ALERT LIC FAILURE AND OPERATION CONTINUATION |
| S17 | DOES CELL WITH ALL FAILED LIC EXIST ? |
| S18 | STOP CHARGING |
| S19 | ALARM OF OPERATION STOP |
|  | END |
| FIG. 10 |  |
| S21 | STOP CHARGING |
| S22 | SWITCH TO THREE-SERIES TWO-PARALLEL |
| S23 | TURN ON DISCHARGING FET |
| S24 | IS DC INPUT ? |
| FIG. 11 |  |
| S31 | IS DC INPUT ? |
| S32 | IS BOTH-TERMINAL VOLTAGE LOWER THAN MINIMUM THRESHOLD VALUE ? |
| S33 | IS FAILED LIC DETECTED ? |
| S34 | ALERT LIC FAILURE AND OPERATION CONTINUATION |
| S35 | DOES CELL WITH ALL FAILED LIC EXIST ? |
| S36 | ALARM OF OPERATION STOP |
| S37 | TURN OFF DISCHARGING FET |
|  | END |