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(54) BATTERY DEVICE

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(57) ABSTRACT

A battery device includes: a storage unit that stores battery information including a closed circuit voltage of a plurality of battery cells electrically connected to each other and a change amount in the closed circuit voltage; a setting unit that sets an acquisition range of the closed circuit voltage based on the battery information; a detection unit that detects the closed circuit voltage; and a conversion unit that converts the closed circuit voltage detected by the detection unit into a digital signal within the acquisition range set by the setting unit.

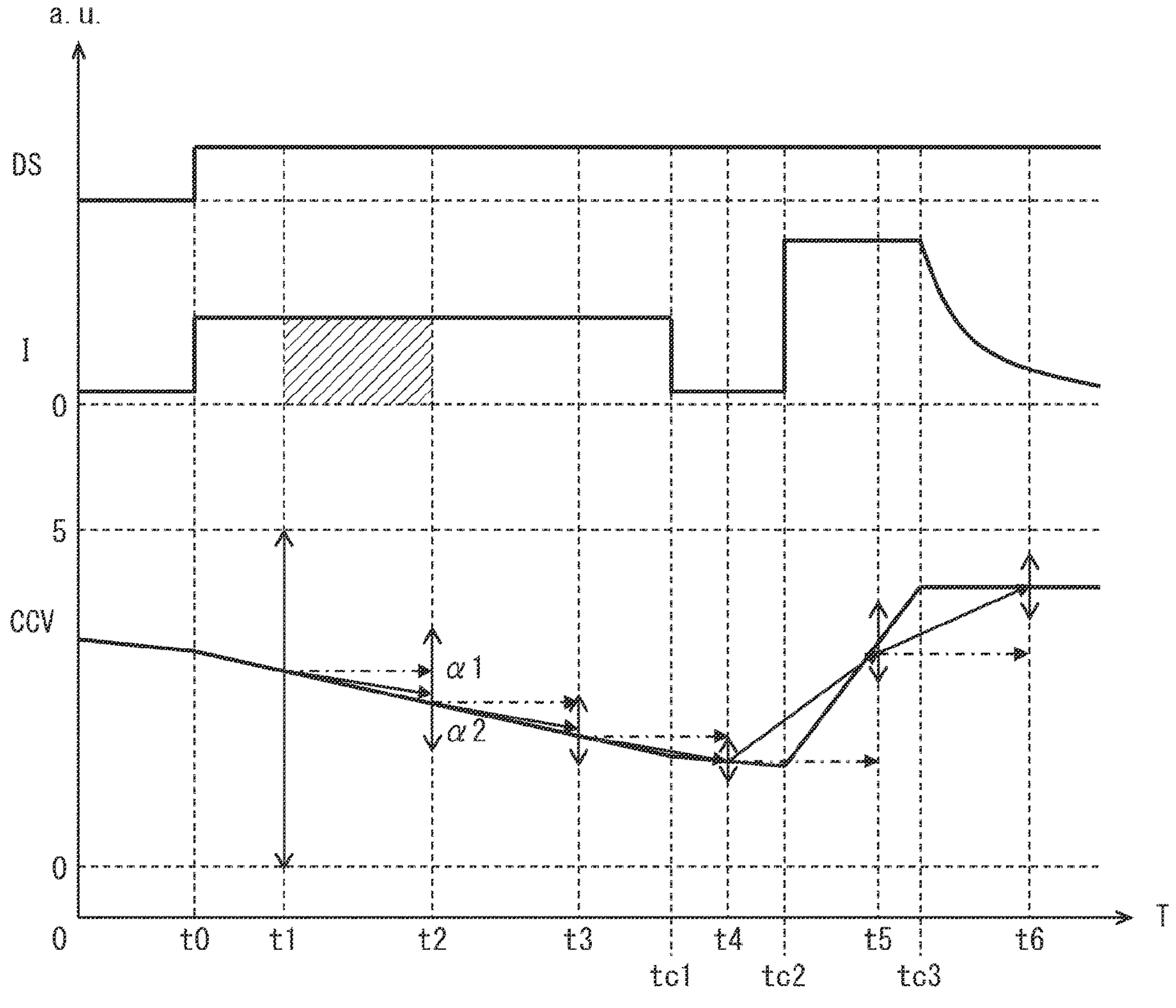
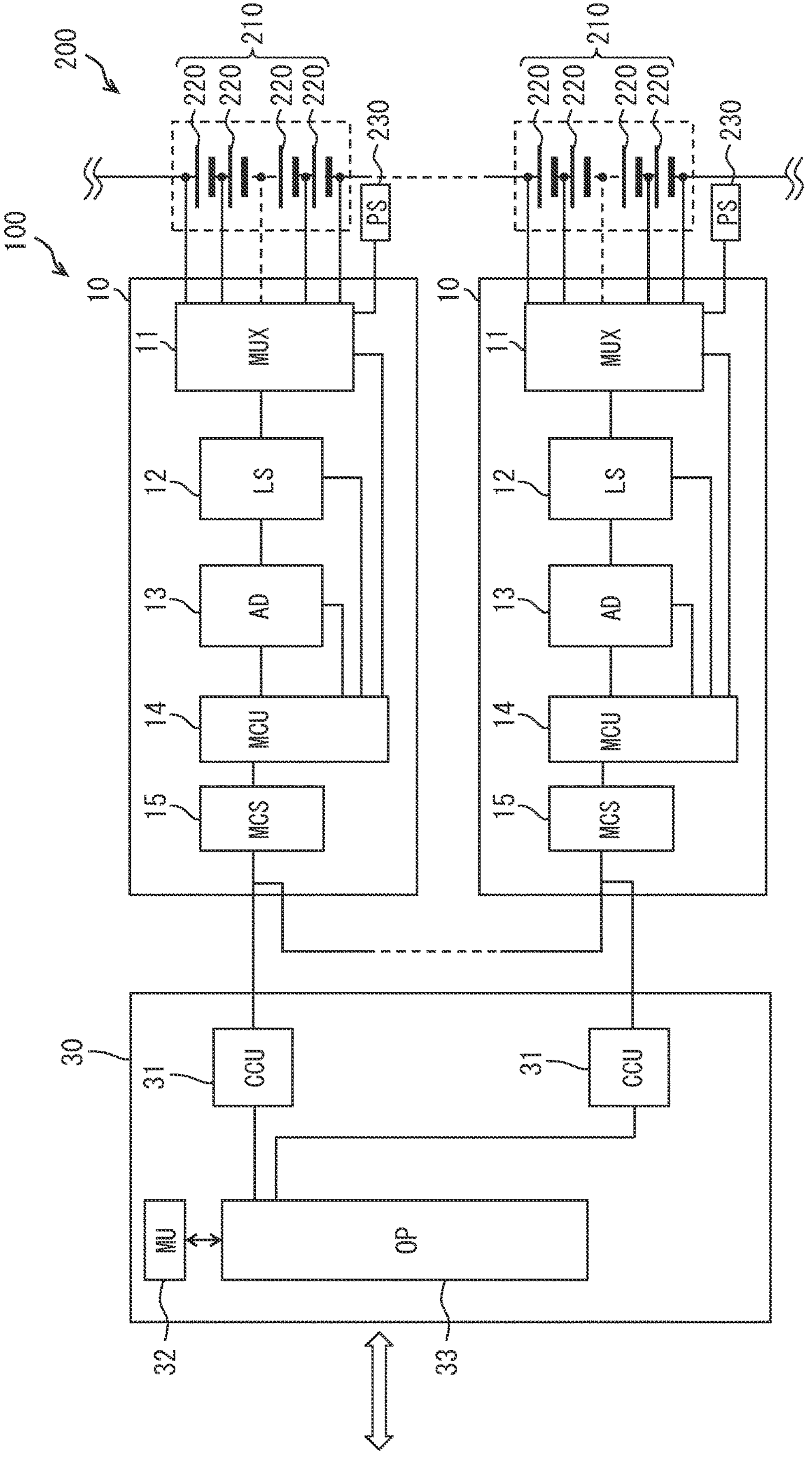


FIG. 1


100
200
210
220
220
220
220
230
PS
10
11
MUX
12
LS
13
AD
14
MCU
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210
220
220
220
220
230
PS
10
11
MUX
12
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MCU
15
MCS
30
31
CCU
31
CCU
MU
OP
32
33

FIG. 2

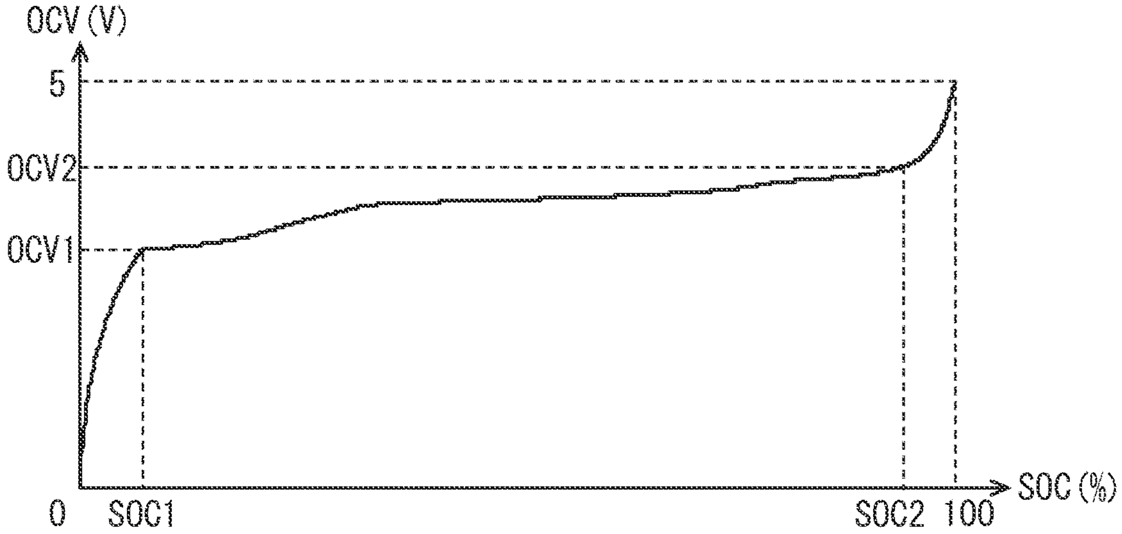


FIG. 3

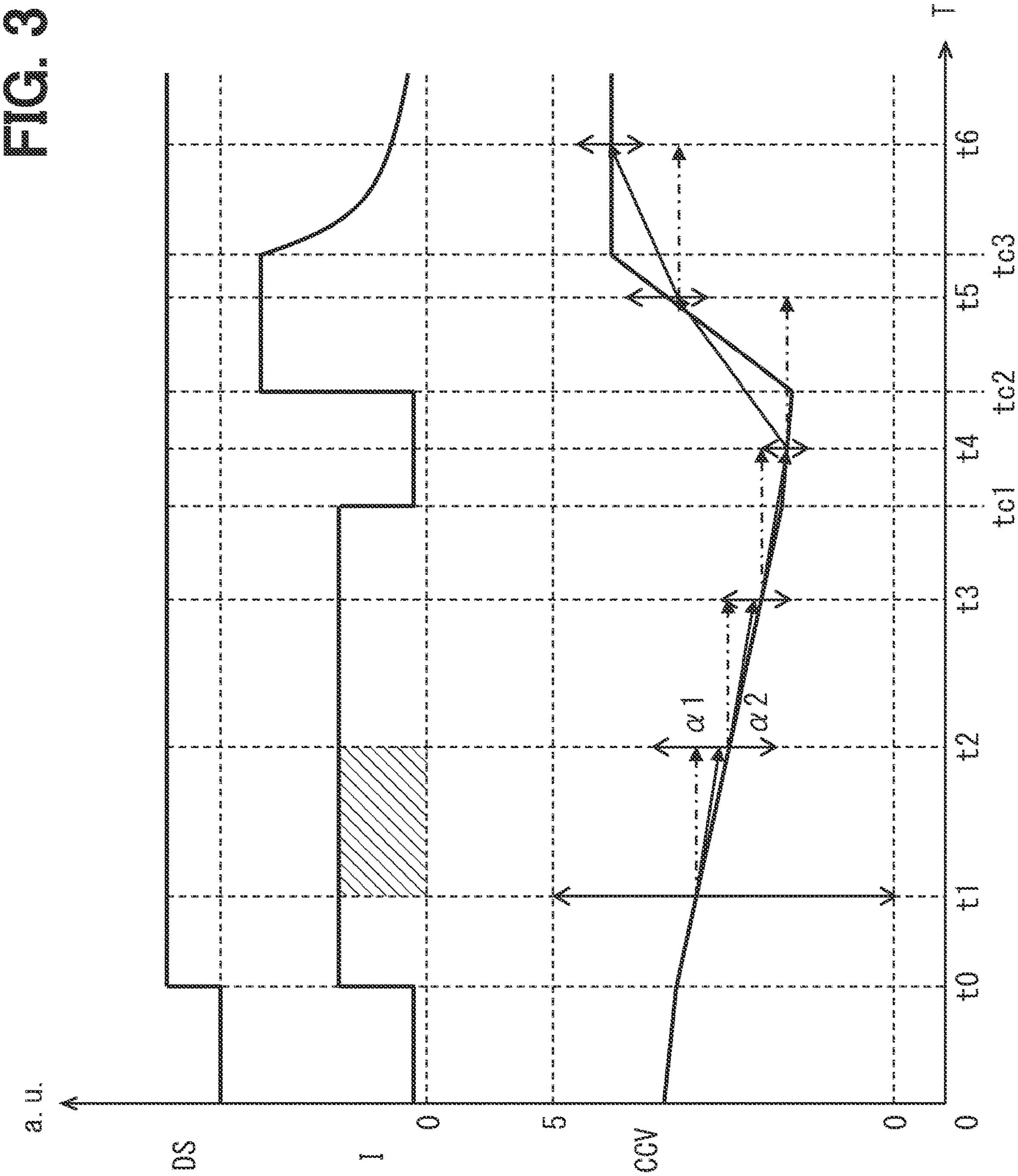


FIG. 4

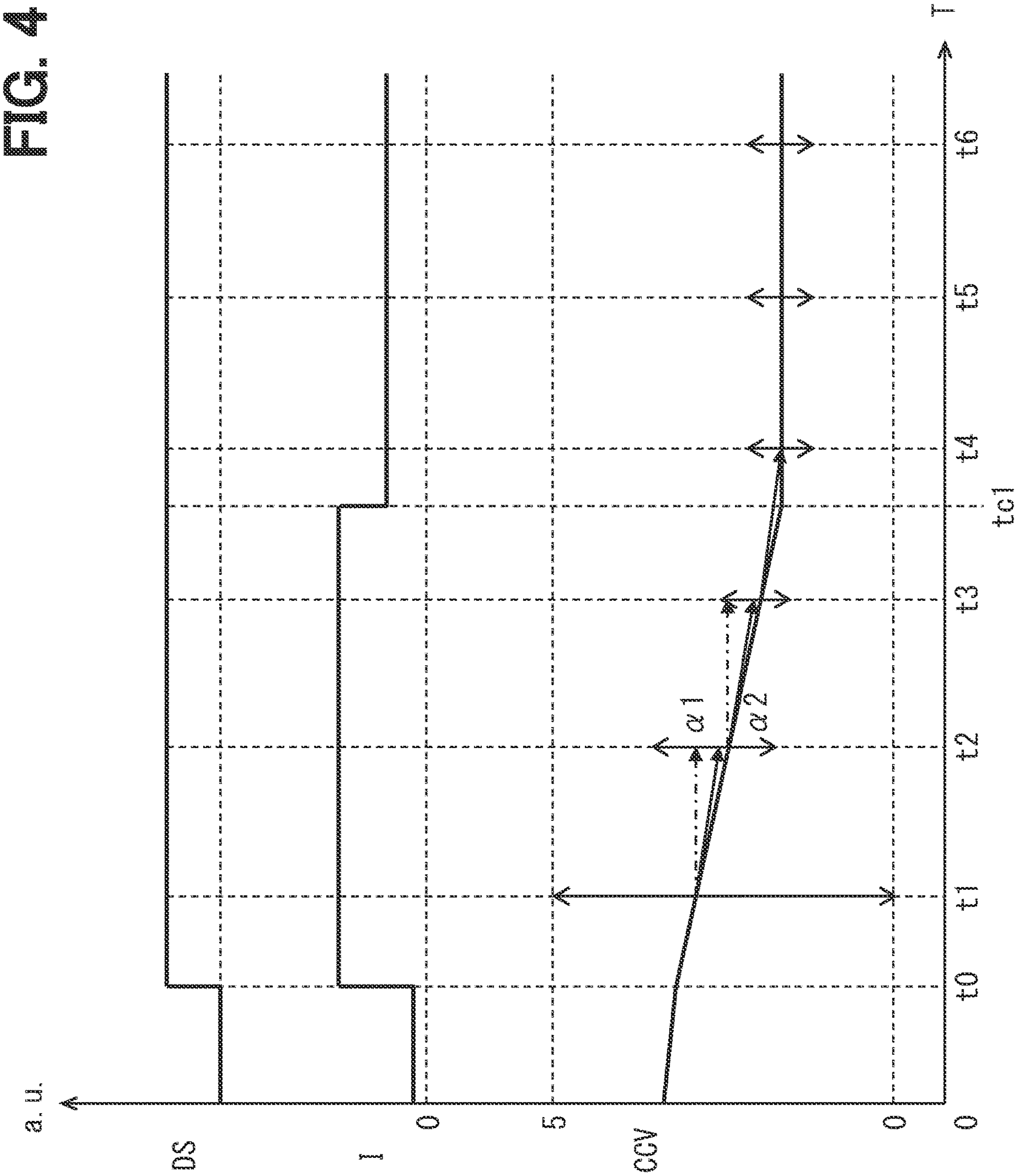
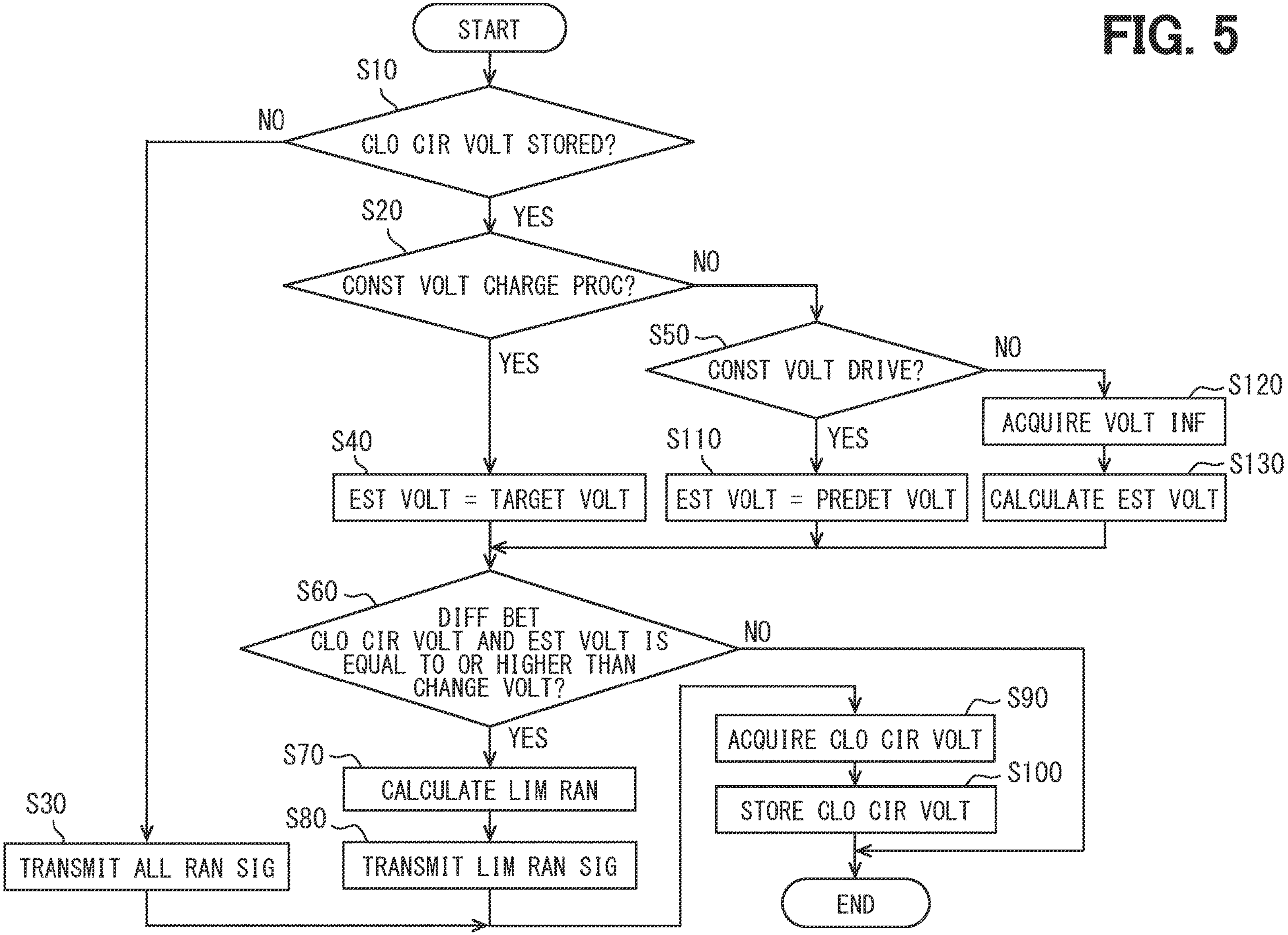


FIG. 5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CLO CIR VOLT STORED?
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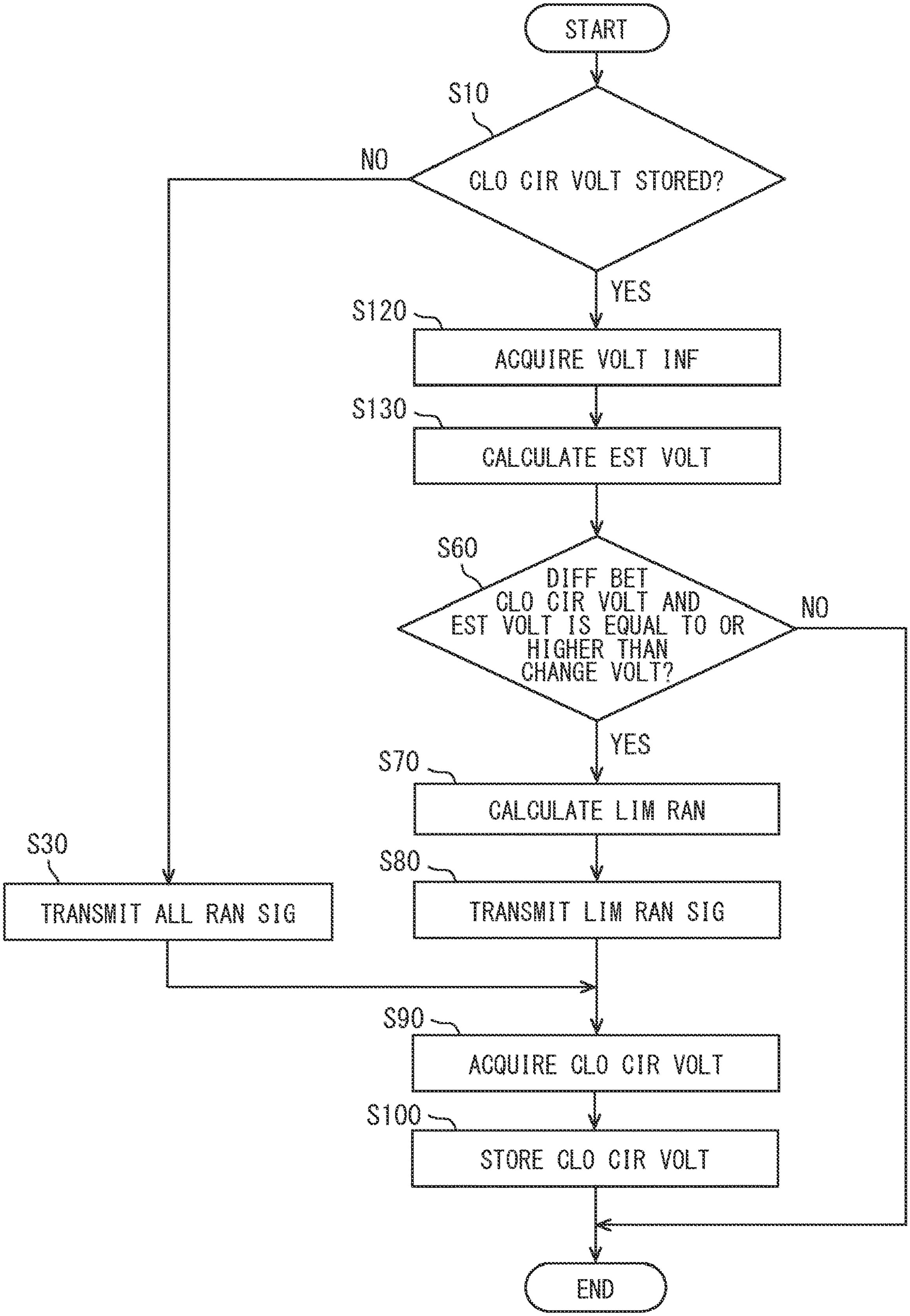
YES
S20
CONST VOLT CHARGE PROC?
NO
S50
CONST VOLT DRIVE?
NO
YES
S40
EST VOLT = TARGET VOLT
S110
EST VOLT = PREDET VOLT
S120
ACQUIRE VOLT INF
S130
CALCULATE EST VOLT
S60
DIFF BET CLO CIR VOLT AND EST VOLT IS EQUAL TO OR HIGHER THAN CHANGE VOLT?
NO
YES
S70
CALCULATE LIM RAN
S80
TRANSMIT LIM RAN SIG
S30
TRANSMIT ALL RAN SIG
S90
ACQUIRE CLO CIR VOLT
S100
STORE CLO CIR VOLT
END

FIG. 6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YES
S120
ACQUIRE VOLT INF
S130
CALCULATE EST VOLT
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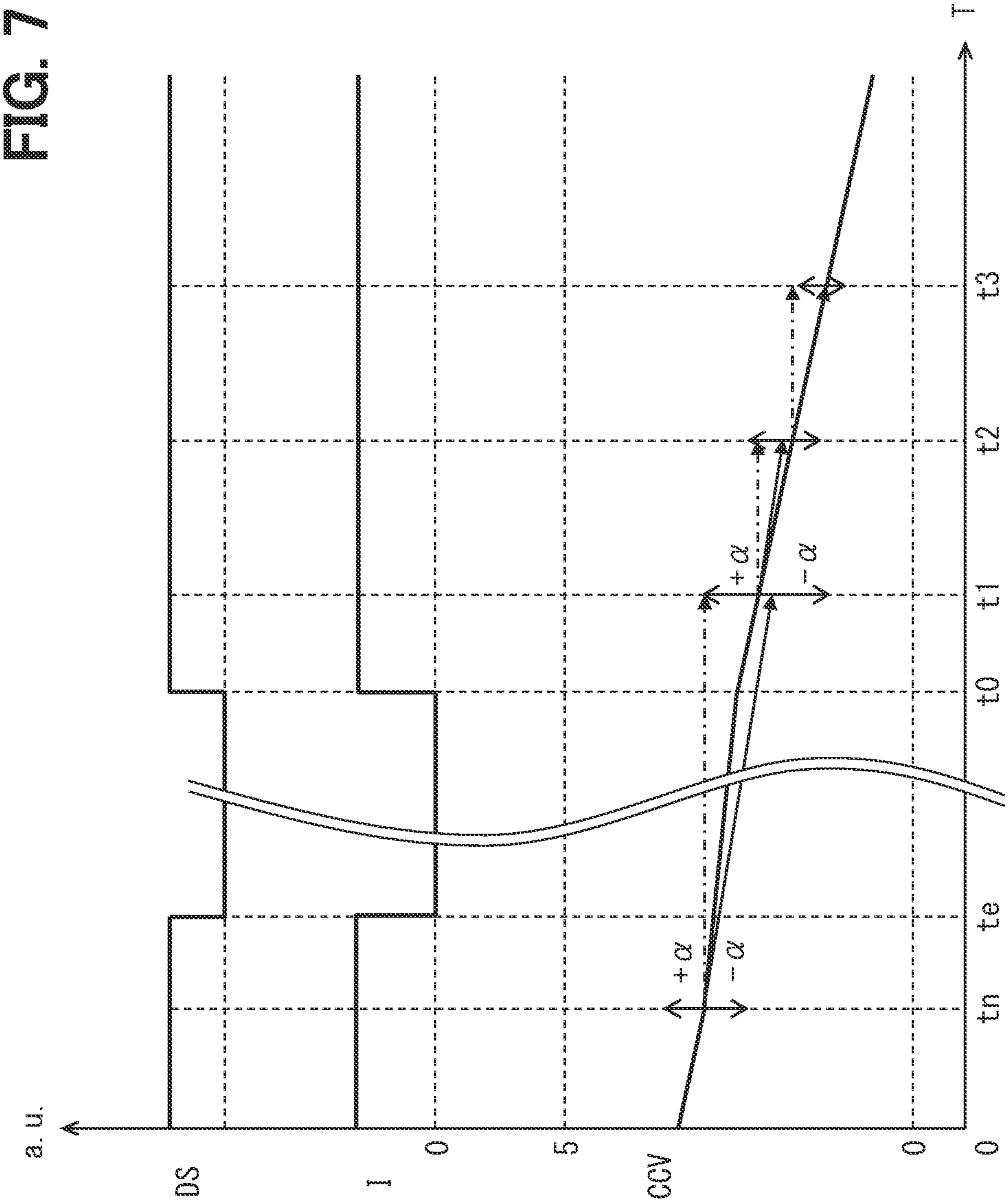
YES
S70
CALCULATE LIM RAN
S80
TRANSMIT LIM RAN SIG
S30
TRANSMIT ALL RAN SIG
S90
ACQUIRE CLO CIR VOLT
S100
STORE CLO CIR VOLT
END

FIG. 7



BATTERY DEVICE

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] The present application is a continuation application of International Patent Application No. PCT/JP2022/004619 filed on Feb. 7, 2022, which designated the U.S. and claims the benefit of priority from Japanese Patent Application No. 2021-049206 filed on Mar. 23, 2021. The entire disclosures of all of the above applications are incorporated herein by reference.

TECHNICAL FIELD

[0002] The disclosure provided herein relates to a battery device.

BACKGROUND

[0003] A conceivable technique teaches a capacity adjustment device that equalizes the SOCs of a plurality of lithium secondary batteries.

SUMMARY

[0004] According to an example, a battery device may include: a storage unit that stores battery information including a closed circuit voltage of a plurality of battery cells electrically connected to each other and a change amount in the closed circuit voltage; a setting unit that sets an acquisition range of the closed circuit voltage based on the battery information; a detection unit that detects the closed circuit voltage; and a conversion unit that converts the closed circuit voltage detected by the detection unit into a digital signal within the acquisition range set by the setting unit.

BRIEF DESCRIPTION OF THE DRAWINGS

[0005] The above and other objects, features and advantages of the present disclosure will become more apparent from the following detailed description made with reference to the accompanying drawings. In the drawings:

[0006] FIG. **1** is a block diagram showing a battery device and an assembled battery;

[0007] FIG. **2** is a graph showing SOC and OCV characteristics;

[0008] FIG. **3** is a timing chart showing voltage detection;

[0009] FIG. **4** is a timing chart showing voltage detection;

[0010] FIG. **5** is a flowchart illustrating voltage detection process;

[0011] FIG. **6** is a flowchart illustrating voltage detection process; and

[0012] FIG. **7** is a timing chart showing voltage detection.

DETAILED DESCRIPTION

[0013] The closed circuit voltage of lithium secondary batteries is used to equalize the SOCs of a plurality of lithium secondary batteries. Therefore, it is required to improve the detection accuracy of the closed circuit voltage.

[0014] An object of the present disclosure is to provide a battery device with improved detection accuracy of a closed circuit voltage.

[0015] A battery device according to an aspect of the present embodiments includes a storage unit that stores battery information including closed circuit voltages of a plurality of electrically connected battery cells and an amount of change in the closed circuit voltage;

[0016] a setting unit that sets an acquisition range of the closed circuit voltage based on the battery information; and

[0017] a detection unit that detects the closed circuit voltage; and

[0018] a conversion unit that converts the closed circuit voltage detected by the detection unit into a digital signal within the acquisition range set by the setting unit.

[0019] According to this, the detection accuracy of the closed circuit voltage is improved.

[0020] The reference numerals in parentheses above indicate only a correspondence relationship with the configuration described in the embodiment to be described later, and do not limit the technical range in any way.

[0021] The following will describe embodiments for carrying out the present disclosure with reference to the drawings. In each of embodiments, parts/configurations corresponding to the elements described in the preceding embodiments are denoted by the same reference numerals, and redundant explanation may be omitted. When only a part of a configuration is described in an embodiment, another preceding embodiment may be applied to the other parts of the configuration.

[0022] When, in each embodiment, it is specifically described that combination of parts is possible, the parts can be combined. In a case where any obstacle does not especially occur in combining the parts of the respective embodiments, it is possible to partially combine the embodiments, the embodiment and the modification, or the modifications even when it is not explicitly described that combination is possible.

First Embodiment

[0023] A first embodiment will be described with reference to FIGS. **1** to **6**.

[0024] FIG. **1** shows a battery device **100** and an assembled battery **200**. The battery device **100** and the assembled battery **200** are mounted on an electric vehicle such as a hybrid vehicle or an electric vehicle. The electric vehicles include passenger cars, buses, construction vehicles, agricultural machinery vehicles, and the like.

[0025] The battery device **100** monitors and controls the state of the assembled battery **200**. The assembled battery **200** supplies electric power to various in-vehicle devices such as an electric motor that provides driving force to the electric vehicle.

[0026] (Assembled Battery)

[0027] The assembled battery **200** has a plurality of battery stacks **210**. Each of the plurality of battery stacks **210** has a plurality of battery cells **220** electrically connected in series. As the battery cell **220**, a secondary battery such as a lithium-ion secondary battery, a nickel-hydrogen secondary battery, or an organic radical battery can be employed. The output voltage of the battery cells **220** connected in series is the output voltage of the battery stack **210**. In FIG. **1**, a plurality of battery cells **220** included in one battery stack **210** are shown surrounded by dashed lines.

[0028] A plurality of battery stacks **210** are electrically connected in series or in parallel. In this embodiment, a plurality of battery stacks **210** are electrically connected in series. The output voltage of the assembled battery **200** is the sum of the output voltages of the plurality of battery stacks **210** connected in series. The power source electric power depending on this output voltage is supplied to various in-vehicle devices.

[0029] Each of the plurality of battery stacks **210** is provided with a physical quantity sensor **230** that detects the physical quantity of the battery cell **220**. The physical quantities detected by the physical quantity sensor **230** include, for example, the temperature and the current of the battery cell **220**.

[0030] The physical quantity detected by the physical quantity sensor **230** is used for estimating the SOC of each of the battery cell **220**, the battery stack **210**, and the assembled battery **200**, and the like. The SOC is an abbreviation for state of charge. The SOC corresponds to the charge amount.

[0031] The SOC is reduced by supplying the above power source electric power to various in-vehicle devices. Also, the battery cell **220** self-discharges. Therefore, the SOC decreases even when the power source electric power is not supplied.

[0032] This decrease in the SOC is improved by supplying the charging power to the assembled battery **200** from a charging device such as an electric station disposed outside the vehicle, for example. The supply of charging the electric power from the charging device to the assembled battery **200** is controlled by the battery device **100**. The battery device **100** controls the charging of the assembled battery **200** while transmitting and receiving a CPLT signal to and from the charging device via a wiring (not shown).

[0033] Note that the quality and environment of the plurality of battery cells **220** are not uniform. Therefore, the SOCs of the plurality of battery cells **220** may vary. This variation is improved by an equalization process, which will be described later.

[0034] <OCV, CCV, SOC>

[0035] The battery cell **220** has an internal resistance. Therefore, there is a difference of a voltage drop between the actual cell voltage according to the SOC of the battery cell **220** and the cell voltage detected by the monitor unit **10**, and the voltage drop corresponds to the internal resistance and the current flowing through the battery cell **220**.

[0036] Hereinafter, the actual cell voltage corresponding to the SOC of the battery cell **220** will be referred to as an open path voltage OCV as required. A cell voltage detected by the monitor unit **10** is indicated as a closed circuit voltage CCV. The internal resistance R is the resistance in the battery cell **220** and the actual current I is the current that actually flows through the battery cell **220**. OCV is an abbreviation for Open Circuit Voltage. CCV is an abbreviation for Closed Circuit Voltage.

[0037] A relationship between the closed circuit voltage CCV and the open circuit voltage OCV is expressed as CCV=OCV±I×R. When the battery cell **220** is discharged, the above relationship is expressed as CCV=OCV−I×R. When the battery cell **220** is charged, the above relationship is expressed as CCV=OCV+I×R.

[0038] <Characteristics of SOC and OCV>

[0039] The battery cell **220** has SOC and OCV characteristics. FIG. **2** shows SOC and OCV characteristic data when the battery cell **220** is a lithium ion battery.

[0040] As shown in FIG. **2**, in the over-discharge region where the SOC is close to 0%, the rate of change of OCV with respect to SOC is high. In the over-charge region where the SOC is close to 100%, the rate of change of OCV with respect to SOC is high.

[0041] On the other hand, in the charge/discharge region between the over-discharge region and the over-charge region, the rate of change of OCV with respect to SOC is low. The battery cell **220** is mainly used in this charge/discharge region. In FIG. **2**, as an example, the values of the SOC and the OCV between the over-discharge region and the charge/discharge region are expressed as SOC**1** and OCV**1**. The values of the SOC and the OCV between the charge/discharge region and the over-charge region are denoted as SOC**2** and OCV**2**.

[0042] The characteristic data shown in FIG. **2** are temperature dependent. Therefore, the rate of change of OCV with respect to SOC changes depending on the temperature. Along with this, the values of SOC**1**, SOC**2**, OCV**1** and OCV**2** also change.

[0043] <Battery Device>

[0044] The battery device **100** has a monitor unit **10** and a control unit **30**. The battery device **100** has the same number of monitor units **10** as the battery stacks **210**. The plurality of monitor units **10** detect battery information related to the state of each of the plurality of battery stacks **210**.

[0045] The control unit **30** acquires battery information detected by the multiple monitor units **10**. The control unit **30** also acquires vehicle information input from various other ECUs and various sensors (not shown). When a charging device is connected to the electric vehicle, the control unit **30** acquires charging information input from the charging device. The input of the vehicle information and charging information to the control unit **30**, and the output of the processing result of the control unit **30** to various ECUs, the charging device and the like are indicated by white arrows in FIG. **1**.

[0046] The control unit **30** determines the state of the assembled battery **200** based on the acquired information. At the same time, the control unit **30** executes processing for the assembled battery **200**. The processing for the assembled battery **200** includes, for example, charge/discharge of the assembled battery **200**, equalization processing for equalizing the SOCs of the plurality of battery cells **220** included in the assembled battery **200**, and the like.

[0047] <Monitor Unit>

[0048] Each of the plurality of monitor units **10** is individually provided for each of the plurality of battery stacks **210**. One monitor unit **10** detects the inter-terminal voltage (i.e., the closed circuit voltage) between the positive and negative electrodes of each of the plurality of battery cells **220** included in one battery stack **210**. Also, the monitor unit **10** acquires the physical quantity detected by the physical quantity sensor **230**. The monitor unit **10** executes processing based on instruction signals input from the control unit **30**.

[0049] As shown in FIG. **1**, the monitor unit **10** has a multiplexer **11**, a level shifter **12**, an AD conversion unit **13**, a monitor control unit **14** and a monitor communication unit **15**. In the drawing, the multiplexer **11** is written as MUX. The level shifter **12** is written as LS. The AD conversion unit **13** is written as AD. The monitor control unit **14** is written as MCU. The monitor communication unit **15** is written as MCS.

[0050] The multiplexer **11** is connected to the positive and negative electrodes of each of the plurality of battery cells **220** included in one battery stack **210**. As a result, the multiplexer **11** receives the closed circuit voltages of the plurality of battery cells **220**.

[0051] Also, the multiplexer **11** is connected to the physical quantity sensor **230**. Thereby, the physical quantity is input to the multiplexer **11**.

[0052] The multiplexer **11** sequentially selects and detects a plurality of input closed circuit voltages. The multiplexer **11** sequentially outputs the detected closed circuit voltages to the level shifter **12**. The multiplexer **11** also sequentially selects and detects a plurality of input physical quantities. The multiplexer **11** also sequentially outputs the detected physical quantities to the level shifter **12**. The multiplexer **11** corresponds to the detection unit.

[0053] The level shifter **12** includes an operational amplifier and multiple feedback circuits connected in parallel between an input terminal and an output terminal of the operational amplifier. This feedback circuit includes a switch and a capacitor connected in series. The capacitances of the capacitors included in the multiple feedback circuits may be the same or different.

[0054] The switches of the plurality of feedback circuits of the level shifter **12** are selectively controlled to turn on and off by the monitor control unit **14**. As a result, the number of capacitors connected between the input terminal and the output terminal of the operational amplifier changes. The capacitance between the input terminal and the output terminal of the operational amplifier changes. In addition, the resistance between the input terminal and the output terminal of the operational amplifier changes. As a result, the gain and the offset of the level shifter **12** are controlled.

[0055] The analog signals of the closed circuit voltage and the physical quantity whose gain and offset are adjusted is input from the level shifter **12** to the AD conversion unit **13**. The AD conversion unit **13** has a clamp circuit for limiting the input range. This clamp circuit is controlled by the monitor control unit **14**. The input range of the AD conversion unit **13** is thereby controlled.

[0056] By limiting the input range of the AD conversion unit **13** and adjusting the gain and the offset of the level shifter **12**, the voltage range of the analog signal converted from analog to digital by the AD conversion unit **13** is controlled. The voltage ranges of the closed circuit voltage and the physical quantity that are analog-to-digital converted by the AD conversion unit **13** are controlled. As a result, the acquisition ranges of the closed circuit voltage and the physical quantity are controlled. Note that it is not necessary to particularly control the acquisition range of the physical quantity. The level shifter **12** and the AD conversion unit **13** correspond to the converter.

[0057] The AD conversion unit **13** intermittently samples continuous analog signals. Then, the AD conversion unit **13** quantizes the sampled values and converts them into discrete digital signals. Due to such conversion, there may be an error (i.e., the quantization error) between the analog signal and the digital signal.

[0058] This quantization error becomes smaller as the number of quantization bits of the AD conversion unit **13** increases. However, the number of quantization bits is fixed. Therefore, for example, when the acquisition range of the closed circuit voltage is between 0.0V and 5.0V, the resolution of the AD conversion unit **13** is the value obtained by dividing this range between 0.0V and 5.0V by the number of quantization bits.

[0059] On the other hand, for example, when the acquisition range of the closed circuit voltage is between 3.0 V and 3.5 V, which is 1/10 of the above range, the resolution of the AD conversion unit **13** is the value obtained by dividing the range between 3.0 V and 3.5 V by the number of quantization bits. In this case, the resolution of the AD conversion unit **13** is increased by about ten times. By limiting the acquisition range in this way, the detection accuracy of the closed circuit voltage is improved.

[0060] The monitor control unit **14** has a processor and a non-transitional tangible storage medium that non-transitory stores a program readable by the processor. A digital signal input from the AD conversion unit **13** and an instruction signal input from the control unit **30** are stored in this non-transitory tangible storage medium. The processor of the monitor control unit **14** controls the multiplexer **11**, the level shifter **12**, and the AD conversion unit **13** based on the instruction signal.

[0061] The instruction signal input to the monitor control unit **14** includes the acquisition range of the closed circuit voltage of the battery cell **220** as a detection target. The monitor control unit **14** controls the gain and the offset of the level shifter **12** when the multiplexer **11** selects the closed circuit voltage as the detection target. The monitor control unit **14** limits the input range of the AD conversion unit **13**. This controls the acquisition range of the closed circuit voltage.

[0062] The digital signals of the closed circuit voltage and the physical quantity are input to the monitor communication unit **15**. The monitor communication unit **15** outputs this digital signal to the control unit **30**.

[0063] <Control Unit>

[0064] As shown in FIG. **1**, the control unit **30** has a control communication unit **31**, a storage unit **32** and a calculation unit **33**. In the drawing, the control communication unit **31** is denoted as CCU. The storage unit **32** is referred to as MU. The calculation unit **33** is referred to as OP.

[0065] Various information is input to the control communication unit **31**. This information includes the closed circuit voltage and the physical quantity acquired by the monitor unit **10**. In addition, this information includes vehicle information and charging information. The vehicle information includes the running state of the electric vehicle and the current time. The charging information includes charging electric power.

[0066] Note that vehicle information and charging information may be input to a communication unit (not shown). And when the control unit **30** has RTC, the present time does not need to be included in the vehicle information. RTC stands for Real Time Clock.

[0067] The storage unit **32** is a non-transitory tangible storage medium that non-transitory stores programs that can be read by a computer or a processor. The storage unit **32** includes a volatile memory and a nonvolatile memory. Various information input to the control communication unit **31** and processing results of the calculation unit **33** are stored in the storage unit **32**.

[0068] In addition, the storage unit **32** stores in advance programs and reference values for the calculation unit **33** to perform calculation processing. The reference values include, for example, the temperature dependence of SOC and OCV characteristic data of various secondary batteries, an equalization determination value for determining execution of equalization processing, manufacturing dates of the plurality of battery cells **220**, and deterioration determination value, and the like.

[0069] The calculation unit **33** has a processor. The calculation unit **33** stores various information input to the control communication unit **31** in the storage unit **32**. The calculation unit **33** executes various calculation processes based on the information stored in the storage unit **32**. An electrical signal including the result of this calculation processing is output to the monitor unit **10** via the control communication unit **31**. An electric signal including the result of the calculation processing is output to various ECUs via the control communication unit **31** or a communication unit (not shown).

[0070] As a specific example of the calculation process, the calculation unit **33** estimates the SOC of the battery cell **220** based on the information stored in the storage unit **32**. The calculation unit **33** generates an instruction signal for instructing the operation of the monitor unit **10** based on the estimated SOC and the information stored in the storage unit **32**. This instruction signal includes the acquisition range of the closed circuit voltage of the battery cell **220** as the detection target. Note that if the battery information for estimating the SOC is not stored in the storage unit **32**, the calculation unit **33** sets the acquisition range of the closed circuit voltage to a possible range of the closed circuit voltage of the battery cell **220**. The calculation unit **33** corresponds to the setting unit.

[0071] In addition to determining the acquisition range of the closed circuit voltage, the calculation unit **33** determines execution of an equalization process for reducing variations in the SOCs of the plurality of battery cells **220**. The calculation unit **33** outputs an instruction signal including equalization processing for each of the plurality of battery stacks **210** to the monitor unit **10**.

[0072] The calculation unit **33** calculates the difference between the maximum value and the minimum value of the closed circuit voltage input from the monitor unit **10**. When this difference exceeds the equalization determination value, the calculation unit **33** determines to execute the equalization process. This equalization process may be performed, for example, only in the battery stack **210** in which at least one of the maximum value and the minimum value of the closed circuit voltage is detected. The equalization process may be performed on all battery stacks **210**.

[0073] Although not clearly shown in the drawing, the monitor unit **10** has a plurality of switches that bridge a plurality of wires connecting the multiplexer **11** and the positive and negative electrodes of the plurality of battery cells **220**, respectively. The monitor control unit **14** selectively controls the plurality of switches between the energization state and the cut-off state based on the instruction signal input from the calculation unit **33**. As a result, the battery cell **220** with a relatively high SOC among the plurality of electrically connected battery cells **220** is discharged. Conversely, a battery cell **220** with relatively low SOC is charged. As a result, the SOCs of the plurality of battery cells **220** are equalized.

[0074] <Acquisition of Closed Circuit Voltage>

[0075] Due to the SOC and OCV characteristics of the battery cell **220** shown in FIG. **2**, when the SOC drops due to discharge, the OCV also drops. Along with this, the closed circuit voltage CCV of the battery cell **220** also decreases. Conversely, when the SOC increases due to the supply of charging electric power from the charging device, the closed circuit voltage CCV also increases.

[0076] FIG. **3** shows the time change of the closed circuit voltage. The vertical axis is an arbitrary unit. The horizontal axis is time. The arbitrary unit is indicated by a. u. The time is indicated by T.

[0077] In addition to the closed circuit voltage, FIG. **3** shows the driving state of the battery device **100**, the actual current flowing through the assembled battery **200**, and the closed circuit voltage of one battery cell **220**. The driving state of the battery device **100** is described as DS. For the sake of simplicity, the behavior of the closed circuit voltage of the battery cell **220** and the behavior of the closed circuit voltage of the assembled battery **200** shown in the drawings are assumed to be the same. In order to clarify the behavior, the drawing shows that the closed circuit voltage of the battery cell **220** changes significantly in a short time.

[0078] In the initial state at time **0**, the battery device **100** is in a non-driving state. The storage unit **32** does not store battery information such as the closed circuit voltage and the physical quantity. The system main relay that controls the conduction state between the assembled battery **200** and various in-vehicle devices is in the cutoff state. Therefore, no current is substantially flowing through the assembled battery **200**. The closed circuit voltage of the battery cell **220** has a value in the charge/discharge region.

[0079] Even when no current is substantially flowing through the battery cell **220**, the SOC of the battery cell **220** decreases due to self-discharge. Therefore, in the initial state of time **0**, the closed circuit voltage of the battery cell **220** tends to decrease in a small amount.

[0080] At time t**0**, the battery device **100** changes from the non-driving state to the driving state. The system main relay changes from the cutoff state to the energization state. As a result, the supply of power source electric power from the assembled battery **200** to various in-vehicle devices is started. The actual current begins to flow in the assembled battery **200**. The rate of decrease in the SOC of the battery cell **220** increases. Along with this configuration, the rate of decrease in the closed circuit voltage of the battery cell **220** also increases.

[0081] At time t**1**, the calculation unit **33** acquires the closed circuit voltage of the battery cell **220**. At this time, the battery information is not stored in the storage unit **32**. Therefore, the calculation unit **33** sets the acquisition range of the closed circuit voltage at the time t**1** to a possible range that the battery cell **220** can take. That is, the calculation unit **33** sets the acquisition range of the closed circuit voltage between 0.0V and 5.0V. The calculation unit **33** acquires the closed circuit voltage detected by the monitor unit **10** in the acquisition range at this time t**1**. Note that there is practically no time difference between time t**1** and time t**0**. When the battery device **100** shifts from the non-drive state to the drive state, the process of detecting the closed circuit voltage is substantially started.

[0082] At time t**2**, the calculation unit **33** acquires the closed circuit voltage of the battery cell **220** again. At this time, it is conceivable that the calculation unit **33** determines the acquisition range of the closed circuit voltage at the time t**2** based on the closed circuit voltage of the battery cell **220** acquired at the time t**1**. For example, if the closed circuit voltage at time t**1** is 3.0V, it is conceivable to set the acquisition range of the closed circuit voltage around this 3.0V.

[0083] However, the SOC of battery cell **220** changes while time elapses from time t**1** to time t**2**. In the example shown in FIG. **3**, the amount of power indicated by hatching is discharged. It is assumed that the closed circuit voltage at time t**1** and the closed circuit voltage at time t**2** may be different due to this discharge.

[0084] Therefore, the calculation unit **33** calculates the median value of the acquisition range of the closed circuit voltage at the time t**2** based on the closed circuit voltage acquired at the time t**1** and the amount of change in the closed circuit voltage from the time t**1** to the time t**2**. That is, the calculation unit **33** estimates the closed circuit voltage at time t**2**. Estimation of the closed circuit voltage at time t**2** will be described in detail later. The median value of the acquisition range is a value between the upper limit value and the lower limit value of the acquisition range.

[0085] In the drawing, the tip of the dashed-dotted line arrow indicates the median value of the acquisition range of the closed circuit voltage when set based only on the acquired closed circuit voltage. The tip of the solid-line arrow indicates the median value of the acquisition range of the closed-circuit voltage when set based on the acquired closed-circuit voltage and the amount of change in the closed-circuit voltage.

[0086] As indicated by the difference in the positions of the tips of these two types of arrows, the median value of the acquisition range approaches the actual value of the closed circuit voltage of the battery cell **220** at time t**2** due to the amount of change in the closed circuit voltage. As a result, the closed circuit voltage of the battery cell **220** moves away from the upper limit value and the lower limit value of the acquisition range. As a result of narrowing the acquisition range, the closed circuit voltage is suppressed from being unintentionally outside the acquisition range.

[0087] The acquisition range of the closed circuit voltage is indicated by the width of the solid double-ended arrow shown in FIG. **3**. The difference between the median value and the upper limit value of the limited acquisition range is set as the upper limit range width α**1**. The difference between the median value and the lower limit value of the limited acquisition range is set to the lower limit range width α**2**. These upper limit range width α**1** and lower limit range width α**2** may be the same or different. The upper limit range width α**1** and the lower limit range width α**2** are values larger than the detection error of the closed circuit voltage. The upper limit range width α**1** and the lower limit range width α**2** are values smaller than half the difference between OCV**1** and OCV**2** shown in FIG. **2**.

[0088] The magnitude relationship between the upper limit range width α**1** and the lower limit range width α**2** can be determined, for example, based on the time change of the closed circuit voltage. When the closed circuit voltage tends to decrease, the lower limit range width α**2** can be set larger than the upper limit range width α**1**. Conversely, when the closed circuit voltage tends to increase, the upper limit range width α**1** can be set larger than the lower limit range width α**2**. The magnitude of the difference between these two range widths can be set based on the time variation of the closed circuit voltage. A correction value for providing a difference between these two range widths is stored in the storage unit **32**.

[0089] The calculation unit **33** sets the limited acquisition range based on the upper limit range width α**1**, the lower limit range width α**2**, and the median value of the acquisition range. In this embodiment, the calculation unit **33** sets the upper limit range width α**1** and the lower limit range width α**2** to be the same. Therefore, in order to simplify the notation, the upper limit range width α**1** and the lower limit range width α**2** are collectively referred to as the range width α. Note that when the upper limit range width α**1** and the lower limit range width α**2** are equal to each other in this manner, the median value of the acquisition range described above becomes the center value of the acquisition range.

[0090] The range width α is pre-stored in the storage unit **32**. The range width α is a value that depends on the temperature and the current of the battery cell **220**. The range width α stored in the storage unit **32** is used as the width of the acquisition range at time t**2**.

[0091] The calculation unit **33** determines the acquisition range at the time t**2** by the calculation processing described above. The calculation unit **33** sets the acquisition range at time t**2** between 2.65V and 2.93V, for example. The calculation unit **33** acquires the closed circuit voltage detected by the monitor unit **10** in the acquisition range at this time t**2**. When time t**1** corresponds to the first detection timing, time t**2** corresponds to the second detection timing.

[0092] Strictly speaking, since the battery device **100** performs a calculation process, the timing of determining the acquisition range and the timing of detecting the closed circuit voltage around time t**2** are not the same. The determination timing is before the detection timing. However, the difference between these two timings is small. Therefore, these two timings are substantially regarded as the same and described.

[0093] The calculation unit **33** acquires the closed circuit voltage at the acquisition cycle. The time between time t**1** and time t**2** corresponds to the acquisition period. This acquisition cycle is an expected time interval in which the SOC of the battery cell **220** does not suddenly change unless the charge or discharge state of the battery cell **220** suddenly changes according to constant current charging or the like. When the acquisition cycle elapses from the time t**1**, the time becomes t**2**.

[0094] At time t**3** after the acquisition period has passed from time t**2**, the calculation unit **33** determines the median value of the acquisition range based on the closed circuit voltage at time t**2** and the amount of change in the closed circuit voltage from time t**2** to time t**3**. Further, the calculation unit **33** calculates the difference between the closed circuit voltage obtained at time t**2** and the median value of the obtained range at time t**2** as an estimation error. The estimation error is a larger value than the detection error.

[0095] The calculation unit **33** calculates the range width α at the time t**3** based on this estimation error and the range width α stored in the storage unit **32**. When the estimation error is smaller than the predetermined value, the range width α at time t**3** is smaller than the range width α stored in the storage unit **32** or the range width α at time t**2**. When the estimation error is larger than the predetermined value, the range width α at time t**3** is larger than the range width α stored in the storage unit **32** or the range width α at time t**2**.

[0096] By performing the calculation processing described above, the calculation unit **33** determines the acquisition range at time t**3**. The calculation unit **33** sets the acquisition range at time t**3** between 2.60V and 2.74V, for example. The calculation unit **33** acquires the closed circuit voltage detected by the monitor unit **10** in the acquisition range at this time t**3**. When time t**2** corresponds to the first detection timing, time t**3** corresponds to the second detection timing.

[0097] From time t**3** to time tc**1**, the actual current decreases. Along with this configuration, the reduction rate of the closed circuit voltage is also reduced.

[0098] At time t**4** after the acquisition cycle has passed from time t**3**, the calculation unit **33** determines the acquisition range based on the closed circuit voltage at time t**3**, the amount of change in the closed circuit voltage from time t**3** to time t**4**, and the range width α that takes into account the estimation error. The calculation unit **33** sets the acquisition range at time t**4** between 2.62V and 2.70V, for example. The calculation unit **33** acquires the closed circuit voltage detected by the monitor unit **10** in the acquisition range at this time t**4**.

[0099] Since the amount of change in closed circuit voltage between time t**3** and time t**4** is taken into account in this way, even if the rate of decrease in closed circuit voltage begins to decrease at time tc**1** between time t**3** and time t**4**, the closed circuit voltage acquired by the calculation unit **33** at time t**4** is disposed within the acquisition range.

[0100] At tc**2** elapsed from time t**4**, the charging device is connected to the electric vehicle. The charging device charges the assembled battery **200** with a constant current. As a result, the actual current rises sharply. The calculation unit **33** acquires such information from vehicle information or charging information.

[0101] At time t**5** after the acquisition cycle has passed from time t**4**, the calculation unit **33** determines the acquisition range based on the closed circuit voltage at time t**4**, the amount of change in the closed circuit voltage from time t**4** to time t**5**, and the range width α that takes into account the estimation error. The calculation unit **33** acquires the closed circuit voltage detected by the monitor unit **10** in the acquisition range at this time t**5**.

[0102] Since the amount of change in closed circuit voltage between time t**4** and time t**5** is taken into account in this way, even if the closed circuit voltage begins to rapidly increase at time tc**2** between time t**4** and time t**5**, the closed circuit voltage acquired by the calculation unit **33** at time t**5** is disposed within the acquisition range.

[0103] Note that when constant current charging is performed in this way, the change rate of the closed circuit voltage per unit time increases. Therefore, the range width α at time t**5** may be amplified and corrected more than the range width α at time t**4**. Alternatively, the range width α during constant current charging may be stored in the storage unit **32**. This range width α may be used at time t**5**. The calculation unit **33** sets the acquisition range at time t**5** between 3.25V and 3.75V, for example.

[0104] When the time t**5** changes to the time tc**3**, the output voltage of the assembled battery **200** reaches the target voltage. When detecting this, the calculation unit **33** terminates the constant current charging by the charging device. The calculation unit **33** causes the charging device to perform the constant voltage charging. Note that the calculation unit **33** may perform forced charging instead of constant voltage charging after completion of constant current charging.

[0105] The constant-current charging and the constant-voltage charging described above may differ in the amount of supplied current. The constant-current charging has a larger current supply than the constant-voltage charging.

[0106] As described above, there is a difference of the voltage drop of I×R between the closed circuit voltage CCV and the open circuit voltage OCV. During the charging, an expression of "CCV=OCV+I×R" is established. Therefore, even if the maximum output voltage of the assembled battery **200** is detected as the closed circuit voltage CCV, the open circuit voltage OCV does not reach the maximum output voltage. The SOC of the assembled battery **200** has not reached the full charge capacity.

[0107] The above target voltage is a value based on the maximum output voltage of the assembled battery **200**. When the calculation unit **33** determines that the closed circuit voltage of the assembled battery **200** has reached the target voltage, it causes the charging device to perform the constant voltage charging. In the constant voltage charging, the charging power is supplied to the assembled battery **200** while maintaining the closed circuit voltage detected in the assembled battery **200** at the target voltage in order to bring the SOC of the assembled battery **200** closer to the full charge amount with avoiding over-charging. The target voltage and the maximum output voltage are stored in advance in the storage unit **32**.

[0108] At time t**6** after the acquisition cycle has elapsed from time t**5**, the calculation unit **33** acquires the closed circuit voltage of the battery cell **220** detected by the monitoring unit **10** in the acquisition range determined based on the target voltage and the range width α during the constant voltage charging. The calculation unit **33** sets the acquisition range at time t**6** between 4.23V and 4.26V, for example.

[0109] After time t**6**, it is expected that the target voltage will be obtained as long as the constant voltage charging continues. In this case, the calculation unit **33** continues to acquire the closed circuit voltage of the battery cell **220** within the acquisition range determined based on the target voltage and the range width α during the constant voltage charging. Alternatively, the calculation unit **33** may stop acquiring the closed circuit voltage. The range width α during the constant-voltage charging is, for example, a smaller value than the range width α used at time t**2**. The range width α during the constant voltage charging is stored in the storage unit **32**.

[0110] <Constant Voltage Drive>

[0111] If the SOC of the assembled battery **200** is excessively reduced or the electric motor of the electric vehicle malfunctions, the electric vehicle performs constant voltage drive with limited driving. At this time, the voltage of the power supply output from the assembled battery **200** is limited. The voltage of the power supply is kept at a constant value, for example. Therefore, it may be expected that the closed circuit voltage of the battery cell **220** is maintained at a predetermined voltage.

[0112] In the example shown in FIG. **4**, at time tc**1** between time t**3** and time t**4**, the electric vehicle transitions from unrestricted normal drive to restricted constant voltage drive. In this case, the calculation unit **33** acquires the closed circuit voltage of the battery cell **220** in the acquisition range determined based on the predetermined voltage and the range width α during constant voltage driving at time t**4**. The calculation unit **33** sets the acquisition range at time t**4** between 2.47V and 2.53V, for example.

[0113] After time t**4**, it may be expected that the predetermined voltage will be obtained as long as the constant voltage drive continues. In this case, the calculation unit **33** continues to acquire the closed circuit voltage of the battery cell **220** within the acquisition range determined based on the predetermined voltage and the range width α during the constant voltage drive. Alternatively, the calculation unit **33** may stop acquiring the closed circuit voltage.

[0114] The range width α during constant voltage drive is smaller than the range width α during normal drive. The range width α during the constant voltage drive is stored in the storage unit **32**. Note that when the electric vehicle changes from a running state to a stopped state, there is a possibility that the closed circuit voltage may suddenly change in a short period of time. The value of the range width α may be set so as to avoid the closed-circuit voltage falling outside the acquisition range due to such a sudden change.

[0115] <Estimation of Closed Circuit Voltage>

[0116] As described above, the calculation unit **33** calculates the median value of the acquisition range when calculating the acquisition range of the closed circuit voltage. That is, the calculation unit **33** estimates the closed circuit voltage at the time of acquisition. For example, at time t**2** shown in FIG. **3**, the calculation unit **33** estimates the closed circuit voltage at time t**2** based on the closed circuit voltage obtained at time t**1** and the amount of change in the closed circuit voltage from time t**1** to time t**2**.

[0117] The amount of change in the closed circuit voltage from time t**1** to time t**2** is calculated based on the charge/discharge history between time t**1** and time t**2**, the temperature between time t**1** and time t**2**, and the temperature dependence of the SOC and OCV characteristic data. The charge/discharge history corresponds to the charge/discharge amount.

[0118] The charge/discharge history between time t**1** and time t**2** is calculated, for example, based on the time difference between time t**1** and time t**2** and the current between time t**1** and time t**2**. The charge/discharge history between time t**1** and time t**2** is calculated as an integrated value of current between time t**1** and time t**2**. Note that the current between time t**1** and time t**2** is estimated by, for example, the addition average value of the current at time t**1** and the current at time t**2**.

[0119] The temperature between time t**1** and time t**2** is estimated by, for example, the addition average value of the temperature at time t**1** and the temperature at time t**2**. The calculation unit **33** reads the SOC and OCV characteristic data of this temperature from the storage unit **32**. Then, the calculation unit **33** calculates the amount of change in the closed circuit voltage from time t**1** to time t**2** based on the read SOC and OCV characteristic data and the calculated charge/discharge history between time t**1** and time t**2**. The current, the temperature, and the characteristic data are included in the variation.

[0120] Here, the calculation unit **33** reads the SOC and OCV characteristic data of the battery cell **220** from the storage unit **32** among the SOC and OCV characteristic data of various secondary batteries. When the battery cell **220** is a lithium-ion secondary battery, the calculation unit **33** reads the SOC and OCV characteristic data of the lithium-ion secondary battery from the storage unit **32**.

[0121] The calculation unit **33** estimates the time-related deterioration of the battery cell **220** at the time t**2**, for example, based on the difference between the date of manufacture of the battery cell **220** and the time t**2** stored in the storage unit **32** and the deterioration determination value. The calculation unit **33** may estimate the internal resistance of the battery cell **220** at time t**2** based on the time-related deterioration of the battery cell **220** and the temperature at time t**2**. The calculation unit **33** may calculate the voltage drop occurring in the battery cell **220** at the time t**2** based on the internal resistance and the current at the time t**2**. The calculation unit **33** may also take this voltage drop into account to estimate the closed circuit voltage at time t**2**. When estimating the internal resistance in this way, the range width α may be set in consideration of the internal resistance.

[0122] Further, the calculation unit **33** may estimate the amount of change in the closed circuit voltage from time t**1** to time t**2** based on the equivalent circuit model or chemical reaction model of the battery cell **220** and the current and the temperature of the battery cell **220**.

[0123] Further, as an example, the storage unit **32** may store a discharge value and a charge value for roughly estimating the amount of change in the closed circuit voltage described above. The amount of change in the closed circuit voltage may be determined by multiplying the predetermined discharge value by the time difference between time t**1** and time t**2**. The amount of change in the closed circuit voltage may be determined by multiplying the predetermined charge value by the time difference between time t**1** and time t**2**. In this modification, the discharge value and the charge value are included in the charge/discharge amount.

[0124] <Voltage Detection Processing>

[0125] Next, the voltage detection processing of the calculation unit **33** will be described with reference to FIG. **5**. The calculation unit **33** executes this voltage detection process as a cycle task. The execution interval of this voltage detection process corresponds to the acquisition period described above.

[0126] In step S**10**, the calculation unit **33** determines whether or not the closed circuit voltage is stored in the storage unit **32**. When the closed circuit voltage is stored in the storage unit **32**, the calculation unit **33** proceeds to step S**20**. If the closed circuit voltage is not stored in the storage unit **32**, the calculation unit **33** proceeds to step S**30**.

[0127] When proceeding to step S**20**, the calculation unit **33** determines whether or not the constant voltage charging process is being performed. If the constant voltage charging process is being executed, the calculation unit **33** proceeds to step S**40**. If the constant voltage charging process is not being executed, the calculation unit **33** proceeds to step S**50**.

[0128] When proceeding to step S**40**, the calculation unit **33** sets the closed circuit voltage (i.e., the estimated voltage) expected to be detected by the monitoring unit **10** as the target voltage. In other words, the calculation unit **33** sets the closed circuit voltage used for the acquisition range of the closed circuit voltage as the target voltage. After this process, in the calculation unit **33**, the process proceeds to step S**60**.

[0129] When proceeding to step S**60**, the calculation unit **33** calculates the difference value between the estimated voltage and the closed circuit voltage stored in the storage unit **32**. The calculation unit **33** determines whether or not this difference value is greater than or equal to the change voltage stored in the storage unit **32**. If the difference value is greater than or equal to the change voltage, the calculation section **33** proceeds to step S**70**. If the difference value is smaller than the change voltage, the calculation unit **33** terminates the voltage detection process.

[0130] When the process proceeds to step S**70**, the calculation unit **33** sets a limited acquisition range of the closed circuit voltage based on the estimated voltage and various information stored in the storage unit **32**. After this process, in the calculation unit **33**, the process proceeds to step S**80**.

[0131] When the process proceeds to step S**70** through step S**40**, the calculation unit **33** reads the range width α during constant voltage charging from the storage unit **32**. The calculation unit **33** calculates the acquisition range of the closed circuit voltage based on the range width α and the target voltage. The calculation unit **33** stores this acquisition range in the storage unit **32**. Then, in the calculation unit **33**, the process proceeds to step S**80**.

[0132] When proceeding to step S**80**, the calculation unit **33** transmits an instruction signal including the acquisition range calculated in step S**70** to the monitoring unit **10** as a limited range signal. After this process, in the calculation unit **33**, the process proceeds to step S**90**.

[0133] When proceeding to step S**90**, the calculation unit **33** acquires the closed circuit voltage detected by the monitor unit **10**. After this process, in the calculation unit **33**, the process proceeds to step S**100**.

[0134] When proceeding to step S**100**, the calculation unit **33** stores the acquired closed circuit voltage in the storage unit **32**. Also, at this time, the calculation unit **33** stores the acquisition range in the storage unit **32**. Then, the calculation unit **33** terminates the voltage detection process.

[0135] Retracing the flow, when it is determined in step S**20** that the constant voltage charging process is not being executed and the process proceeds to step S**50**, the calculation unit **33** determines whether or not the electric vehicle is in the constant voltage drive. That is, the calculation unit **33** determines whether or not the closed circuit voltage of the battery cell **220** is the predetermined voltage. In the case of the constant voltage drive, the calculation unit **33** proceeds to step S**110**. If it is not the constant voltage drive, the calculation unit **33** proceeds to step S**120**.

[0136] When proceeding to step S**110**, the calculation unit **33** sets the estimated voltage to a predetermined voltage. In other words, the calculation unit **33** sets the closed circuit voltage used for calculating the acquisition range of the closed circuit voltage to a predetermined voltage. After this process, in the calculation unit **33**, the process proceeds to step S**60**.

[0137] When the process proceeds to step S**110** through step S**40**, the calculation unit **33** reads the range width α during the constant voltage drive from the storage unit **32**. The calculation unit **33** sets the acquisition range of the closed circuit voltage based on the range width α and the predetermined voltage.

[0138] Retracing the flow, when it is determined in step S**50** that the constant voltage drive is not performed and the process proceeds to step S**120**, the calculation unit **33** acquires various information for calculating the estimated voltage. This information includes the closed circuit voltage, the acquisition cycle, the current, the temperature, the SOC and OCV characteristic data, and the like stored in the storage unit **32**. After this process, in the calculation unit **33**, the process proceeds to step S**130**.

[0139] When proceeding to step S**130**, the calculation unit **33** calculates the estimated voltage based on the various information acquired in step S**120**. After this process, in the calculation unit **33**, the process proceeds to step S**60**.

[0140] When the process proceeds to step S**70** through step S**130**, the calculation unit **33** reads the range width α from the storage unit **32**. The calculation unit **33** sets the acquisition range of the closed circuit voltage based on the range width α and the estimated voltage.

[0141] As described above, the voltage detection process is a cycle task. If step S**80** has been performed in the previous voltage detection process, in step S**70** the calculation unit **33** calculates the estimated error by subtracting the closed circuit voltage stored in the storage unit **32** from the estimated voltage. The calculation unit **33** sets the acquisition range of the closed circuit voltage based on the range width α and the estimated voltage. Unlike this, when step S**30** has been executed in the previous voltage detection process, the calculation unit **33** stops calculating the estimated error. In this case, the calculation unit **33** sets the acquisition range of the closed circuit voltage based on the range width α and the estimated voltage.

[0142] Returning the flow, when it is determined in step S**10** that the closed circuit voltage is not stored in the storage unit **32** and the process proceeds to step S**30**, the calculation unit **33** transmits the instruction signal including the possible acquisition range of the closed circuit voltage to the monitor unit **10** as a full range signal. After this process, in the calculation unit **33**, the process proceeds to step S**90**.

[0143] Note that the calculation unit **33** may not execute steps S**20**, S**40**, S**50**, and S**110** shown in FIG. **5**. In this case, as shown in FIG. **6**, when it is determined in step S**10** that the closed circuit voltage is stored in the storage unit **32**, the calculation unit **33** proceeds to step S**120**.

[0144] <Operations and Effects>

[0145] As described above, the calculation unit **33** sets the acquisition range of the closed circuit voltage based on the past closed circuit voltage stored in the storage unit **32** and the amount of change in the closed circuit voltage of the battery cell **220** until the closed circuit voltage is acquired again.

[0146] For example, the calculation unit **33** changes the acquisition range of the closed circuit voltage from a possible acquisition range of 0.0V to 5.0V to a limited acquisition range of 2.65V to 2.93V. In this limited acquisition range, the analog closed circuit voltage is converted into a digital signal by the AD conversion unit **13**. This reduces the quantization error of the AD conversion unit **13**. As a result, the detection accuracy of the closed circuit voltage is improved.

[0147] In addition, as described above, the calculation unit **33** sets the acquisition range of the closed circuit voltage in consideration of the amount of change in the closed circuit voltage of the battery cell **220** until the closed circuit voltage is acquired again. Therefore, the closed circuit voltage is suppressed from being out of the acquisition range.

[0148] The range width α of the acquisition range is determined in consideration of the difference (i.e., the estimation error) between the past closed circuit voltage stored in the storage unit **32** and the median value of the acquisition range of the closed circuit voltage set when the closed circuit voltage is detected. According to this, it is effectively suppressed that the closed circuit voltage is out of the acquisition range.

[0149] If the estimated error is smaller than the predetermined value, the calculator **33** narrows the range width α. This narrows the acquisition range of the closed circuit voltage. Detection accuracy of the closed circuit voltage is improved.

[0150] If the difference value between the estimated voltage and the closed circuit voltage stored in the storage unit **32** is smaller than the change voltage, the calculation unit **33** stops setting a new acquisition range. According to this, the calculation processing in the calculation unit **33** is simplified.

Second Embodiment

[0151] Next, a second embodiment will be described with reference to FIG. **7**.

[0152] In the first embodiment, as described with reference to FIG. **3**, the example in which battery information is not stored in the storage unit **32** when the calculation unit **33** switches from the non-drive state to the drive state is shown. Alternatively, the battery information may be stored in the storage unit **32** when the calculation unit **33** switches from the non-drive state to the drive state. Then, the calculation unit **33** may determine the acquisition range of the closed circuit voltage when the non-drive state is switched to the drive state based on the battery information stored in the storage unit **32** and the amount of change in the closed circuit voltage.

[0153] For example, in the initial state of time **0** shown in FIG. **7**, the battery device **100** is in a drive state. The storage unit **32** stores the battery information such as the closed circuit voltage and the physical quantity. The system main relay is energized. Therefore, current flows through the assembled battery **200**. The closed circuit voltage is the value in the charge/discharge region.

[0154] At time tn, the calculation unit **33** determines the acquisition range. The calculation unit **33** acquires the closed circuit voltage and the physical quantity detected by the monitoring unit **10** in the acquisition range at this time tn. The calculation unit **33** stores the closed circuit voltage and the physical quantity detected at the time tn in the storage unit **32**. At the same time, the calculation unit **33** stores the acquisition range determined at the time tn in the storage unit **32**. The battery information at time tn is stored in the storage unit **32**.

[0155] From time tn to time te, the battery device **100** changes from the drive state to the non-drive state. At this time, the battery information stored in the storage unit **32** is saved. The system main relay changes from the energization state to the cut off state. The electric current does not substantially flow through the assembled battery **200**. After that, the SOC of the battery cell **220** gradually decreases due to self-discharge. At the same time, the closed circuit voltage is also gradually reduced.

[0156] At time t**0**, the battery device **100** changes from the non-driving state to the driving state. The system main relay changes from the cutoff state to the energization state. The current begins to flow in the assembled battery **200**. The reduction rates of the SOC and the closed circuit voltage of the battery cell **220** increase.

[0157] At time t**1**, the calculation unit **33** calculates the median value of the acquisition range of the closed circuit voltage at time t**1** based on the closed circuit voltage stored in the storage unit **32** and the amount of change in the closed circuit voltage from time tn at which the closed circuit voltage was stored to time t**1**.

[0158] As described in the first embodiment, the amount of change in the closed circuit voltage is calculated based on the charge/discharge history between time tn and time t**1**, the temperature between time tn and time t**1**, and the temperature dependence of the characteristic data of the SOC and the OCV. The amount of change in the closed circuit voltage may be calculated in consideration of the internal resistance of the battery cell **220**. Also, the amount of change in the closed circuit voltage may be calculated based on the equivalent circuit model or chemical reaction model of the battery cell **220** and the current and the temperature of the battery cell **220**.

[0159] Here, as described above, the voltage detection process is executed in cycle tasks. The acquisition cycle is set in units of several microseconds to several seconds. Note that there is practically no time difference between time t**1** and time t**0**.

[0160] Therefore, the time difference between the time tn and the time te, which is shorter than the acquisition cycle, is considered to be negligibly short compared to the time difference between the time te and the time t**0** when the battery device **100** is in the non-drive state. Similarly, the time difference between time t**0** and time t**1** with no substantial time difference is negligibly small compared to the time difference between time te and time t**0** when battery device **100** is in the non-drive state.

[0161] Between time tn and time te and between time t**0** and time t**1**, which can be regarded as negligibly short compared to the time difference between this time te and time t**0**, the battery cell **220** is actively discharged effectively. The battery cell **220** self-discharges during the time interval between time te and time t**0**.

[0162] Thus, between time tn and time t**1**, the time during which the battery cell **220** actively discharges is negligibly short compared to the time during which the battery cell **220** self-discharges. Therefore, the amount of change in closed circuit voltage from time tn to time t**1** can be estimated based on the amount of self-discharge of the battery cell **220** per unit time and the time difference between time tn and time t**1**. The self-discharge amount of the battery cell **220** per unit time can be estimated based on the type of the battery cell **220**, the temperature, the temperature dependency of SOC and OCV characteristic data, the current, the degree of deterioration, and the like.

[0163] By executing such calculation processing, it is possible to improve the detection accuracy of the closed circuit voltage even when the battery device **100** transitions from the non-drive state to the drive state.

[0164] In the present embodiment, an example is shown in which the battery device **100** does not detect the closed circuit voltage at the time te when the battery device **100** changes from the drive state to the non-drive state. Alternatively, the battery device **100** may detect the closed circuit voltage at this time te.

[0165] Note that when the electric vehicle is in a non-drive state, the calculation unit **33** is periodically activated to determine whether or not the equalization process should be performed. When the calculation unit **33** performs the equalization process while the electric vehicle is in the non-drive state, the calculation unit **33** acquires the charge/discharge amounts of the plurality of battery cells **220** associated with the equalization process and stores them in the storage unit

32. Then, when the electric vehicle shifts from the non-drive state to the drive state, the calculation unit **33** determines the acquisition range of the closed circuit voltage based on the various information stored in the storage unit **32** and the physical quantity acquired at this time.

[0166] (Other Modifications)

[0167] In this embodiment, an example is shown in which one control unit **30** is provided for a plurality of monitor units **10**. Alternatively, a configuration in which a plurality of controllers **30** are provided individually for a plurality of monitor units **10** may also be adopted.

[0168] In this embodiment, an example of setting the acquisition range of the closed circuit voltage of each of the plurality of battery cells **220** has been described. Alternatively, it may be also possible to employ a configuration in which the acquisition range of the closed circuit voltage of each of the plurality of battery stack **210** is set. It may be also possible to employ a configuration in which a common closed circuit voltage acquisition range is set for each of the plurality of battery cells **220** included in one battery stack **210**. In such a modification, the assembled battery **200** has at least two battery stacks **210**.

[0169] In this embodiment, an example is shown in which each of the plurality of battery cells **220** is the same type of secondary battery. Alternatively, a part of the plurality of battery cells **220** may be different secondary batteries among the plurality of battery cells **220**. For example, some battery stacks **210** among the plurality of battery stacks **210** may include first type battery cells **220**, and the remaining battery stacks **210** may include second type battery cells **220** different from the first type. As the battery cells **220** of different types, for example, the battery cells **220** having the same internal configuration and external configuration but different composition materials for the positive and negative electrodes can be employed.

[0170] In the case of such a modification, when estimating the amount of change in the closed circuit voltage, the calculation unit **33** reads the SOC and OCV characteristic data of the first type battery cell **220** and the SOC and OCV characteristic data of the second type battery cell **220** from the storage unit **32**.

[0171] Although the present disclosure has been described in accordance with the examples, it is understood that the present disclosure is not limited to such examples or structures. To the contrary, the present disclosure is intended to cover various modification and equivalent arrangements. In addition, while various combinations and modes are described in the present disclosure, other combinations and modes including only one element, more elements, or less elements therein are also within the scope and spirit of the present disclosure.

[0172] The controllers and methods described in the present disclosure may be implemented by a special purpose computer created by configuring a memory and a processor programmed to execute one or more particular functions embodied in computer programs. Alternatively, the controllers and methods described in the present disclosure may be implemented by a special purpose computer created by configuring a processor provided by one or more special purpose hardware logic circuits. Alternatively, the controllers and methods described in the present disclosure may be implemented by one or more special purpose computers created by configuring a combination of a memory and a processor programmed to execute one or more particular functions and a processor provided by one or more hardware logic circuits. The computer programs may be stored, as instructions being executed by a computer, in a tangible non-transitory computer-readable medium.

[0173] It is noted that a flowchart or the processing of the flowchart in the present application includes sections (also referred to as steps), each of which is represented, for instance, as S**10**. Further, each section can be divided into several sub-sections while several sections can be combined into a single section. Furthermore, each of thus configured sections can be also referred to as a device, module, or means.

What is claimed is:

1. A battery device comprising:

a storage unit that stores battery information including a closed circuit voltage of a plurality of battery cells electrically connected to each other and a change amount in the closed circuit voltage;

a setting unit that sets an acquisition range of the closed circuit voltage based on the battery information;

a detection unit that detects the closed circuit voltage; and

a conversion unit that converts the closed circuit voltage detected by the detection unit into a digital signal within the acquisition range set by the setting unit.

2. The battery device according to claim **1**, wherein:

the change amount includes a charge and discharge amount of the battery cells during a period from a first detection timing at which the closed circuit voltage stored in the storage unit is detected by the detection unit to just before a second detection timing at which the closed circuit voltage is newly detected by the detection unit.

3. The battery device according to claim **2**, wherein:

the setting unit sets a median value of the acquisition range at the second detection timing based on the closed circuit voltage and the change amount stored in the storage unit.

4. The battery device according to claim **3**, wherein:

the setting unit sets a width of the acquisition range at the second detection timing based on a difference between the closed circuit voltage stored in the storage unit and the median value of the acquisition range at the first detection timing.

5. The battery device according to claim **3**, wherein:

the setting unit sets a magnitude relationship between an upper limit range width and a lower limit range width based on the change amount;

the upper limit range width is a difference between the median value of the acquisition range at the second detection timing and an upper limit value of the acquisition range at the second detection timing; and

the lower limit range width is a difference between the median value of the acquisition range at the second detection timing and a lower limit value of the acquisition range at the second detection timing.

6. The battery device according to claim **5**, wherein:

the setting unit sets the lower limit range width larger than the upper limit range width when the change amount tends to decrease; and the setting unit sets the upper limit range width larger than the lower limit range width when the change amount tends to increase.

7. The battery device according to claim **3**, wherein:

the setting unit determines to newly set the acquisition range at the second detection timing when a difference value between the median value of the acquisition range at the second detection timing and the closed circuit voltage stored in the storage unit is equal to or greater than a change voltage; and

the setting unit stops newly setting the acquisition range at the second detection timing when the difference value is smaller than the change voltage.

8. The battery device according to claim **3**, wherein:

when the closed circuit voltage is a predetermined voltage, the setting unit sets the median value of the acquisition range at the second detection timing to the predetermined voltage.

9. The battery device according to claim **2**, wherein:

the first detection timing is before the setting unit switches from a drive state to a non-drive state; and the second detection timing is after the setting unit switches from the non-drive state to the drive state.

10. The battery device according to claim **9**, wherein:

the change amount includes an amount of self-discharge of the battery cells from the first detection timing to the second detection timing.

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