IE0

DESCRIPCIÓN

SISTEMA Y PROCEDIMIENTO DE GESTIÓN DE CARGA DE BATERÍAS DE UN VEHÍCULO ELÉCTRICO

OBJETO DE LA INVENCIÓN

La presente invención describe un sistema y un procedimiento para gestionar de una manera óptima la carga y descarga de un conjunto de baterías, más particularmente, un conjunto de baterías para un vehículo eléctrico.

ANTECEDENTES DE LA INVENCIÓN

El funcionamiento de un vehículo eléctrico requiere de un almacén de energía, normalmente constituido por un grupo de baterías interconectadas según diferentes combinaciones serie/paralelo según cada caso. Aunque las características de las baterías que se utilizan en un mismo coche eléctrico son similares, puede haber pequeñas diferencias entre ellas debido a los procesos de fabricación, principalmente en cuanto al nivel de energía eléctrica que son capaces de almacenar o a parámetros como la corriente de auto descarga. Estas diferencias, aun siendo pequeñas, provocan que en la repetición de ciclos de carga y descarga algunas baterías acumulen tensión por encima del resto y que otras se descarguen más de lo debido.

Sin embargo, para alargar lo máximo posible su vida útil es aconsejable mantener en todo momento las baterías dentro de las especificaciones del fabricante, que normalmente consisten en unos niveles de tensión de celda máximo y mínimo. Esto es especialmente importante en ciertos tipos de baterías, como por ejemplo en las baterías de ión de litio, cuya vida útil puede verse reducida enormemente si se sobrecargan o se sobredescargan. Este problema es especialmente grave en vista del elevado precio de las baterías.

En consecuencia, es necesario controlar de un modo sencillo el estado de cada una de las baterías de forma individual, de forma que el mal funcionamiento de una de ellas sea rápidamente detectado y no comprometa el funcionamiento del conjunto completo. Además, es también muy importante conocer en todo momento el nivel de energía disponible dentro de cada batería para poder estimar el alcance de un vehículo eléctrico.

Por otro lado, es critico controlar la adecuada conexión de las baterías entre si, ya que, debido a las elevadas intensidades que circulan en un vehículo eléctrico, la existencia de pequeñas resistencias causadas por mal contacto eléctrico entre las baterías pueden provocar perdida de potencia y sobrecalentamiento.

Además, el sistema debe controlar también las situaciones catastróficas, por ejemplo un consumo de corriente de las baterías por encima del máximo marcado para el motor eléctrico, como el que se produciría en caso de un cortocircuito accidental a la salida del bloque de las baterías. Estas situaciones no siempre pueden controlarse adecuadamente con un fusible convencional, ya que el tiempo de actuación de un fusible de gran tamaño es muy largo, y además necesita una corriente muy elevada respecto a la corriente normal de trabajo para que pueda fundirse.

Aunque existen actualmente algunos sistemas que realizan algunas de estas funciones, ninguno de ellos ha resuelto aún el problema de modo satisfactorio.

DESCRIPCIÓN DE LA INVENCIÓN

El sistema de la presente invención resuelve la problemática anterior gracias a un sistema que mide la carga de cada batería, su temperatura y la corriente de carga/descarga que la atraviesa, y en función de estos datos decide si es necesario disipar parte de la energía aportada a una batería particular durante una operación de carga, o bien tomar otro tipo de medidas. Para ello, el sistema de gestión de carga de baterías en un vehículo eléctrico de la presente invención comprende:

a) Un sensor de la corriente que atraviesa las baterías, preferentemente un sensor de corriente por efecto Hall. Este sensor de corriente permite controlar el estado de carga de las baterías, y detectar situaciones tales como una sobrecorriente por encima de los niveles máximos recomendados.

b) Una pluralidad de tarjetas de control de baterías, cada una de las cuales está conectada hasta a 12 baterías y hasta a 3 sensores de temperatura. Los sensores de temperatura sirven para comprobar la temperatura en la zona de las baterías y, adicionalmente, aseguran que en el proceso de balanceo por cargas resistivas de las baterías no se produzcan sobrecalentamientos en las tarjetas de control de baterías. En este contexto, un proceso de balanceo consiste en disipar en calor la energía sobrante de una batería particular durante una operación de carga. Cada tarjeta de control de baterías comprende un conversor A/D que convierte las tensiones de las baterías de analógico a digital, una pluralidad de resistencias de potencia que disipan energía sobrante durante procesos de balanceo, y un microcontrolador que controla su funcionamiento. Preferentemente, el conversor A/D es un modelo LTC6802, aunque podría ser cualquier otro modelo.

c) Un coordinador de tarjetas de control de baterías conectado al microcontrolador de cada tarjeta de control de baterías y a un sensor de la corriente que atraviesa las baterías, preferentemente un sensor de corriente de efecto Hall. El coordinador de tarjetas recibe los datos acerca del nivel de carga de las baterías y su temperatura (de las tarjetas de control de baterías), así como acerca de la corriente que las atraviesa (del sensor de corriente), y determina si es necesario un proceso de balanceo para seguir dentro de las especificaciones del fabricante de la batería.

d) Un bus con aislamiento galvánico, que interconecta las baterías, el controlador y el sensor de corriente. De este modo, es posible solucionar las diferencias de tensión que generan las propias baterías que se pretenden controlar.

BREVE DESCRIPCIÓN DE LOS DIBUJOS

La Fig. 1 muestra un esquema de las diferentes partes que componen el sistema de la invención.

REALIZACIÓN PREFERENTE DE LA INVENCIÓN

Se describe a continuación un ejemplo de sistema de acuerdo con la presente invención haciendo referencia a la figura adjunta, en la que se ha representado un conjunto de 15 baterías (B) que alimenta un motor (M) de un vehículo eléctrico y que está controlado por medio del sistema de la invención.

El sistema de este ejemplo comprende 3 tarjetas (T) de lectura respectivamente conectadas a conjuntos de 5 baterías (B1…B5; B6… B10; B11…B15). Nótese que se trata únicamente de un ejemplo simplificado de la invención, ya que realmente cada tarjeta (T) es conectable hasta a 12 baterías (B). Cada tarjeta (T) de lectura está conectada además a 3 sensores de temperatura, que por simplicidad no se muestran en la figura. Los sensores de temperatura obtienen datos acerca de la temperatura en la zona de las baterías y de la propia tarjeta (T) de lectura.

El sistema comprende además un coordinador (C) de tarjetas conectado a través de un bus (B) aislado galvánicamente a las diferentes tarjetas (T) de lectura y al sensor (I) de corriente. De este modo, cada tarjeta (T) recibe periódicamente datos acerca de las baterías (B) a las que está conectada, en concreto nivel de carga y temperatura, y envía estos datos al coordinador (C) de tarjetas a través del bus (B) aislado galvánicamente. El coordinador (C), teniendo también en cuenta la corriente de carga que recibe del sensor (I) de corriente, realiza los cálculos necesarios para determinar si es necesario balancear la carga de alguna de las baterías (B) y, en ese caso, se comunica con la tarjeta (T) correspondiente para enviar las órdenes adecuadas.

Más concretamente, durante los procesos de descarga, el sistema verifica el estado de las baterías (B) comprobando posibles excesos de temperatura y controlando, a través de la medida simultánea de la tensión y de la corriente, el estado de la carga de cada batería (B) y el valor de su resistencia interna gracias a la variación de la tensión en función de la corriente consumida en la descarga. Además, durante la descarga el sistema comprueba la correcta integridad de todas las interconexiones de las baterías (B) entre sí al formar el circuito serie de baterías (B), ya que en caso de haber una conexión defectuosa que tuviera un cierto valor ohmico esta pequeña resistencia sería visualizada como un aumento de la resistencia interna de esa misma batería (B).

Este sistema también asegura que durante el proceso de descarga ninguna de las baterías (B) llegue a tener una tensión por debajo de la tensión mínima de trabajo recomendada por el fabricante. Además, esta información de la cantidad de energía disponible en cada batería (B) durante la descarga puede utilizarse para forzar un modo de consumo reducido (por ejemplo, mediante la limitación de la velocidad máxima) en el vehículo eléctrico cuando la carga de las baterías (B) cae por debajo de un umbral determinado.

Por otro lado, durante procesos de carga, la función del sistema es comprobar que ninguna de las baterías (B) se carga por encima de la tensión máxima recomendada por el fabricante. En caso de detectarse esta situación, se activarán las líneas de salida necesarias para detener la carga y de esta forma evitar la sobrecarga de una batería (B).

Adicionalmente, durante el proceso de carga se realiza un proceso de balanceado consistente en activar una corriente de descarga individual en aquellas baterías (B) cuyo nivel de carga sea demasiado elevado. La carga sobrante se disipa por medio de unas resistencias colocadas sobre las propias tarjetas para aquellas baterías (B) que tengan una tensión por encima del resto de baterías (B). De esta forma, mediante la descarga selectiva de aquellas baterías (B) con tensiones más altas se consigue alcanzar en los pasos finales del proceso de balanceo una tensión uniforme y equivalente a la tensión máxima de carga recomendada por el fabricante en todo el grupo de baterías (B).

El sistema también es capaz de detectar cortocircuitos accidentales a la salida de las baterías, que pueden producirse de forma excepcional en situaciones como una mala manipulación de la zona del motor o en un accidente de circulación, complementando así la funcionalidad que puede proporcionar un fusible convencional. Para ello, el sensor (I) de corriente del sistema monitoriza de forma periódica la corriente consumida de las baterías (B), y en caso de detectar una corriente mayor a un determinado umbral durante un determinado tiempo, acciona una línea de salida que permite cortar con el procedimiento mecánico adecuado (normalmente un relé) la salida de las baterías (B) que va hacia el motor (M), salvaguardando de esta forma la integridad de las baterías (B).

REIVINDICACIONES

1. Sistema de gestión de carga de baterías (B) de un vehículo eléctrico, caracterizado porque comprende:

- una pluralidad de tarjetas (T) de lectura de baterías (B), cada una de las cuales está conectada a hasta 12 baterías (B) y a hasta 3 sensores de temperatura, y que comprende un conversor A/D que convierte las tensiones de las baterías (B) de analógico a digital, una pluralidad de resistencias de potencia que disipan energía sobrante durante operaciones de balanceo, y un microcontrolador que controla su funcionamiento;

- un coordinador (C) de tarjetas (T) de control de baterías (B) conectado al microcontrolador de cada tarjeta (T) de control de baterías (B) y a un sensor (I) de la corriente que atraviesa las baterías (B), que recibe la corriente, temperatura y carga de cada batería (B) y determina si es necesario una operación de balanceo para no superar la tensión máxima recomendada de alguna de las baterías (B); y

- un bus (B) con aislamiento galvánico que interconecta las baterías (B), el controlador (C) y el sensor (I) de corriente.

2. Sistema de acuerdo con la reivindicación anterior, donde el sensor (I) de corriente es un sensor de corriente por efecto Hall.

3. Coche eléctrico que comprende el sistema de gestión de baterías de cualquiera de las reivindicaciones 1-2.

4. Procedimiento de gestión de carga de baterías (B) de un vehículo eléctrico mediante el sistema de cualquiera de las reivindicaciones 1-2, caracterizado porque comprende verificar que ninguna de las baterías (B) se carga por encima de una tensión máxima recomendada, realizando descargas

individuales en baterías (B) cuyo nivel de carga sea excesivo.

5. Procedimiento de gestión de carga de baterías (B) según la reivindicación 4, que además comprende monitorizar la resistencia interna de las baterías (B) y determinar la aparición de una conexión defectuosa en caso de detectar un aumento excesivo de alguna de ellas.

6. Procedimiento de gestión de carga de baterías (B) según cualquiera de las reivindicaciones 4-5, que además comprende verificar que ninguna de las baterías (B) llegue a tener una tensión por debajo de la tensión mínima recomendada.

7. Procedimiento de gestión de carga de baterías (B) según cualquiera de las reivindicaciones 4-6, que además comprende limitar la velocidad del vehículo cuando la carga de las baterías (B) cae por debajo de un umbral inferior.

8. Procedimiento de gestión de carga de baterías (B) según la reivindicación 4, que además comprende detener la carga cuando alguna de las baterías (B) supera la tensión máxima recomendada.

9. Procedimiento de gestión de carga de baterías (B) según cualquiera de las reivindicaciones 4-6, que además comprende desconectar el motor (M) cuando la corriente por las baterías (B) supera un determinado umbral

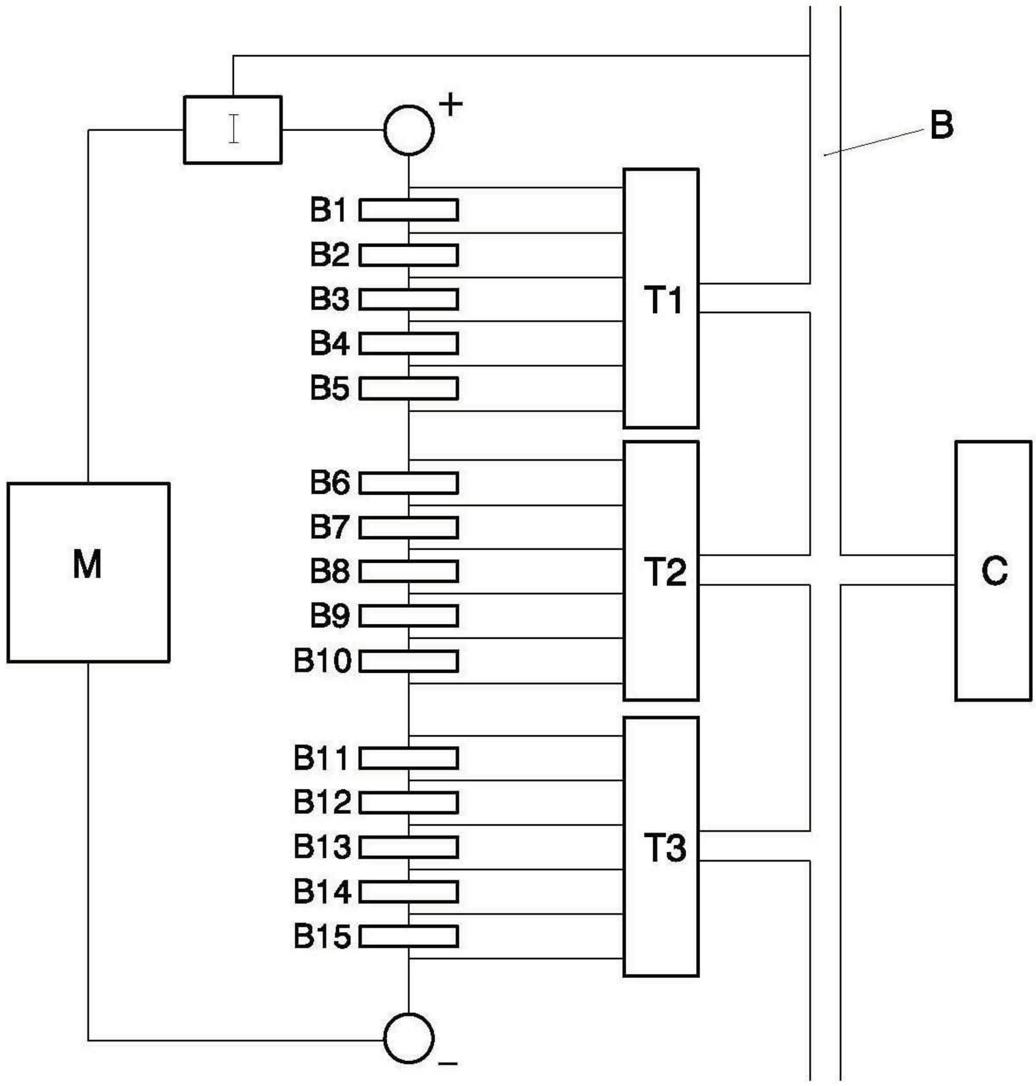


FIG. 1

IE1

FIG. 1

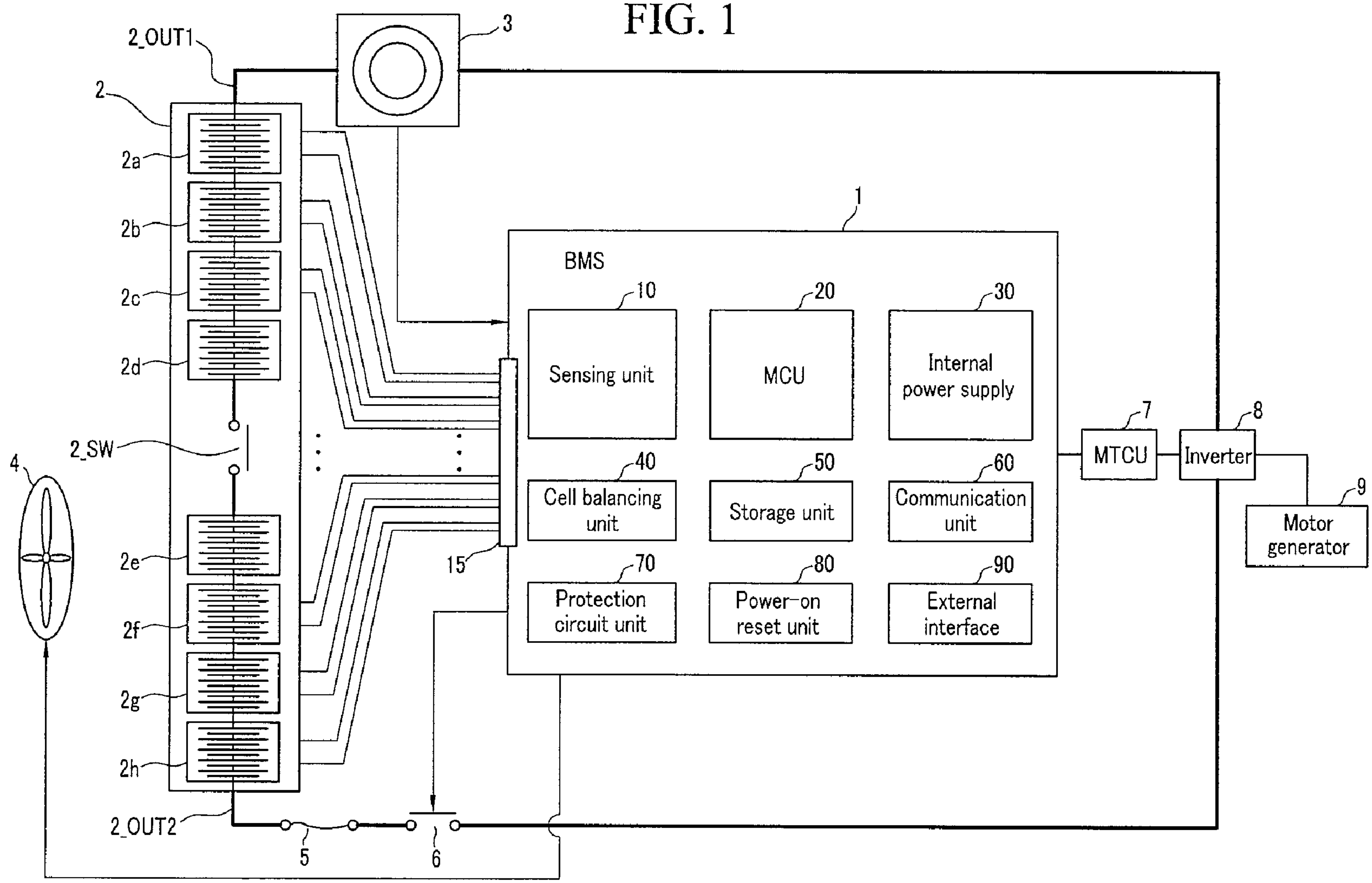

2_OUT1
2
2a
2b
2c
2d
2_SW
2e
2f
2g
2h
2_OUT2
3
4
5
6
15
1
BMS
10
Sensing unit
20
MCU
30
Internal
power supply
40
Cell balancing
unit
50
Storage unit
60
Communication
unit
70
Protection
circuit unit
80
Power-on
reset unit
90
External
interface
7
MTCU
8
Inverter
9
Motor
generator

FIG. 2

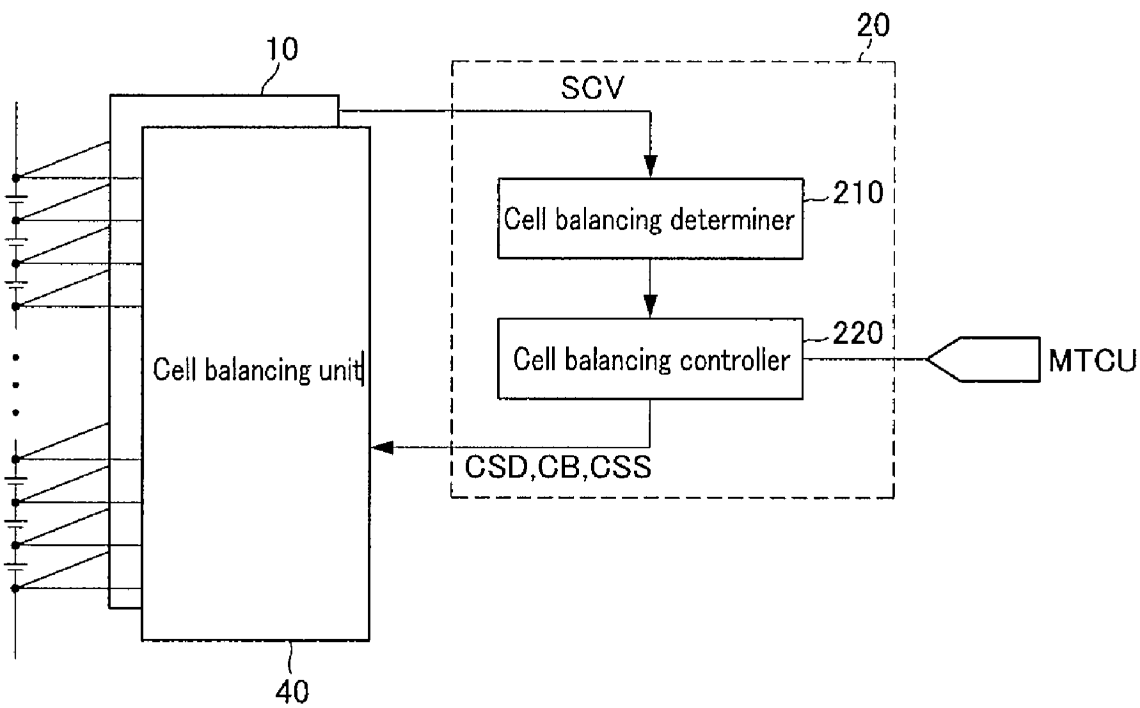
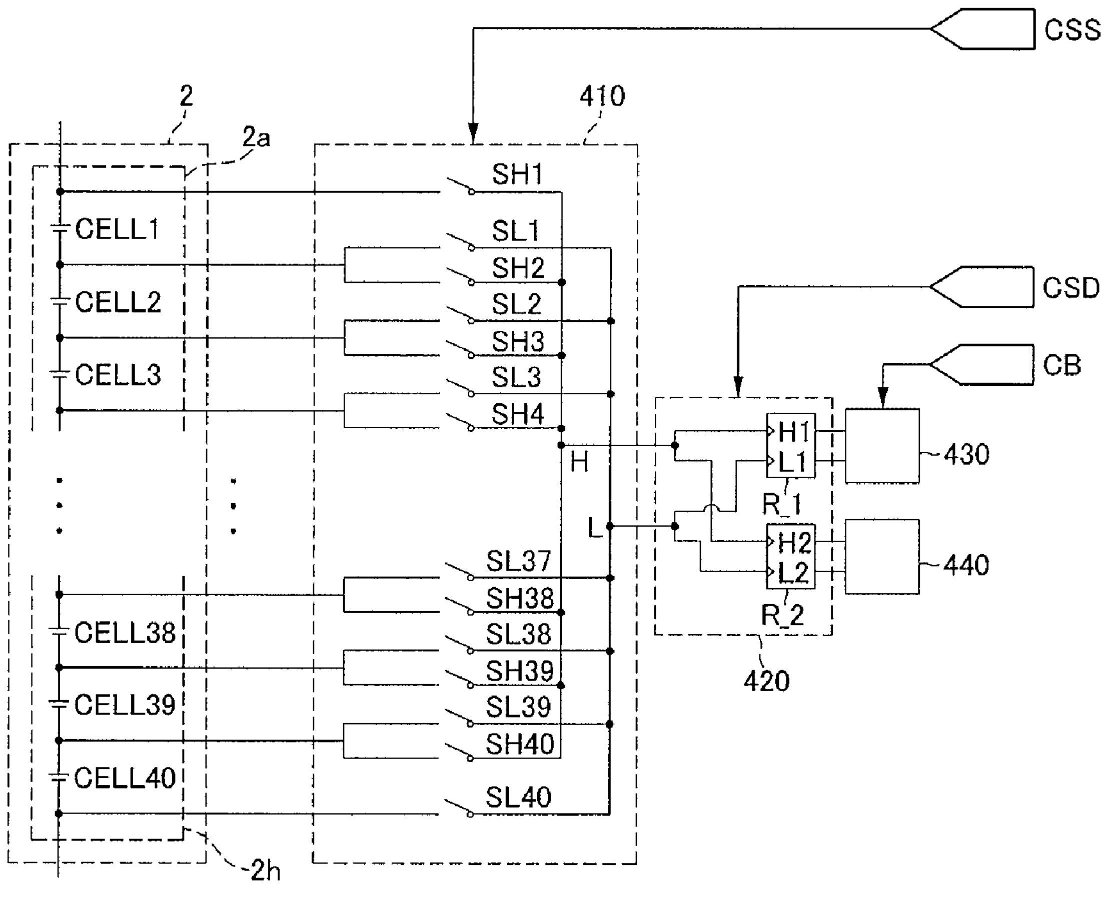

10
20
SCV
Cell balancing determiner
210
Cell balancing controller
220
MTCU
Cell balancing unit
CSD,CB,CSS
40

FIG. 3



CSS
CSD
CB
2
2a
2h
410
420
430
440
CELL1
CELL2
CELL3
CELL38
CELL39
CELL40
SH1
SL1
SH2
SL2
SH3
SL3
SH4
SL37
SH38
SL38
SH39
SL39
SH40
SL40
H
L
H1
L1
R_1
H2
L2
R_2

FIG. 4

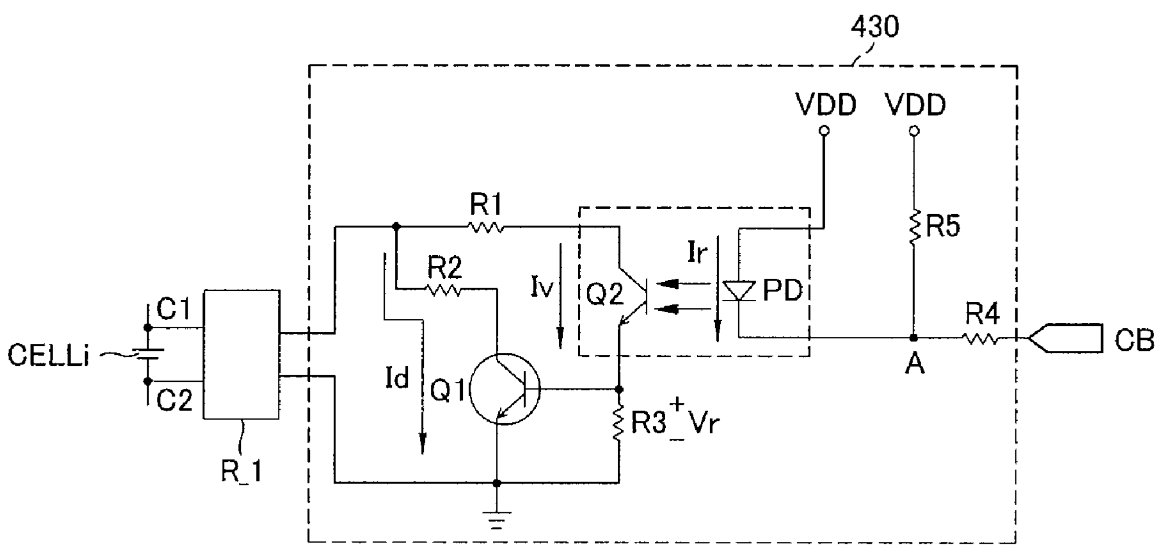

430
VDD
VDD
R1
R5
Ir
R2
Iv
Q2
PD
C1
R4
CELLi
CB
A
Id
Q1
C2
R3
+
Vr
_
R_1

FIG. 5

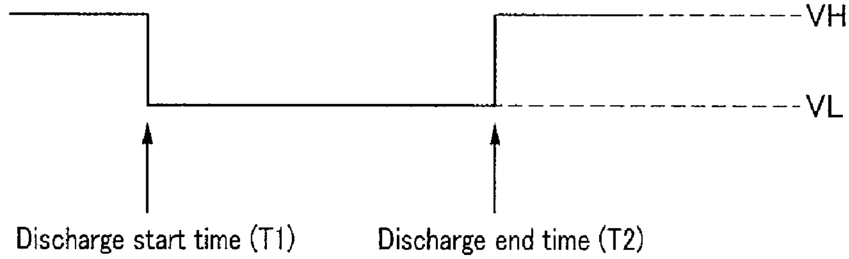

VH
VL
Discharge start time (T1)
Discharge end time (T2)

FIG. 6

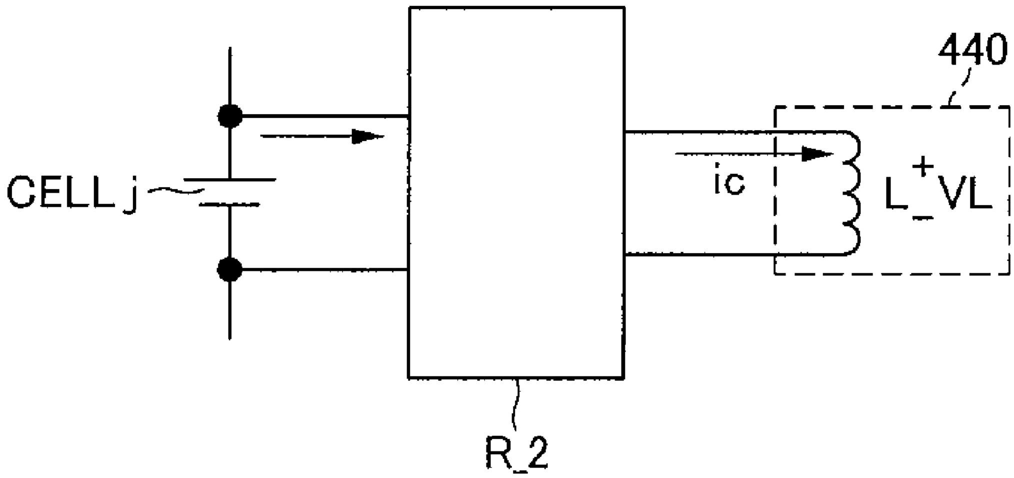


FIG. 7

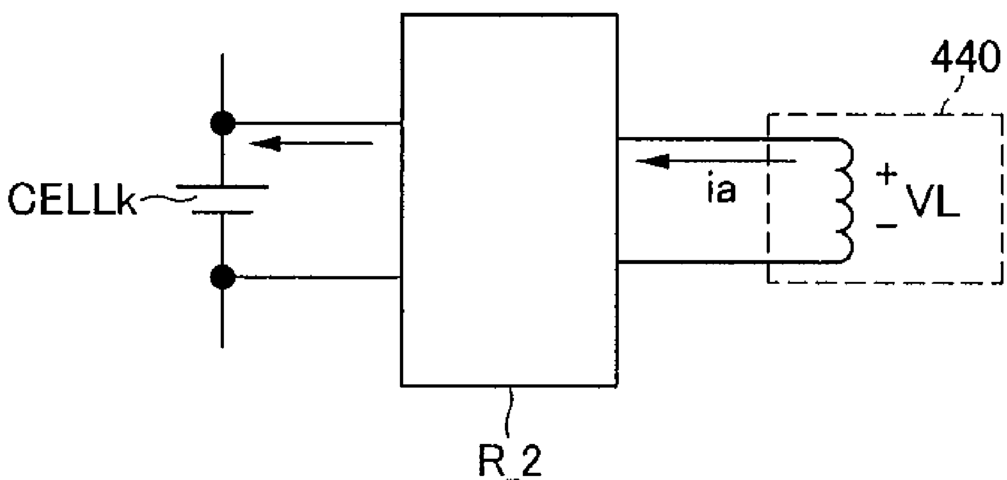
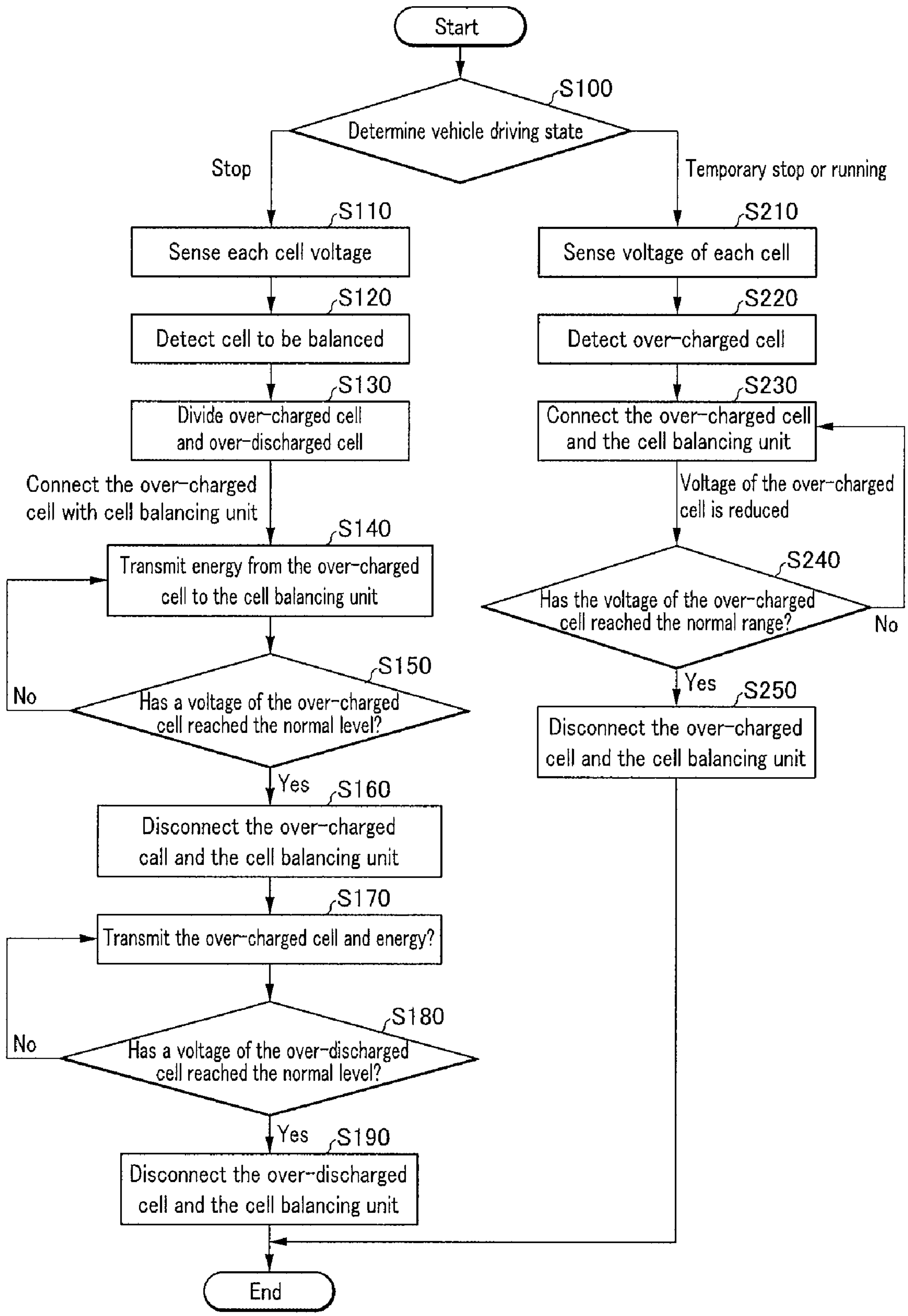


FIG. 8



Start
S100
Determine vehicle driving state
Stop
Temporary stop or running
S110
Sense each cell voltage
S120
Detect cell to be balanced
S130
Divide over-charged cell and over-discharged cell
Connect the over-charged cell with cell balancing unit
S140
Transmit energy from the over-charged cell to the cell balancing unit
S150
Has a voltage of the over-charged cell reached the normal level?
No
Yes
S160
Disconnect the over-charged call and the cell balancing unit
S170
Transmit the over-charged cell and energy?
S180
Has a voltage of the over-discharged cell reached the normal level?
No
Yes
S190
Disconnect the over-discharged cell and the cell balancing unit
End
S210
Sense voltage of each cell
S220
Detect over-charged cell
S230
Connect the over-charged cell and the cell balancing unit
Voltage of the over-charged cell is reduced
S240
Has the voltage of the over-charged cell reached the normal range?
No
Yes
S250
Disconnect the over-charged cell and the cell balancing unit

FIG. 9

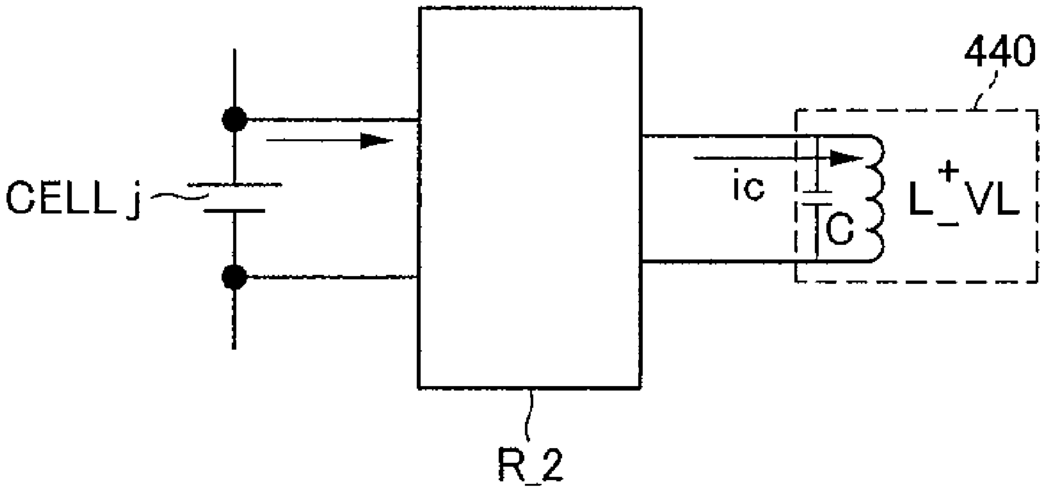
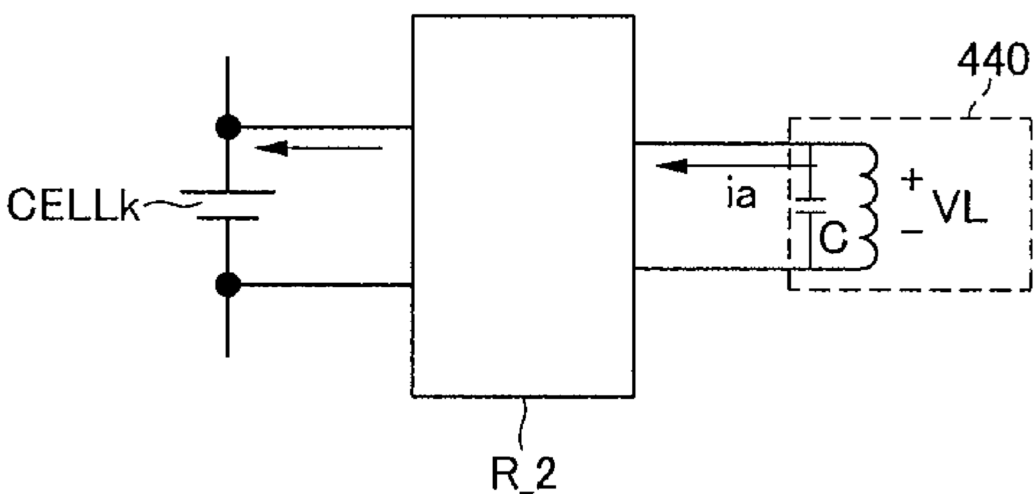


FIG. 10



BATTERY MANAGEMENT SYSTEM AND DRIVING METHOD THEREOF

CROSS-REFERENCE TO RELATED APPLICATION

[0001]

BACKGROUND OF THE INVENTION

[0002] 1. Field of the Invention

[0003] The present invention relates to a battery management system, and more particularly, to a battery management system for a vehicle and a driving method thereof.

[0004] 2. Description of the Related Art

[0005] Vehicles using an internal combustion engine powered by gasoline or diesel have caused serious air pollution. Accordingly, various efforts for developing electric or hybrid vehicles have recently been undertaken to reduce air pollution.

[0006] An electric vehicle uses an electric motor operating by electrical energy output by a battery. Because the electric vehicle mainly uses a battery formed by one battery pack including a plurality of rechargeable/dischargeable secondary cells, there are no emission gasses and the electric vehicle makes less noise.

[0007] A hybrid vehicle commonly refers to a gasoline-electric hybrid vehicle that uses gasoline to power an internal-combustion engine and a battery to power an electric motor.

[0008] In order to enhance output power of a vehicle using a battery as a power source, the number of rechargeable battery cells has increased, and a battery management system (BMS) is required for efficiently managing a plurality of cells connected to each other.

[0009] When a plurality of cells are serially connected, balance between the cells is important. In order to maintain a balance between the cells, a voltage difference between a plurality of cells forming a battery is maintained within an allowable range. The balance between the cells will be referred to as "cell balancing." The cell balancing is closely related to cycle life and the output power of the battery. When the cells are not balanced, the cells deteriorate such that the cycle-life of the battery is reduced, thereby reducing the output power.

[0010] In addition, a conventional cell balancing method uses a discharge path that is formed according to control of a main controller. In this case, the discharge path includes a resistance. The main controller compares a voltage of each cell with a predetermined voltage by using a comparator so as to determine whether the cells are balanced. Therefore, a lot of time is required for determining cell balancing. In addition, constituent elements of a circuit for cell balancing are increased as the number of cells forming the battery is increased, and accordingly, wiring is additionally required for information exchange between a main controller and the cells. Further, when the number of cells increases, another main controller is required.

SUMMARY OF THE INVENTION

[0011] A battery management system for managing a battery is provided. The battery supplies power to a vehicle and includes a plurality of cells. The battery management system includes a sensing unit for measuring a voltage of each of the plurality of cells. The battery management system detects at least one first cell among the plurality of cells needing to be balanced according to a measured voltage of each of the plurality of cells, and performs a cell balancing operation on said at least one first cell by using different methods depending upon an operational state of the vehicle.

[0012] According to an exemplary embodiment of the present invention, the battery management system further includes a cell balancing determiner for detecting said at least one first cell by comparing the measured voltage of each of the plurality of cells with a normal range. In addition, the battery management system includes a cell balancing controller for controlling a voltage of said at least one first cell to be discharged when the vehicle is in a temporary stop state, a running state, or a stop state. Furthermore, the battery management system includes a cell balancing unit for discharging the voltage of said at least one first cell.

[0013] According to an exemplary embodiment of the present invention, when the vehicle is in the stop state, the cell balancing determiner detects an over-charged cell or an over-discharged cell from among the plurality of cells, and the cell balancing unit receives energy from the over-charged cell and transmits the energy received from the over-charged cell to the over-discharged cell.

[0014] According to an exemplary embodiment of the present invention, the cell balancing unit includes a plurality of first cell balancing switches having first ends respectively coupled to the plurality of cells and second ends coupled to a first output terminal; a plurality of second cell balancing switches having first ends respectively coupled to the plurality of cells and second ends coupled to a second output terminal; a first cell balancing driver for discharging said at least one first cell when the vehicle is in the temporary stop state or the running state; a second cell balancing driver for transmitting the energy received from the over-charged cell to the over-discharged cell when the vehicle is in the stop state; a first relay for connecting the first cell balancing driver, the first output terminal, and the second output terminal; and a second relay for connecting the second cell balancing driver, the first output terminal, and the second output terminal.

[0015] According to an exemplary embodiment of the present invention, when the vehicle is in the temporary stop state or the running state, the cell balancing controller turns on the first relay and turns on first switches and second switches among the plurality of first cell balancing switches and the plurality of second cell balancing switches that correspond to said at least one first cell.

[0016] According to an exemplary embodiment of the present invention, the first relay has a first relay first end and a first relay second end. The first cell balancing driver includes a first resistor having a first resistor first end and a first resistor second end. The first resistor first end is coupled to the first relay first end. A second resistor has a second resistor first end and a second resistor second end. The second resistor first end is coupled to the first relay first end and to the first resistor first end. A first transistor has a first transistor first electrode, a first transistor second electrode, and a first transistor control electrode. The first transistor first electrode is coupled to the second transistor second end. The first transistor second electrode is coupled to the first relay second end. A second transistor has a second transistor first electrode and a second transistor second electrode. The second transistor first electrode is coupled to the first resistor second end. A third resistor has a third resistor first end and a third resistor second end. The third resistor first end is coupled to the second transistor second electrode and to the first transistor control electrode. The third transistor second end is coupled to the first transistor second electrode and to the first relay second end. A photodiode forms a photocoupler with the second transistor. The photodiode has a photodiode anode electrode and a photodiode cathode electrode. A first power source is coupled to the photodiode anode electrode. A fourth resistor has a fourth resistor first end and a fourth resistor second end. The fourth resistor first end is coupled to the photodiode cathode electrode. A fifth resistor has a fifth resistor first end and a fifth resistor second end. The fifth resistor first end is coupled to the first power source. The fifth resistor second end is coupled to the fourth resistor first end and to the photodiode cathode electrode.

[0017] According to an exemplary embodiment of the present invention, the cell balancing controller transmits a discharge control signal to the fourth transistor second end to permit a driving current to flow to the photodiode.

[0018] According to an exemplary embodiment of the present invention, a bias current flows to the second transistor in response to the driving current, and the first transistor is turned on by a bias voltage applied to the first transistor control electrode and to the first transistor second electrode in response to the bias current and the third resistor.

[0019] According to an exemplary embodiment of the present invention, when the first transistor is turned on, charges of said at least one first cell are discharged by a discharge path having the second resistor and the first transistor so that a voltage of said at least one first cell is decreased.

[0020] According to an exemplary embodiment of the present invention, wherein when the vehicle is in the stop state, the cell balancing controller turns on first switches and second switches among the plurality of first cell balancing switches and the plurality of second cell balancing switches that correspond to the over-charged cell, and turns off the first switches and the second switches when a voltage of the over-charged cell reaches the normal range.

[0021] According to an exemplary embodiment of the present invention, after turning off the first switches and the second switches when the vehicle is in the stop state, the cell balancing controller turns on third switches among the plurality of first cell balancing switches corresponding to the over-discharged cell, and turns on fourth switches among the plurality of second cell balancing switches corresponding to the over-discharged cell.

[0022] According to an exemplary embodiment of the present invention, when the vehicle is in the stop state, the cell balancing controller turns off the third switches and the fourth switches when the voltage of the over-discharged cell reaches the normal range.

[0023] According to an exemplary embodiment of the present invention, the second relay has a second relay first end and a second relay second end. The second cell balancing driver includes an inductor having an inductor first end and an inductor second end. The inductor first end is coupled to the second relay first end. The inductor second end is coupled to the second relay second end. The inductor stores energy transmitted through the first switches, the second switches, and the second relay.

[0024] According to an exemplary embodiment of the present invention, the energy stored in the inductor is transmitted to the over-discharged cell through the third switches, the fourth switches, and the second relay.

[0025] According to an exemplary embodiment of the present invention, the second cell balancing driver further comprises a capacitor coupled in parallel with the inductor.

[0026] According to an exemplary embodiment of the present invention, the battery management system further includes a connection port unit coupled to the plurality of cells. The connection port unit couples the battery management system and the plurality of cells.

[0027] According to an exemplary embodiment of the present invention, the battery management system is formed of one chip.

[0028] According to an exemplary embodiment of the present invention, a driving method of a battery management system for managing a battery is provided. The battery supplies power to a vehicle and includes a plurality of cells. The driving method includes a) determining a driving state of the vehicle; b) sensing a voltage of each of the plurality of cells; c) determining a cell needing to be balanced among the plurality of cells; and d) performing a cell balancing operation on the cell by using different methods depending upon an operational state of the vehicle.

[0029] According to an exemplary embodiment of the present invention, in a), when the vehicle is in a stop state, c) comprises detecting an over-charged cell and an over-discharged cell, and d) comprises performing the cell balancing operation on the over-charged cell and the over-discharged cell by transmitting energy from the over-charged cell to the over-discharged cell.

[0030] According to an exemplary embodiment of the present invention, in a), when the vehicle is in a temporary stop state or a running state, c) comprises detecting an over-charged cell, and d) comprises performing the cell balancing operation by discharging the over-charged cell.

BRIEF DESCRIPTION OF THE DRAWINGS

[0031] FIG. **1** schematically shows a battery, a battery management system (BMS), and a peripheral device of the BMS according to an exemplary embodiment of the present invention.

[0032] FIG. **2** shows a sensing unit, a cell balancing unit, and a main control unit (MCU) according to an exemplary embodiment of the present invention.

[0033] FIG. **3** shows a BMS that performs cell balancing according to a driving state of a vehicle.

[0034] FIG. **4** shows connection between a cell that needs to be balanced among a plurality of cells, a first relay, and a first cell balancing driver.

[0035] FIG. **5** shows a discharge control signal according to an exemplary embodiment of the present invention.

[0036] FIG. **6** shows a case in which energy from an over-charged cell is transmitted to a cell balancing driver.

[0037] FIG. **7** shows a case in which energy from the cell balancing driver is transmitted to an over-discharged cell.

[0038] FIG. **8** is a flowchart showing a BMS driving method according to an exemplary embodiment of the present invention.

[0039] FIG. **9** and FIG. **10** depict a cell balancing driver according to another exemplary embodiment of the present invention.

DETAILED DESCRIPTION

[0040] Throughout this specification and the claims that follow, when it is described that an element is "coupled" to another element, the element may be "directly coupled" to the other element or "electrically coupled" to the other element through a third element. In addition, unless explicitly described to the contrary, the word "comprise" and variations such as "comprises" and "comprising" will be understood to imply the inclusion of stated elements but not the exclusion of any other elements.

[0041] FIG. **1** schematically shows a battery, a BMS **1**, and a peripheral device of the BMS **1** according to an exemplary embodiment of the present invention. The BMS **1** according to an exemplary embodiment of the present invention is formed of one chip.

[0042] The battery **2** includes a plurality of sub-packs **2***a* to **2***h* having a plurality of battery cells coupled in series to each other, and output terminal **2**_OUT**1**, an output terminal **2**_OUT**2**, and a safety switch **2**_SW provided between the sub-pack **2***d* and the sub-pack **2***e*. While eight sub-packs **2***a* to **2***h* are exemplified, and one sub-pack is a group of a plurality of battery cells in an exemplary embodiment of the present invention, it is not limited thereto. The safety switch **2**_SW is manually turned on/off to guarantee safety for a worker when performing operations for the battery or replacing the battery. In the present exemplary embodiment, the safety switch **2**_SW is provided between the sub-pack **2***d* and the sub-pack **2***e*, but it is not limited thereto. The output terminal **2**_OUT**1** and the output terminal **2**_OUT**2** are coupled to the inverter **8**.

[0043] The current sensor **3** measures an output current value of the battery **2** and outputs the measured output current value to the sensing unit **10** of the BMS **1**. The current sensor **3** may be provided as a Hall current transformer (Hall CT) using a Hall element to measure a current value and outputting an analog current signal corresponding to the measured current value. The sensor **3** transmits information on the measured current value of the battery **2** to the BMS **1**.

[0044] The cooling fan **4** cools down heat generated by charging and discharging the battery **2** in response to a control signal of the BMS **1**, and prevents the battery **2** from being deteriorated by a temperature increase and prevents the charging and discharging efficiency from being deteriorated.

[0045] The fuse **5** prevents an overflowing current, which may be caused by a disconnection or short circuit of the battery **2**, from being transmitted to the battery **2**. That is, when an overcurrent is generated, the fuse **5** is disconnected so as to interrupt the current from overflowing.

[0046] The main switch **6** turns on/off the battery **2** in response to the control signal of the BMS **1** when an unusual phenomenon, including an overflowed voltage, an over-current, and a high temperature, occurs.

[0047] The BMS **1** includes a sensing unit **10**, a main control unit (MCU) **20** an internal power supply **30**, a cell balancing unit **40**, a storage unit **50**, a communication unit **60**, a protective circuit unit **70**, a power-on reset unit **80**, and an external interface **90**. In addition, a plurality of cells are respectively electrically coupled to the BMS **1** through a connection port unit **15**. The connection port unit **15** according to an exemplary embodiment of the present invention includes a number of connection terminals that is greater than the number of cells. Hereinafter, a plurality of connection terminals connected to the cells are referred to as cell connection terminals.

[0048] The sensing unit **10** is electrically coupled to a plurality of cells that form the battery **2** through a plurality of cell connection terminals. The sensing unit **10** measures each battery cell voltage and each battery terminal voltage and measures battery current by using an electrical signal transmitted from the Hall sensor **3**. Further, the sensing unit **10** measures a cell temperature and a battery temperature. The sensing unit **10** transmits the battery cell voltage, the battery terminal voltage, the battery current, and the cell temperature to the MCU **20**. The battery terminal voltage is a voltage between the output terminals **2**_OUT**1** and **2**_OUT**2**, and the battery current is a current flowing to the battery.

[0049] The MCU **20** estimates a state of charge (SOC) and a state of health (SOH) based on the battery current, the battery terminal voltage, the respective battery cell voltages, the cell temperature, and an ambient temperature, which are transmitted from the sensing unit **10**. The MCU **20** generates information that informs a state (i.e., SOC and SOH) of the battery **2** and transmits the information to the MoTor Control Unit (MTCU) **7** of the vehicle. The MTCU **7** controls charge or discharge of the battery **2** based on the SOC and the SOH. The MCU **20** according to an exemplary embodiment of the present invention can recognize the number of cells when the cell terminals of the connection port unit **15** are respectively coupled to the corresponding cells. The MCU **20** generates signals for controlling the cell balancing unit **40** corresponding to the recognized number of cells. A configuration and operation of the cell balancing unit **40** will be described in further detail later.

[0050] The internal power supply **30** supplies power by using a backup battery to transmit a voltage (e.g., a bias voltage) to the BMS **1** for operation.

[0051] The cell balancing unit **40** balances a SOC of each cell. That is, the cell balancing unit **40** controls a SOC of each cell to be within a reference range by charging/discharging a cell whose SOC is not within the reference range. Herein, the reference range may be set according to a battery terminal voltage, a SOC, a SOH, and temperature. In addition, the reference range may be set within a predetermined range that is set on the basis of an average value of the plurality of cell voltages. The cell balancing unit **40** operates according to a control signal of the MCU **20** that has received information on each cell voltage, or directly receives information on each cell voltage from the sensing unit **10**, determines whether a cell is balanced or not based on the information, and balances each cell. The cell balancing unit **40** is electrically coupled to the respective cells through the plurality of cell connection terminals. The cell balancing unit **40** according to an exemplary embodiment of the present invention may use a different cell balancing method according to a driving state of the vehicle. The BMS and a driving method thereof according to an exemplary embodiment of the present invention will be described in further detail later with reference to FIG. **2**, FIG. **3**, FIG. **4**, and FIG. **5**.

[0052] When the BMS **1** is turned off, the storage unit **50** stores data including a current SOC and a current SOH. Herein, the storage unit **50** may be provided as a non-volatile electrically erasable programmable read-only memory (EEPROM).

[0053] The communication unit **60** communicates with the MTCU **7** of the vehicle. The protective circuit unit **70** uses firmware to protect the battery **2** from shocks, over-flowed currents, and low voltages.

[0054] The power-on reset unit **80** resets the overall system when the power source of the BMS **1** is turned on. The external interface **90** couples auxiliary devices for the BMS **1**, such as the cooling fan **4** and the main switch **6**. While the cooling fan **4** and the main switch **6** are shown as the auxiliary devices in the present exemplary embodiment, it is not limited thereto.

[0055] The MTCU **7** determines a torque state based on information on an accelerator, a brake, and a vehicle speed, and controls an output of the motor-generator **9** so that the output corresponds to the torque information. That is, the MTCU **7** controls the motor-generator **9** to output an output corresponding to the torque information by controlling a switching operation of the inverter **8**. In addition, the MTCU **7** receives the SOC of the battery **2** from the MCU **20** through the communication unit **60** and controls the SOC level of the battery **2** to be a target level (e.g., 55%). For example, when the SOC level transmitted from the MCU **20** is less than 55%, the MTCU **7** controls the switching operation of the inverter **8** so as to output power toward the battery **2** and charge the battery **2**. In this case, the battery pack current has a negative (−) value. When the SOC level is greater than 55%, the MTCU **7** controls the switching operation of the inverter **8** so as to output the power toward the motor-generator **9** and discharge the battery **2**. In this case, the battery pack current has a positive (+) value.

[0056] The inverter **8** controls the battery **2** to be charged or discharged in accordance with a control signal of the MTCU **7**.

[0057] The motor generator **9** uses the electrical energy of the battery **2** to drive the vehicle based on the torque information transmitted from the MTCU **7**.

[0058] As described, the BMS **1** according to an exemplary embodiment of the present invention transmits battery information and a charge/discharge control signal to the MTCU **7** and the MTCU **7** performs charge or discharge, accordingly. In addition, in the BMS **1**, each cell is balanced by using the sensing unit **10**, the cell balancing unit **40**, and the MCU **20**.

[0059] Hereinafter, a configuration and operation for performing cell balancing according to an exemplary embodiment of the present invention will be described in further detail with reference to FIG. **2**, FIG. **3**, FIG. **4**, and FIG. **5**. The BMS and the plurality of cells are electrically coupled through the respective cell connection terminals. In FIG. **2** and FIG. **3**, the connection port unit **15** is omitted for convenience of description.

[0060] FIG. **2** shows the sensing unit **10**, the cell balancing unit **40**, and the MCU **20** of the BMS **1** according to an exemplary embodiment of the present invention. These constituent elements are directly associated with the cell balancing operation. Wires connected to the lateral ends of each cell are coupled to the sensing unit **10** and the cell balancing unit **40**, and the sensing unit **10** is coupled to the MCU **20**, and therefore a measured voltage can be transmitted therethrough. In addition, the cell balancing unit **40** is coupled to the MCU **20**. The MCU **20** receives information on a driving state of the vehicle from the MTCU **7**. According to an exemplary embodiment of the present invention, the MCU **20** receives information on a cell voltage from the sensing unit **10**, determines the necessity of the cell balancing operation, and controls the cell balancing operation, but this is not restrictive. Alternatively, the cell balancing unit **40** may individually include a micro control unit (MCU), may receive cell voltage information from the sensing unit **10** and the vehicle driving state from the MTCU **7**, may determine the necessity of the cell balancing operation, and may control the cell balancing operation. That is, in an alternatively embodiment, the cell balancing determiner **210** and a cell balancing controller **220** can be included in the cell balancing unit **40**.

[0061] The sensing unit **10** transmits a cell voltage signal SCV generated by measuring a voltage of each cell to the cell balancing determiner **210**. The cell balancing determiner **210** compares a voltage of the cell voltage signal SCV with a normal range. When the voltage of the cell voltage signal SCV is not in the normal range, the cell balancing determiner **210** determines that the cell balancing operation needs to be performed. When the voltage of the cell voltage signal SCV is less than the normal range, the corresponding cell is determined to be a discharge target cell, and when the voltage of the cell voltage signal SCV is greater than the normal range, the corresponding cell is determined to be a charge target cell. The cell balancing controller **220** receives information on a cell that needs to be balanced from the cell balancing determiner **210**, and transmits a cell balancing control signal CSD to the cell balancing unit **40**. The cell balancing controller **220** generates the cell balancing control signal CSD according to the information on the vehicle driving state, transmitted from the MTCU **7**, and information on the cell that needs to be balanced, and transmits the cell balancing control signal CSD to the cell balancing unit **40**.

[0062] The vehicle driving state or operational state according to an exemplary embodiment of the present invention can be divided into a stop state, a running state, and a temporary stop state. The stop state means that the vehicle is parked and operation of the vehicle is stopped, and the temporary stop state means that the vehicle is temporarily stopped while it is running.

[0063] The BMS **1** according to an exemplary embodiment of the present invention detects a cell that needs to be balanced and performs the cell balancing operation when the vehicle driving state is set to the stop state or the temporary stop state. A different cell balancing method is used in accordance with a vehicle driving state, and a control signal CSD is also changed, accordingly. The different cell balancing method will be described in further detail later with reference to FIG. **3**. The cell balancing controller **220** generates a connection control signal CSS that controls a connection between the cell that is determined to be balanced and the cell balancing unit **40** and transmits the connection control signal CSS to the cell balancing unit **40**, and generates a discharge control signal CB for controlling discharge of a cell and transmits the discharge control signal CB to the cell balancing unit **40**.

[0064] FIG. **3** shows a BMS that performs a cell balancing operation according to a vehicle driving state according to an exemplary embodiment of the present invention. The battery **2** includes a plurality of cells (e.g., CELL**1** to CELL**40**), and every five cells forms one pack. Therefore, the battery **2** is formed of eight packs **2***a* to **2***h*.

[0065] The cell balancing unit **40** includes a cell balancing multiplexer **410**, a cell balancing connector **420**, a first cell balancing driver **430**, and a second cell balancing driver **440**.

[0066] The cell balancing multiplexer **410** includes a plurality of cell balancing switches SH**1** to SH**40** and SL**1** to

SL40, and the plurality of cell balancing switches SH1 to SH40 and SL1 to SL40 are turned on/off according to the connection control signal CSS. A first end of the cell balancing switch SH1 is coupled to a first end of the cell CELL1, and a second end of the cell balancing switch SH1 is electrically coupled to a first output terminal H. A first end of the cell balancing switch SL1 is coupled to a second end of the cell CELL1, and a second end of the cell balancing switch SL1 is electrically coupled to a second output terminal L.

[0067] In a like manner to the above, each of the cell balancing switches SH1 to SH40 has one end electrically coupled to one end of the corresponding cell and the other end electrically coupled to the first output terminal H. In addition, each of the cell balancing switches SL1 to SL40 has one end coupled to one end of the corresponding cell and the other end electrically coupled to the second output terminal L. The plurality of cell balancing switches SH1 to SH40 and SL1 to SL40 are turned on/off in response to the connection control signal CSS transmitted from the cell balancing controller **220**. The connection control signal CSS according to an exemplary embodiment of the present invention refers to a plurality of signals respectively corresponding to the plurality of cell balancing switches SH1 to SH40 and SL1 to SL40.

[0068] Particularly, for example, when the cell balancing determiner **210** determines that the cell CELL3 needs to be balanced, the cell balancing controller **220** transmits a connection control signal CSS that turns on the cell balancing switches SH3 and SL3 to the cell balancing switches SH3 and SL3. Then, the cell balancing switches SH3 and SL3 are turned on, and the first output terminal H and the second output terminal L are respectively coupled to the lateral ends of the cell CELL3.

[0069] The cell balancing connector **420** is coupled to the first and second output terminals H and L of the cell balancing multiplexer **410**, the first cell balancing driver **430**, and the second cell balancing driver **440**. The cell balancing connector **420** includes first and second relays R_1 and R_2 and output terminals H1 and H2 of the first and second relays R_1 and R_2 are coupled to the first output terminal H, and input terminals L1 and L2 of the first and second relays R_1 and R_2 are coupled to the second output terminal L. The first and second relays R_1 and R_2 operate according to a cell balancing control signal CSD.

[0070] In further detail, the cell balancing control signal CSD turns on the first relay R_1 when the vehicle is in the temporary stop state or the running state, and electrically couples the first cell balancing driver **430** with a cell that needs to be balanced. When the first cell balancing driver **430** is coupled with the cell, a discharge path is formed by using a resistor and reduces a voltage of the cell to thereby control the voltage of the cell to be included within the normal range. In this case, a discharge control signal CB that controls the start and end of discharge of the cell that needs to be balanced is transmitted to the first cell balancing driver **430**.

[0071] When the vehicle is in the stop state, the cell balancing control signal CSD turns on the second relay R_2, and electrically couples the second balancing driver **440** with a cell that needs to be balanced.

[0072] When the vehicle is in the stop state, the second cell balancing driver **440** receives energy from a cell having a relatively high voltage among cells that need to be balanced, and transmits the energy to a cell having a relatively low voltage among the cells that need to be balanced. Then, the voltage of the cell having the relatively high voltage is reduced, and the voltage of the cell having the relatively low voltage is increased such that each of the respective cells has a voltage within the normal range.

[0073] The first cell balancing driver **430** will be described in further detail with reference to FIG. **4**. FIG. **4** shows a case in which a cell CELLi among the plurality of cells needs to be balanced. In this case, the cell CELLi is coupled with the first cell balancing driver **430** through the first relay R_1.

[0074] As shown in FIG. **4**, the first cell balancing driver **430** includes a plurality of resistors R1 to R5, a second transistor that forms a photocoupler, a photodiode PD, and a first transistor. The first cell balancing driver **430** is controlled by the discharge control signal CB.

[0075] In further detail, the cell balancing determiner **210** determines that the cell CELLi needs to be balanced, and transmits information on the cell CELLi to the cell balancing controller **220**. The information on the cell CELLi includes identification information according to a location of the cell CELLi. Then, the cell balancing controller **220** generates a connection control signal CSS according to the identification information of the cell CELLi.

[0076] According to the connection control signal CSS, cell balancing switches SHi and SLi of the cell balancing multiplexer **410** are turned on. In addition, the cell balancing controller **220** generates a cell balancing control signal CSD for selecting one of the first cell balancing driver **430** or the second cell balancing driver **440** in accordance with a vehicle driving state transmitted from the MTCU **7**, and transmits the cell balancing control signal CSD to the cell balancing connector **420**. When the current vehicle driving state is set to the temporary stop state, the cell balancing control signal CSS turns on the first relay R_1 to operate the first cell balancing driver **430**. Then, as shown in FIG. **4**, the cell CELLi and the first cell balancing driver **430** are electrically coupled.

[0077] In this case, the discharge control signal CB is generated by the cell balancing controller **220**, and controls the cell CELLi to be discharged until a voltage of the cell CELLi reaches the normal range. The cell balancing determiner **210** compares the voltage of the cell CELLi, transmitted from the sensing unit **10**, with the normal range in real time, and notifies the cell balancing controller **220** that the cell balancing operation is completed when the voltage of the cell CELLi is within the normal range. Then, the cell balancing controller **220** controls the discharge control signal CB to stop the discharging of the cell CELLi. The discharge control signal CB according to an exemplary embodiment of the present invention is changed to a first level (i.e., a low level) at a discharge start time, and is maintained at the first level while the discharge is continued. When the cell balancing operation is completed, the discharge control signal is changed to a second level that is higher than the first level.

[0078] FIG. **5** shows a discharge control signal CB according to an exemplary embodiment of the present invention. As shown in FIG. **5**, when the discharge control signal CB of the first level VL is transmitted to the first cell balancing driver **430** at the discharge start time T1, a voltage VA between a voltage of a power source VDD and the voltage of the first level VL is applied to a node A of a resistor R4 and a resistor R5. The voltage VA is determined by a resistance ratio between the resistors R4 and R5. A level of the voltage VA according to an exemplary embodiment of the present invention is set to provide a driving current to the photodiode PD.

[0079] Therefore, when the discharge control signal CB of the first level is applied, a driving current Ir is generated in the photodiode PD due to a voltage difference between the voltage of the power source VDD and the voltage VA. The photodiode PD and the second transistor Q**2** that forms the photocoupler are turned on in correspondence with the driving current Ir flowing to the photodiode PD, and a bias current Iv is generated. When the bias current Iv flows, the resistor R**3** is applied with the bias current Iv, and the first transistor Q**1** is turned on. Through the turned-on first transistor Q**1**, a discharge current Id flows. Then, a discharge path formed from a first end C**1** of the cell CELLi to a second end C**2** is formed through the turned-on relay R_**1** and the resistor R**2**, and the voltage of the cell CELLi is quickly reduced through the discharge current Id. When the voltage of the cell CELLi is reduced through the discharge and thus it is included within the normal range, the discharge control signal CB is changed to the second level VH at a time T**2**, and the discharge current Id is not generated. The first and second transistors according to an exemplary embodiment of the present invention are respectively bipolar junction transistors (BJT) having a collector electrode and an emitter electrode as two electrodes and a base electrode as a control electrode. The first and second transistors are n-channel type transistors. However, this is not restrictive, and another transistor performing the same operation can also be used.

[0080] As described, the BMS according to an exemplary embodiment of the present invention controls the voltage of the cell CELLi to be included with the normal range by forcing a discharge so as to perform the cell balancing operation when the vehicle driving state is set to the temporary stop state.

[0081] In the case that the vehicle driving state is set to the stop state, cell balancing by using the BMS and the driving method thereof according to an exemplary embodiment of the present invention will be described in further detail with reference to FIG. **6** and FIG. **7**.

[0082] Unlike the temporary stop or the running state, a discharge does not need to be forcibly performed when the vehicle is in the stop state. That is, the cell balancing operation does not need to be quickly completed. Therefore, the BMS and the driving method thereof according to an exemplary embodiment of the present invention move energy of a cell having a relatively high voltage to a cell having a relatively low voltage so as to include voltages of a plurality of cells within the normal range.

[0083] FIG. **6** and FIG. **7** show an operation of the second cell balancing driver **440** of the cell balancing unit **40** according to an exemplary embodiment of the present invention. A cell having a voltage that is greater than an average voltage of the voltages of the plurality of cells is referred to as an over-charged cell, and a cell having a voltage that is less than the average voltage is referred to as an over-discharged cell. The normal range may correspond to a range including an error range based on the average voltage, or it may correspond to the average voltage.

[0084] FIG. **6** shows a case in which energy of an over-charged cell CELLj is transmitted to the cell balancing driver **440**. FIG. **7** shows a case in which the cell balancing driver **440** transmits energy to an over-discharged cell CELLk.

[0085] The cell balancing determiner **210** detects a cell that needs to be balanced from among the plurality of cells and transmits the detected cell to the cell balancing controller **220**, and the cell balancing controller **220** divides an over-charged cell CELLj having a voltage that is greater than the normal range and an over-discharged cell CELLk having a voltage that is less than the normal range among cells that need to be balanced.

[0086] In addition, the cell balancing controller **220** transmits a connection control signal CSS to the cell balancing multiplexer **410** so as to turn on the cell balancing switches SHj and SLj, and transmits a cell balancing control signal CSD to the second relay R_**2** so as to turn on the second relay R_**2**. Then, as shown in FIG. **6**, the lateral ends of an inductor L of the second cell balancing driver **440** are coupled to the over-charged cell CELLj and a current ic flows to the inductor L, and accordingly a voltage VL is increased and a voltage of the over-charged cell CELLj is decreased. When the voltage of the over-charged cell CELLj reaches the normal range, the cell balancing determiner **210** informs the cell balancing controller **220** that the voltage of the over-charged cell CELLj has reached the normal range. The cell balancing controller **220** disconnects the cell balancing switches SHj and SLj and the second relay R_**2** by using the connection control signal CSS and the cell balancing control signal CSD.

[0087] In addition, the cell balancing controller **220** turns on the cell balancing switches SHk and SLk and the second relay R_**2** by using the connection control signal CSS and the cell balancing control signal CSD, and electrically couples the over-discharged cell CELLk and the inductor L. Then, a voltage of the inductor L becomes greater than a voltage of the over-discharged cell CELLk so that a current ia flows to the over-discharged cell CELLk. Accordingly, energy stored in the inductor L is transmitted to the over-discharged cell CELLk and the voltage of the cell CELLk is increased. When the voltage of the cell CELLk reaches the normal range, the cell balancing determiner **210** informs the cell balancing controller **220** that the voltage of the cell CELLk has reached the normal range. The cell balancing controller **220** turns off the cell balancing switches SHk and SLk by using the connection control signal CSS and the cell balancing control signal CSD, and disconnects the cell CELLk and the inductor L.

[0088] Although in FIG. **6** and FIG. **7** the second cell balancing driver **440** includes only the inductor L according to an exemplary embodiment of the present invention, it is not restrictive. For example, as depicted in FIG. **9** and FIG. **10**, the second cell balancing driver **440** may further include a capacitor C for maintaining a voltage of the inductor L at a constant level.

[0089] As described, the plurality of cell voltages can be balanced to the average voltage by using the second cell balancing driver **440** including the inductor L.

[0090] A driving method of the BMS according to an exemplary embodiment of the present invention will be described with reference to FIG. **8**.

[0091] FIG. **8** is a flowchart showing a driving method of the BMS according to an exemplary embodiment of the present invention.

[0092] As shown in FIG. **8**, the BMS **1** determines a driving state of the vehicle in step S**100**. When it is determined in step S**100** that the vehicle is in the stop state, the BMS **1** senses a voltage of respective cells in step S**110**. The BMS **1** detects cells that need to be balanced to the average voltage based on the sensing result in step S**120**. The BMS **1** divides an over-charged cell and an over-discharged cell from among the detected cells in step S**130**. The BMS **1** controls the cell balancing unit **40** to receive energy from the over-charged cell in step S**140**. In addition, the BMS **1** determines whether a voltage of the over-charged cell reaches the normal range in step **S150**. When it is determined in step **S150** that the voltage of the over-charged cell reaches the normal range, the BMS **1** disconnects the over-charged cell and the cell balancing unit **40** in step **S160**.

[0093] When it is determined in step **S150** that the voltage of the over-charged cell has not reached the normal range, the BMS **1** controls the cell balancing unit **40** to receive the energy from the over-charged cell. After step **S160**, the BMS **1** connects the cell balancing unit **40** and the over-discharged cell, and the cell balancing unit **40** transmits the received energy to the over-discharged cell in step **S170**. The BMS **1** determines whether a voltage of the over-discharged cell reaches the normal range in step **S180**. When it is determined in step **S180** that the voltage of the over-discharged cell has reached the normal range, the BMS **1** disconnects the over-discharged cell and the cell balancing unit **40** in step **S190**. When it is determined in step **S180** that the voltage of the over-discharged cell has not reached the normal range, the BMS **1** controls the cell balancing unit **40** to transmit the energy to the over-discharged cell.

[0094] When it is determined in step **S100** that the vehicle is in the temporary stop state or the running state, the BMS **1** senses a voltage of respective cells in step **S210**. The BMS **1** detects an over-charged cell that needs to be balanced based on the sensing result in step **S220**. The BMS **1** connects the detected over-charge cell and the cell balancing unit **40** in step **S230**. Then, the over-charged cell is discharged, and thus a voltage of the over-charged cell is reduced. The BMS **1** determines whether the reduced voltage has reached the normal range in step **S240**. When it is determined in **S250** that the reduced voltage of the over-charged cell has reached the normal range, the BMS **1** disconnects the over-charged cell and the cell balancing unit **40** in step **S250**.

[0095] As described, the cell balancing operation can be performed in accordance with a driving state of the vehicle by using the BMS and the driving method thereof according to an exemplary embodiment of the present invention. According to an exemplary embodiment of the present invention, equalization and balancing between cells can be efficiently performed. In addition, because the BMS is formed of one chip, there is no need for increasing the amount of wiring or replacing the main controller even through the number of cells is changed.

[0096] While this invention has been described in connection with what is presently considered to be practical exemplary embodiments, it is to be understood that the invention is not limited to the disclosed embodiments, but, on the contrary, is intended to cover various modifications and equivalent arrangements included within the spirit and scope of the appended claims.

What is claimed is:

1. A battery management system for managing a battery having a plurality of cells for supplying power to a vehicle, the battery management system comprising:

a sensing unit for measuring a voltage of each of the plurality of cells,

wherein the battery management system detects at least one first cell among the plurality of cells needing to be balanced according to a measured voltage of each of the plurality of cells, and performs a cell balancing operation on said at least one first cell by using different methods depending upon an operational state of the vehicle.

2. The battery management system of claim **1**, further comprising:

a cell balancing determiner for detecting said at least one first cell by comparing the measured voltage for each of the plurality of cells with a normal range;

a cell balancing controller for controlling a voltage of said at least one first cell to be discharged when the vehicle is in a temporary stop state, a running state, or a stop state; and

a cell balancing unit for discharging the voltage of said at least one first cell.

3. The battery management system of claim **2**, wherein when the vehicle is in the stop state, the cell balancing determiner detects an over-charged cell or an over-discharged cell from among the plurality of cells, and the cell balancing unit receives energy from the over-charged cell and transmits the energy received from the over-charged cell to the over-discharged cell.

4. The battery management system of claim **3**, wherein the cell balancing unit comprises:

a plurality of first cell balancing switches having first ends respectively coupled to the plurality of cells and second ends coupled to a first output terminal;

a plurality of second cell balancing switches having first ends respectively coupled to the plurality of cells and second ends coupled to a second output terminal;

a first cell balancing driver for discharging said at least one first cell when the vehicle is in the temporary stop state or the running state;

a second cell balancing driver for transmitting the energy received from the over-charged cell to the over-discharged cell when the vehicle is in the stop state;

a first relay for connecting the first cell balancing driver, the first output terminal, and the second output terminal; and

a second relay for connecting the second cell balancing driver, the first output terminal, and the second output terminal.

5. The battery management system of claim **4**, wherein when the vehicle is in the temporary stop state or the running state, the cell balancing controller turns on the first relay and turns on first switches and second switches among the plurality of first cell balancing switches and the plurality of second cell balancing switches that correspond to said at least one first cell.

6. The battery management system of claim **5**, wherein the first relay has a first relay first end and a first relay second end, and wherein the first cell balancing driver comprises:

a first resistor having a first resistor first end and a first resistor second end, the first resistor first end being coupled to the first relay first end;

a second resistor having a second resistor first end and a second resistor second end, the second resistor first end being coupled to the first relay first end and to the first resistor first end;

a first transistor having a first transistor first electrode, a first transistor second electrode, and a first transistor control electrode, the first transistor first electrode being coupled to the second transistor second end, the first transistor second electrode being coupled to the first relay second end;

a second transistor having a second transistor first electrode and a second transistor second electrode, the second transistor first electrode being coupled to the first resistor second end;

a third resistor having a third resistor first end and a third resistor second end, the third resistor first end being coupled to the second transistor second electrode and to the first transistor control electrode, the third transistor second end being coupled to the first transistor second electrode and to the first relay second end;

a photodiode for forming a photocoupler with the second transistor, the photodiode having a photodiode anode electrode and a photodiode cathode electrode;

a first power source coupled to the photodiode anode electrode;

a fourth resistor having a fourth resistor first end and a fourth resistor second end, the fourth resistor first end being coupled to the photodiode cathode electrode; and

a fifth resistor having a fifth resistor first end and a fifth resistor second end, the fifth resistor first end being coupled to the first power source, the fifth resistor second end being coupled to the fourth resistor first end and to the photodiode cathode electrode.

7. The battery management system of claim **6**, wherein the cell balancing controller transmits a discharge control signal to the fourth transistor second end to permit a driving current to flow to the photodiode.

8. The battery management system of claim **7**, wherein a bias current flows to the second transistor in response to the driving current, and the first transistor is turned on by a bias voltage applied to the first transistor control electrode and to the first transistor second electrode in response to the bias current and the third resistor.

9. The battery management system of claim **8**, wherein when the first transistor is turned on, charges of said at least one first cell are discharged by a discharge path having the second resistor and the first transistor so that a voltage of said at least one first cell is decreased.

10. The battery management system of claim **4**, wherein when the vehicle is in the stop state, the cell balancing controller turns on first switches and second switches among the plurality of first cell balancing switches and the plurality of second cell balancing switches that correspond to the over-charged cell, and turns off the first switches and the second switches when a voltage of the over-charged cell reaches the normal range.

11. The battery management system of claim **10**, wherein after turning off the first switches and the second switches when the vehicle is in the stop state, the cell balancing controller turns on third switches among the plurality of first cell balancing switches corresponding to the over-discharged cell, and turns on fourth switches among the plurality of second cell balancing switches corresponding to the over-discharged cell.

12. The battery management system of claim **11**, wherein when the vehicle is in the stop state, the cell balancing controller turns off the third switches and the fourth switches when the voltage of the over-discharged cell reaches the normal range.

13. The battery management system of claim **12**, wherein:

the second relay has a second relay first end and a second relay second end;

the second cell balancing driver comprises an inductor having an inductor first end and an inductor second end, the inductor first end being coupled to the second relay first end, the inductor second end being coupled to the second relay second end; and

the inductor stores energy transmitted through the first switches, the second switches, and the second relay.

14. The battery management system of claim **13**, wherein the energy stored in the inductor is transmitted to the over-discharged cell through the third switches, the fourth switches, and the second relay.

15. The battery management system of claim **14**, wherein the second cell balancing driver further comprises a capacitor coupled in parallel with the inductor.

16. The battery management system of claim **1**, further comprising a connection port unit coupled to the plurality of cells, the connection port unit coupling the battery management system and the plurality of cells.

17. The battery management system of claim **1**, wherein the battery management system is formed of one chip.

18. A driving method of a battery management system for managing a battery having a plurality of cells supplying power to a vehicle, the driving method comprising:

a) determining a driving state of the vehicle;

b) sensing a voltage for each of the plurality of cells;

c) determining a cell among the plurality of cells needing to be balanced; and

d) performing a cell balancing operation on the cell by using different methods depending upon an operational state of the vehicle.

19. The driving method of claim **18**, wherein when the vehicle is in a stop state, determining a cell needing to be balanced comprises detecting an over-charged cell and an over-discharged cell, and performing a cell balancing operation comprises performing the cell balancing operation on the over-charged cell and the over-discharged cell by transmitting energy from the over-charged cell to the over-discharged cell.

20. The driving method of claim **18**, wherein when the vehicle is in a temporary stop state or a running state, determining a cell needing to be balanced comprises detecting an over-charged cell, and performing a cell balancing operation comprises performing the cell balancing operation by discharging the over-charged cell.

* * * * *

IE2

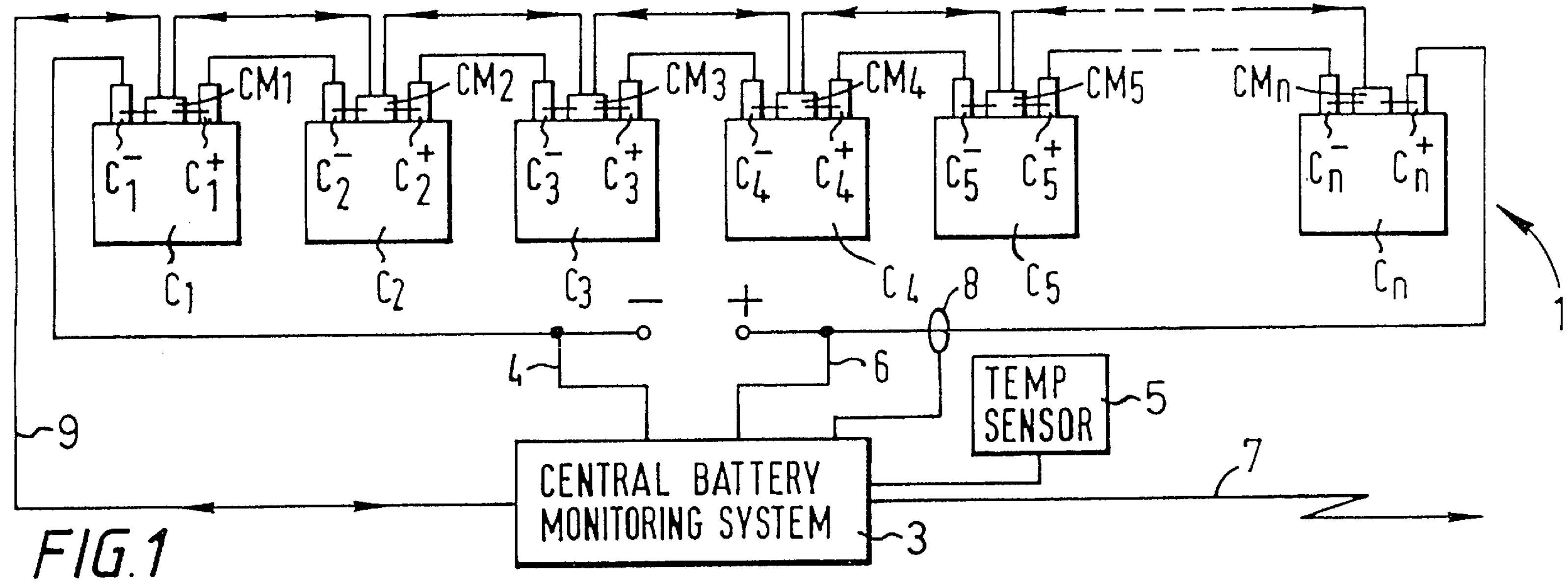

CM1
CM2
CM3
CM4
CM5
CMn
C1
C2
C3
C4
C5
Cn
−
+
1
3
4
5
6
7
8
9
TEMP SENSOR
CENTRAL BATTERY MONITORING SYSTEM

FIG.1

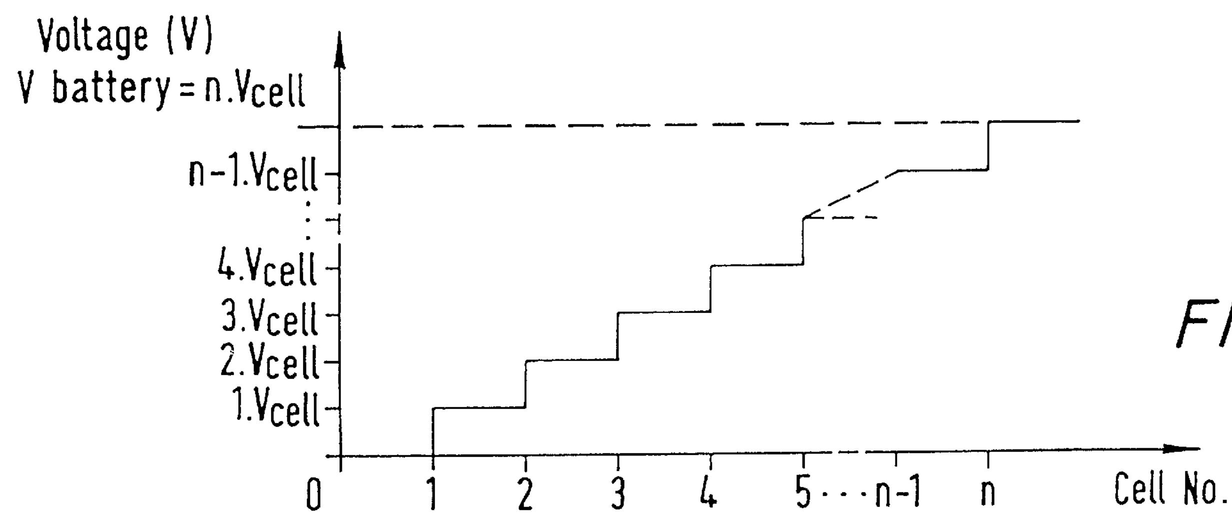

Voltage (V)
V battery = n.Vcell
n-1.Vcell
4.Vcell
3.Vcell
2.Vcell
1.Vcell
0
1
2
3
4
5 · · · n-1
n
Cell No.

FIG.4

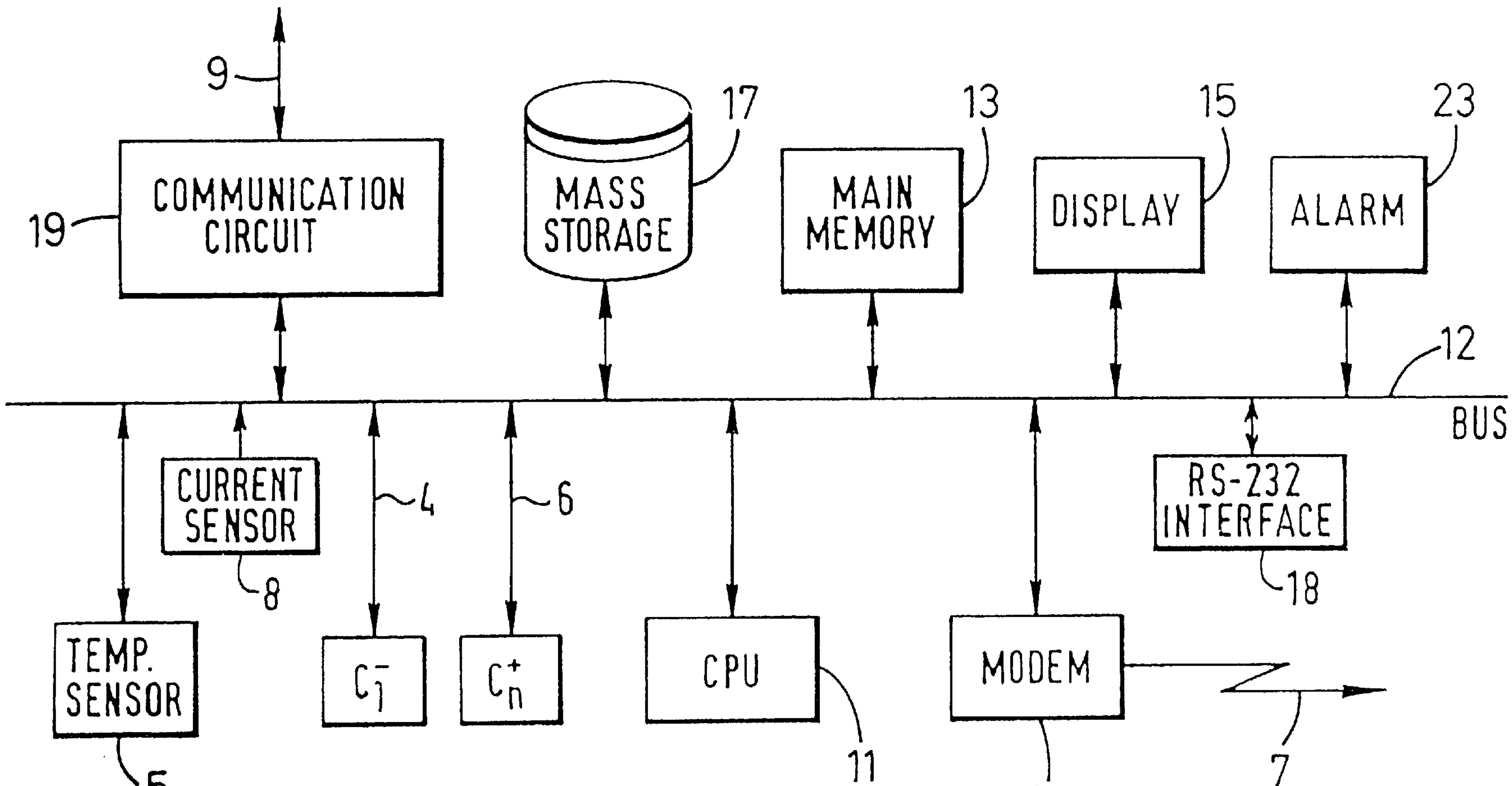

COMMUNICATION CIRCUIT
MASS STORAGE
MAIN MEMORY
DISPLAY
ALARM
BUS
CURRENT SENSOR
TEMP. SENSOR
C_1^-
C_n^+
CPU
MODEM
RS-232 INTERFACE
9
19
17
13
15
23
12
4
6
8
5
11
21
18
7

FIG. 2

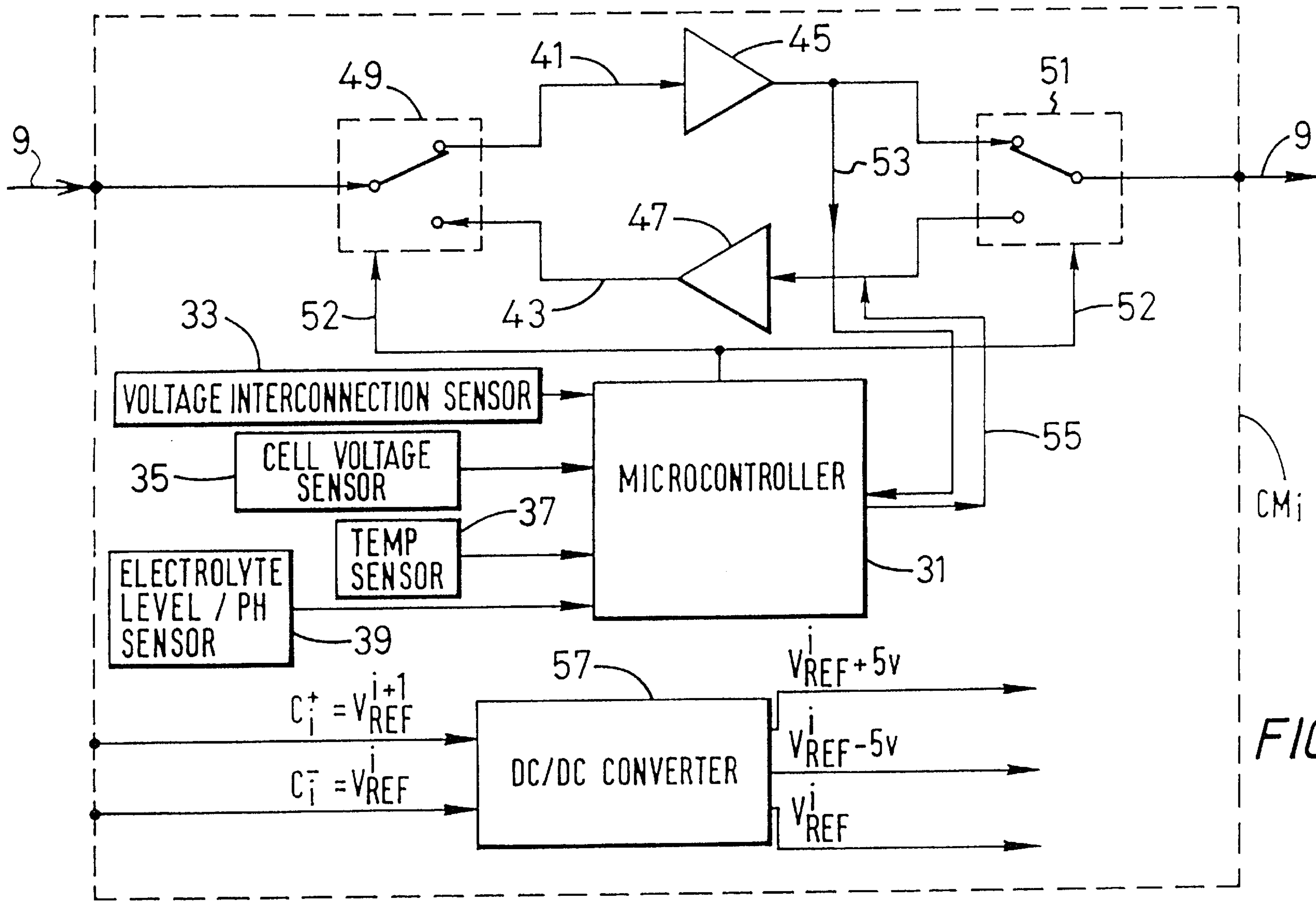

9
49
41
45
51
9
53
47
33
52
43
52
VOLTAGE INTERCONNECTION SENSOR
CELL VOLTAGE SENSOR
35
MICROCONTROLLER
55
CMi
TEMP SENSOR
37
31
ELECTROLYTE LEVEL / PH SENSOR
39
57
$V^{i}_{REF}+5v$
$C^{+}_{i}=V^{i+1}_{REF}$
$V^{i}_{REF}-5v$
DC/DC CONVERTER
$C^{-}_{i}=V^{i}_{REF}$
V^{i}_{REF}

FIG.3

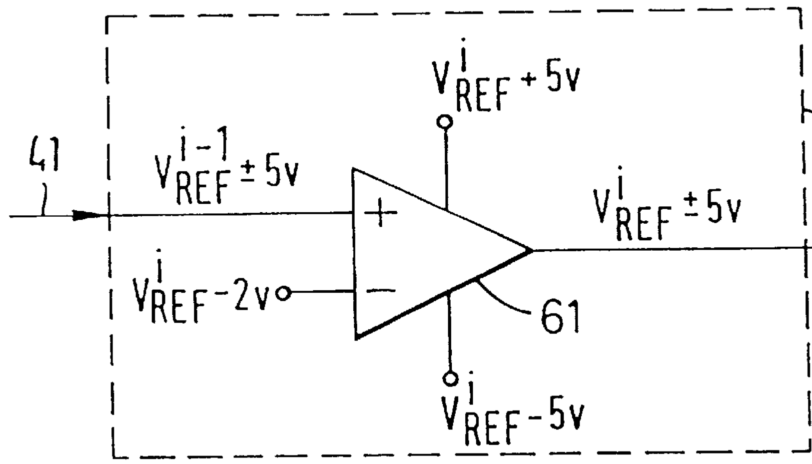


FIG. 5a

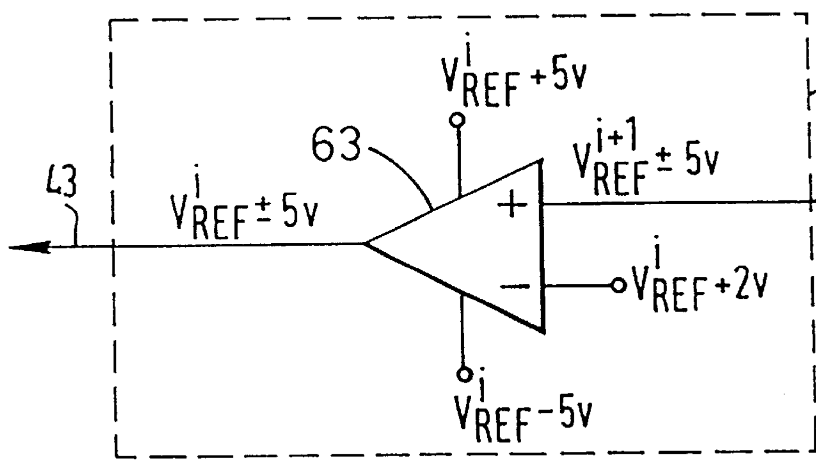


FIG. 5b

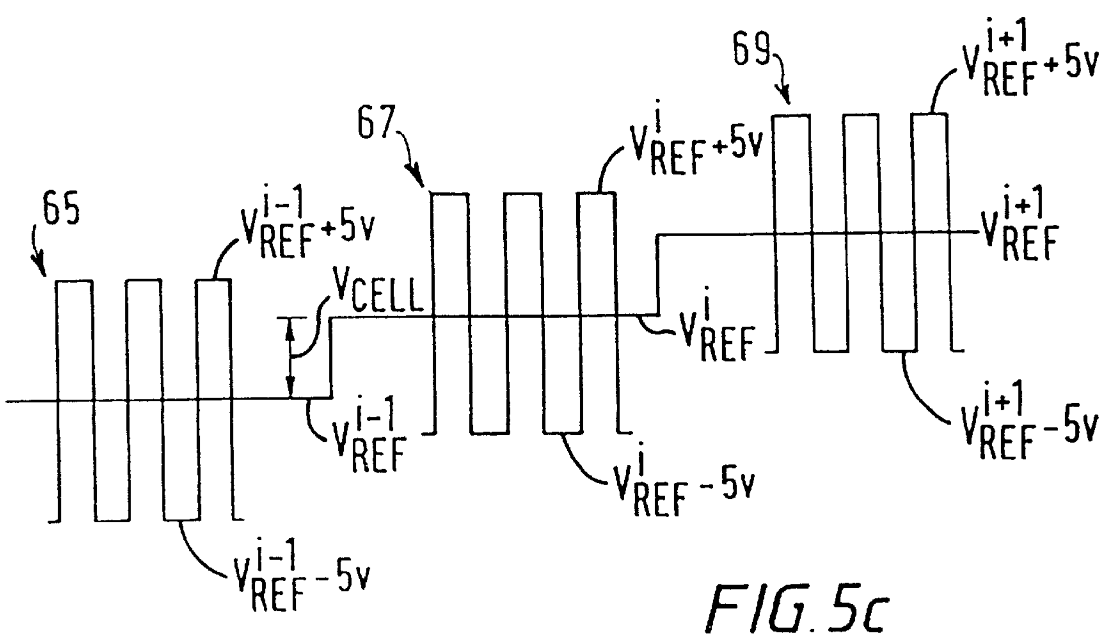
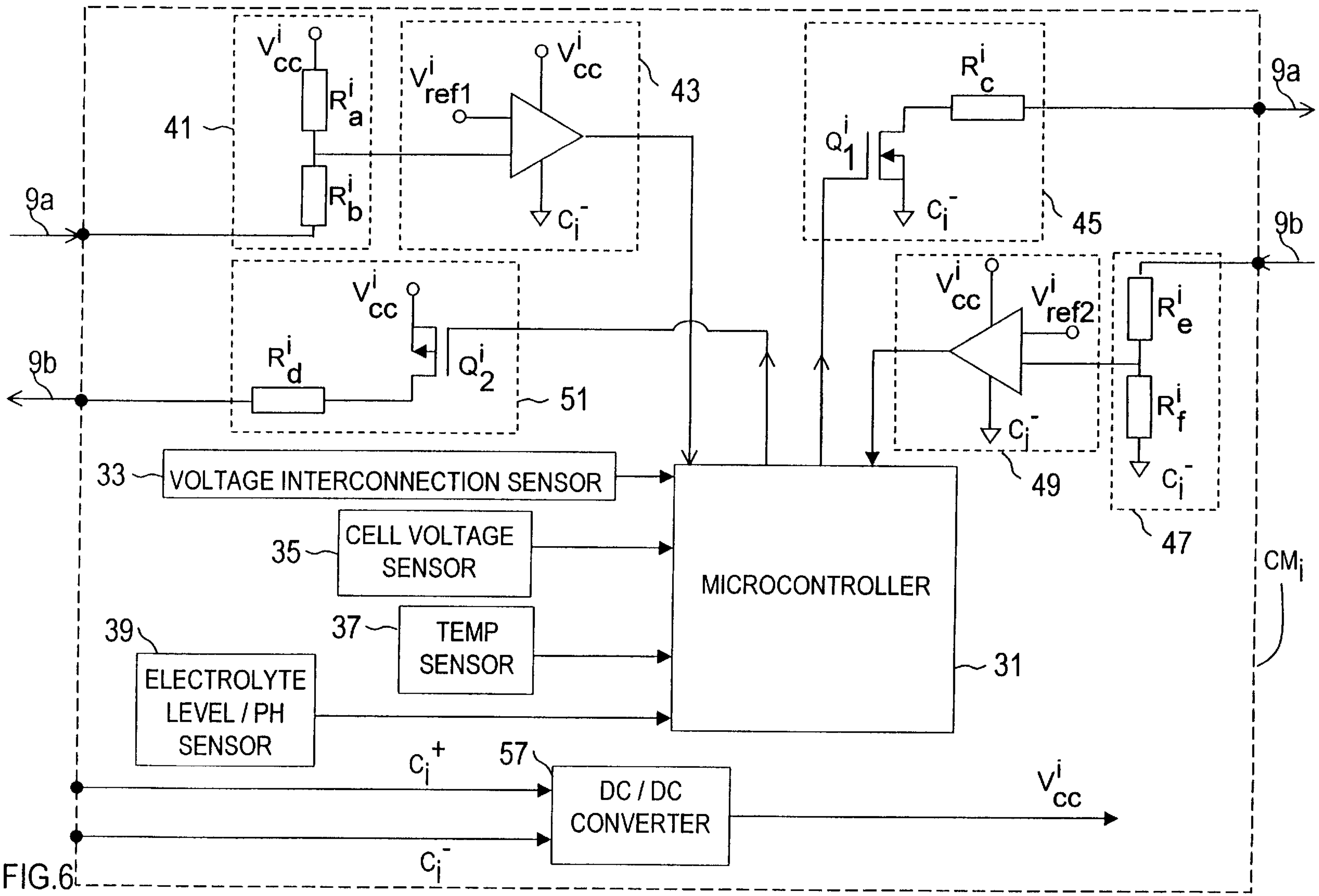


FIG. 5c


9a
9b
41
43
45
47
49
51
33
35
37
39
31
57
CMi
VOLTAGE INTERCONNECTION SENSOR
CELL VOLTAGE SENSOR
TEMP SENSOR
ELECTROLYTE LEVEL / PH SENSOR
MICROCONTROLLER
DC / DC CONVERTER
FIG.6

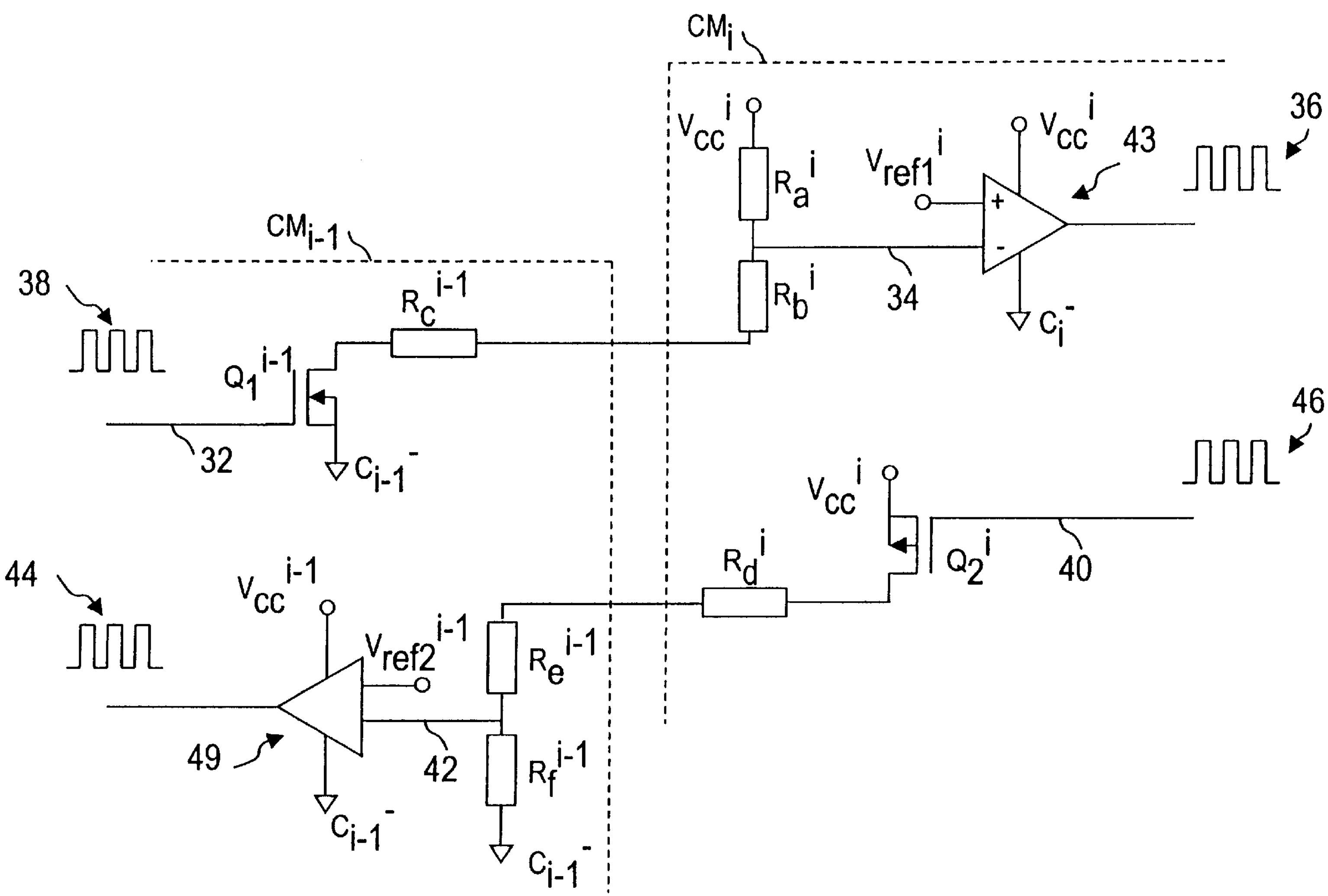
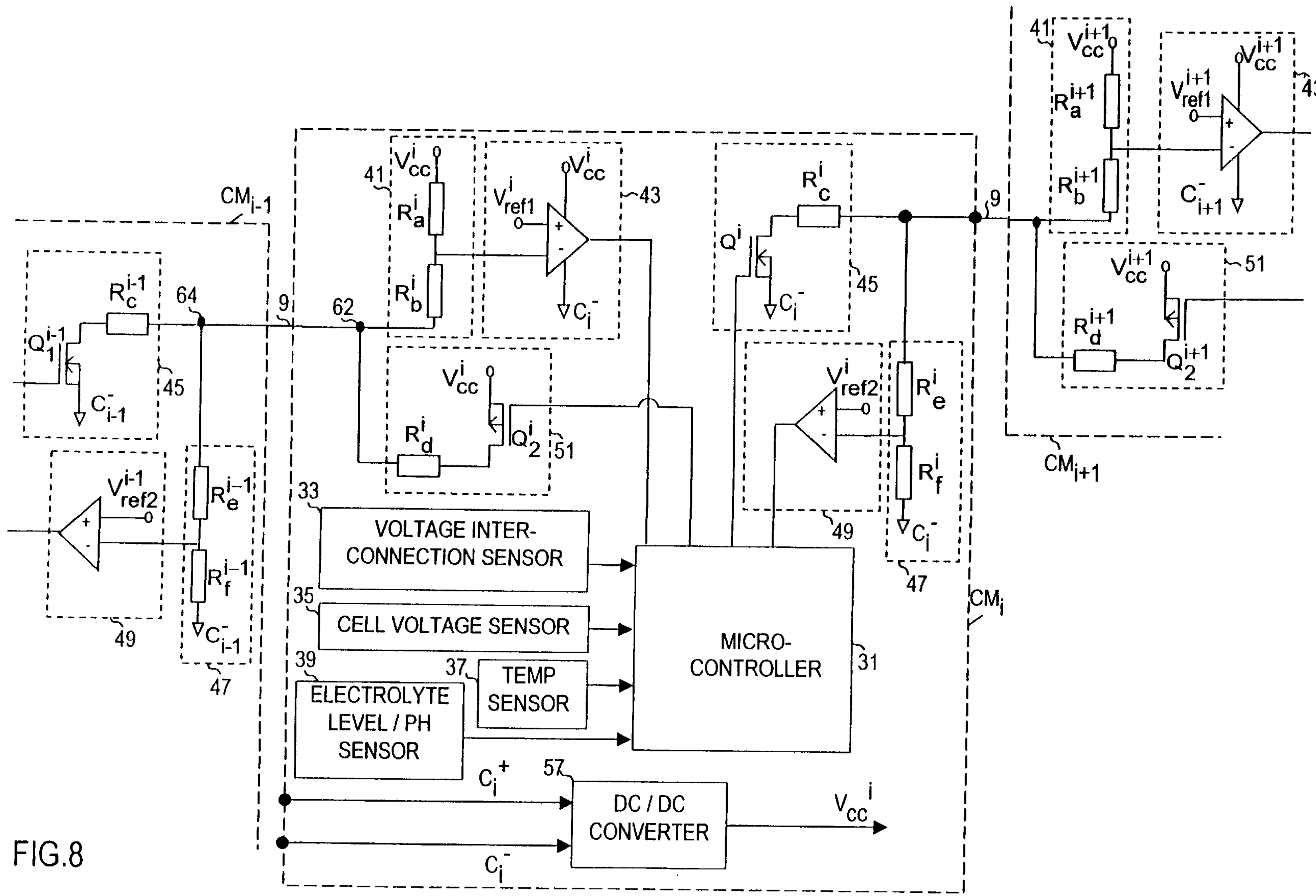

CMi
CMi-1
38
Q1 i-1
Rc i-1
32
Ci-1 -
Vcc i
Ra i
Rb i
Vref1 i
Vcc i
43
36
34
Ci -
46
Vcc i
Q2 i
40
Rd i
44
Vcc i-1
Vref2 i-1
Re i-1
Rf i-1
49
42
Ci-1 -
Ci-1 -

FIG.7



VOLTAGE INTER-CONNECTION SENSOR
CELL VOLTAGE SENSOR
ELECTROLYTE LEVEL / PH SENSOR
TEMP SENSOR
MICRO-CONTROLLER
DC / DC CONVERTER
CMi-1
CMi
CMi+1

FIG.8

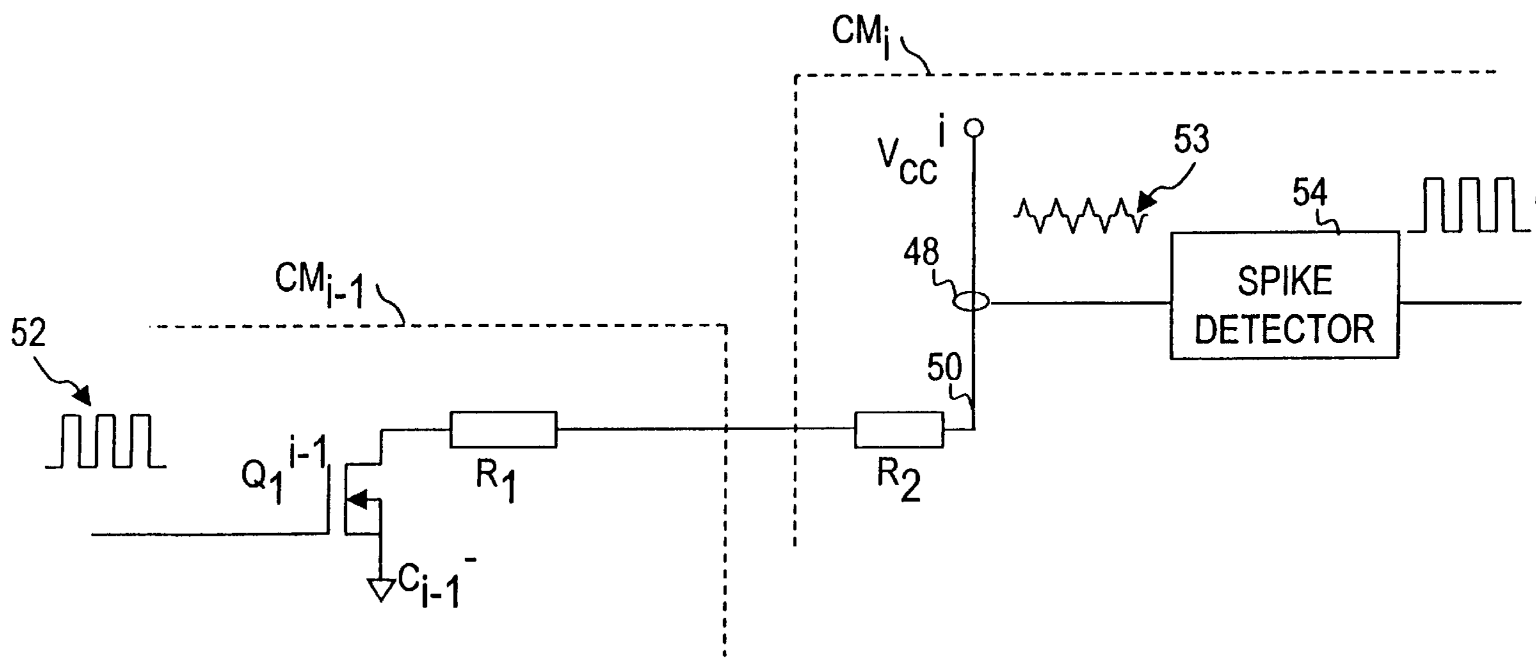
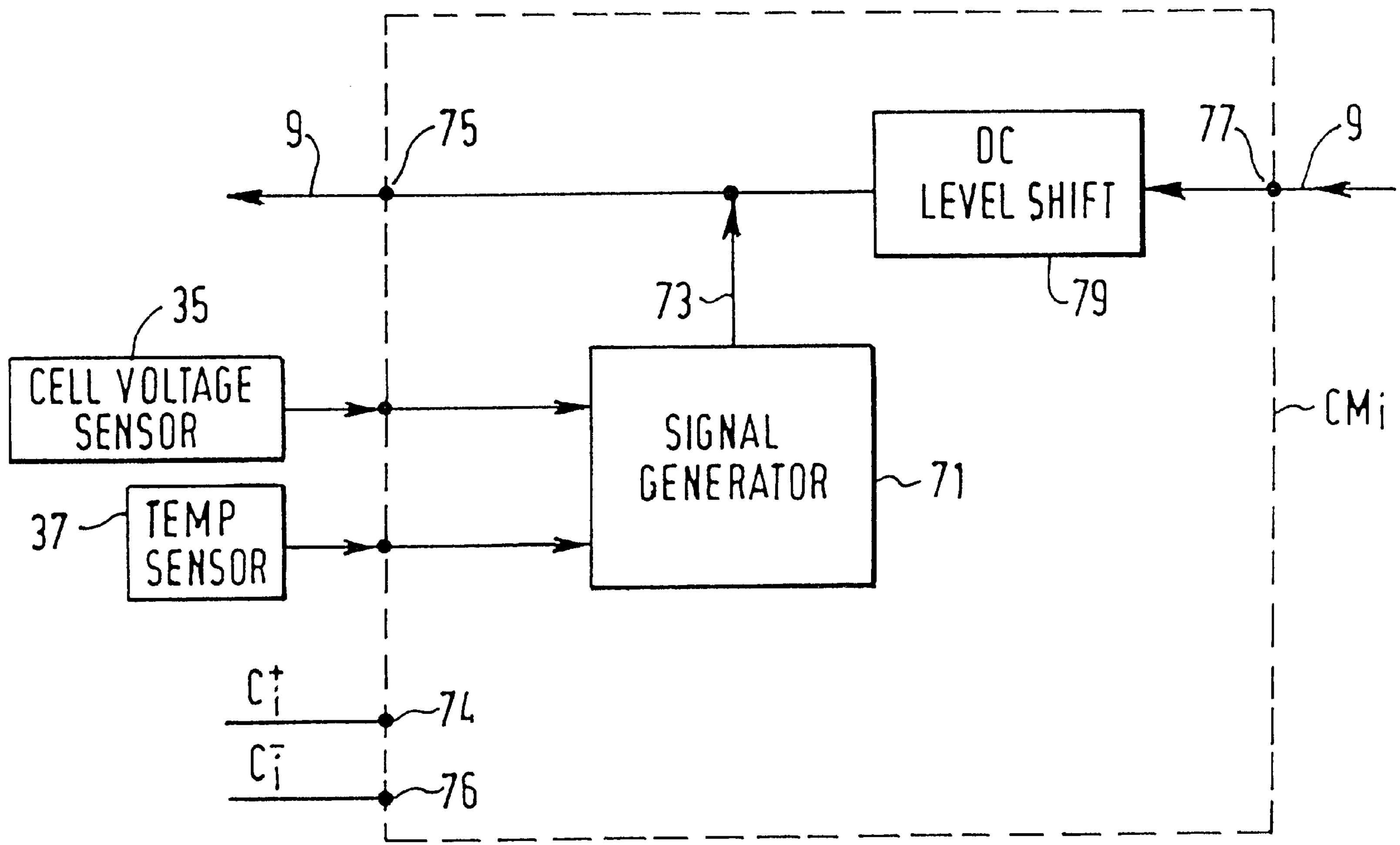


FIG.9

FIG. 10



9
75
DC
LEVEL SHIFT
77
9
79
73
35
CELL VOLTAGE
SENSOR
SIGNAL
GENERATOR
71
CMi
37
TEMP
SENSOR
C_i^+
74
C_i^-
76

FIG. 11

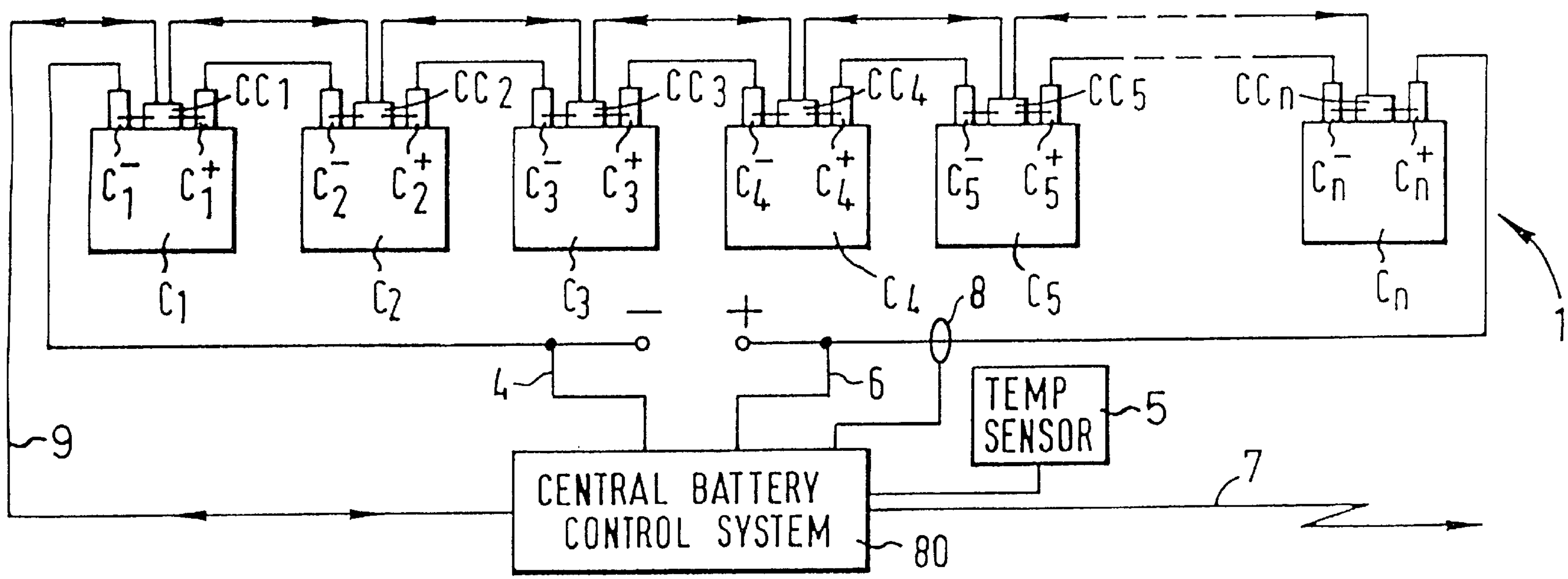
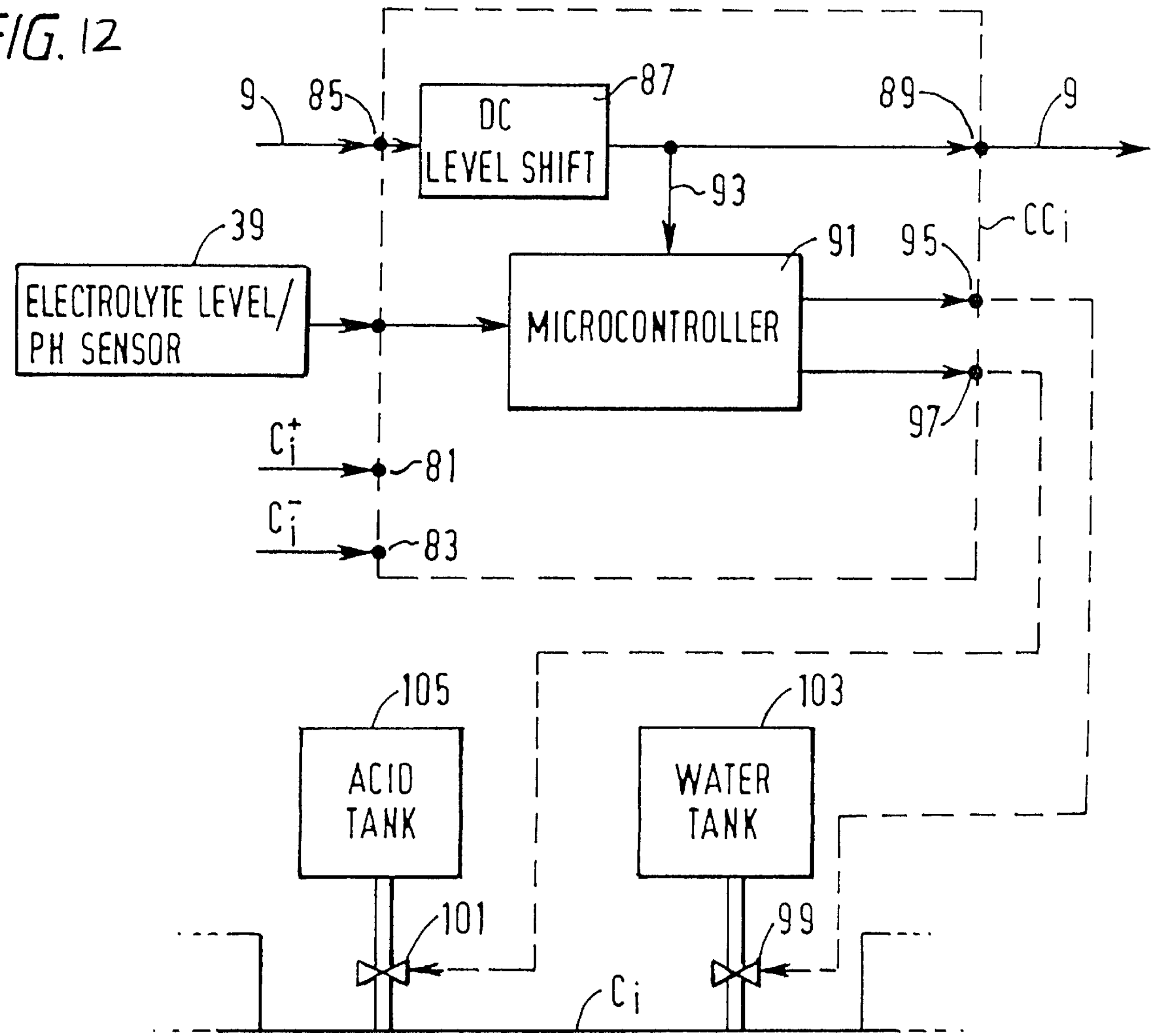

CC1
CC2
CC3
CC4
CC5
CCn
C1
C2
C3
C4
C5
Cn
TEMP SENSOR
CENTRAL BATTERY CONTROL SYSTEM
80
1
4
5
6
7
8
9

FIG. 12


9
85
DC
LEVEL SHIFT
87
89
9
93
39
ELECTROLYTE LEVEL/
PH SENSOR
MICROCONTROLLER
91
95
CCi
97
Ci+
81
Ci−
83
105
ACID
TANK
103
WATER
TANK
101
99
Ci

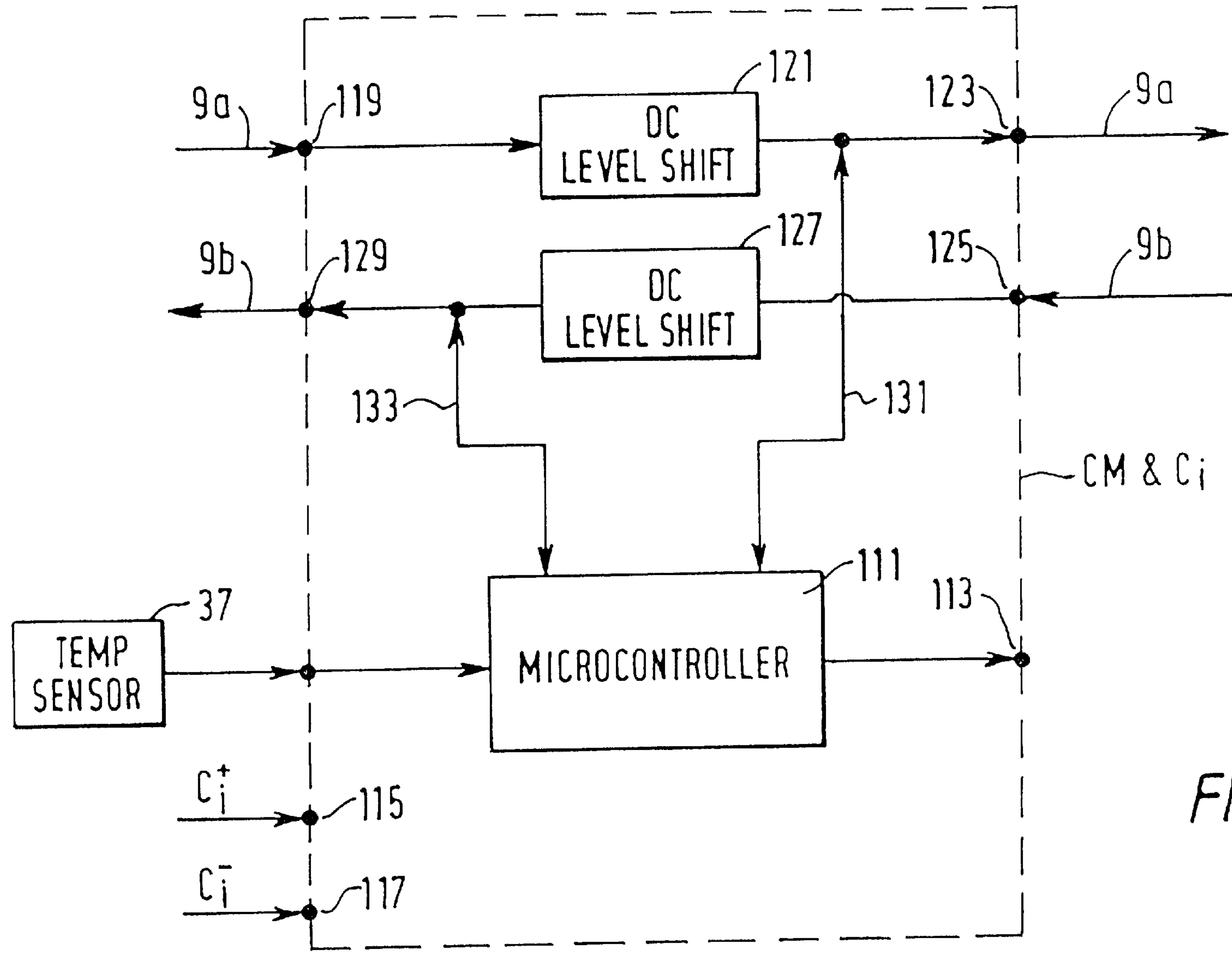

9a
119
121
DC
LEVEL SHIFT
123
9a
9b
129
127
DC
LEVEL SHIFT
125
9b
133
131
CM & Ci
37
TEMP
SENSOR
111
MICROCONTROLLER
113
C_i^+
115
C_i^-
117

FIG. 13

FIG. 14

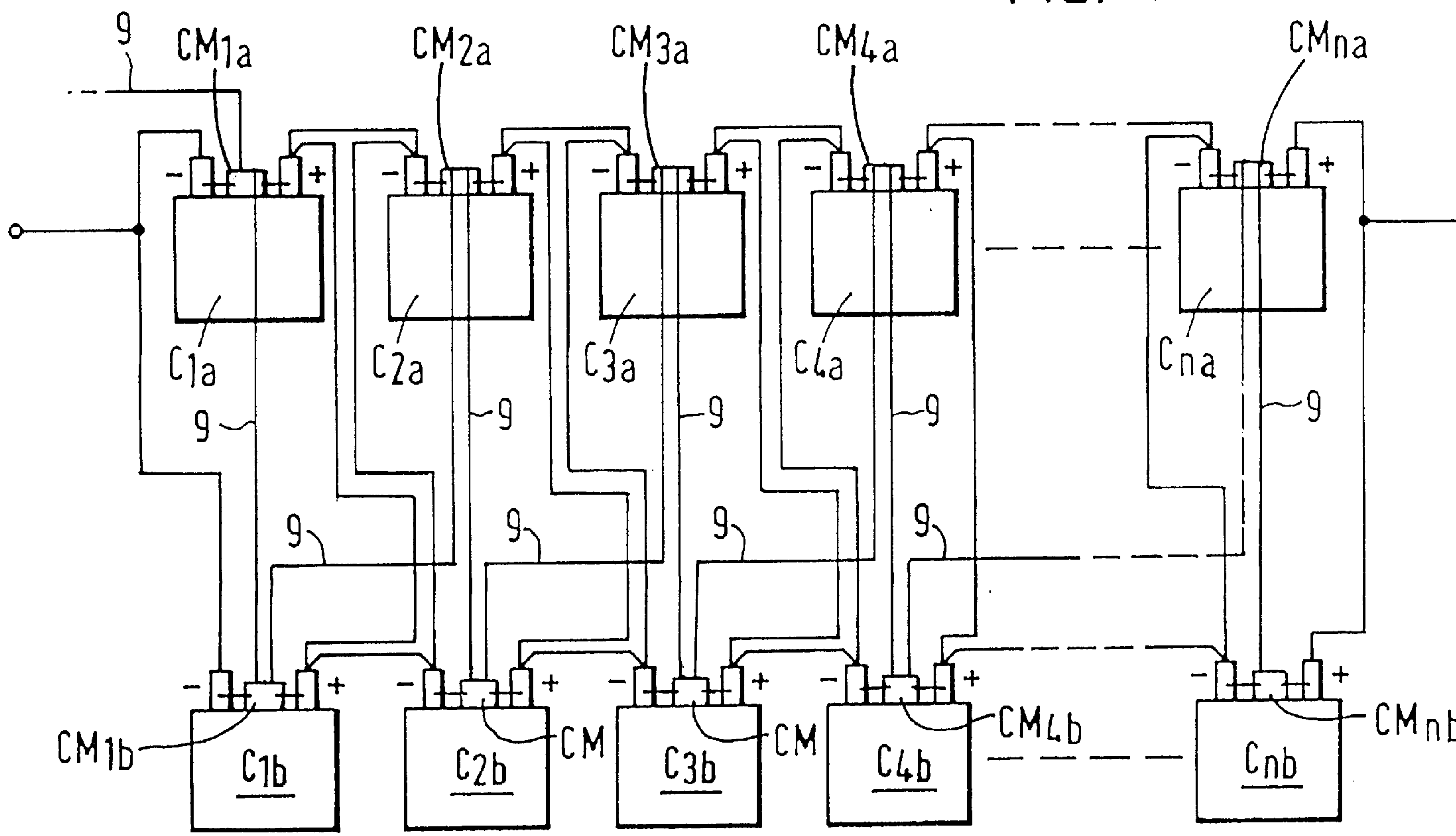
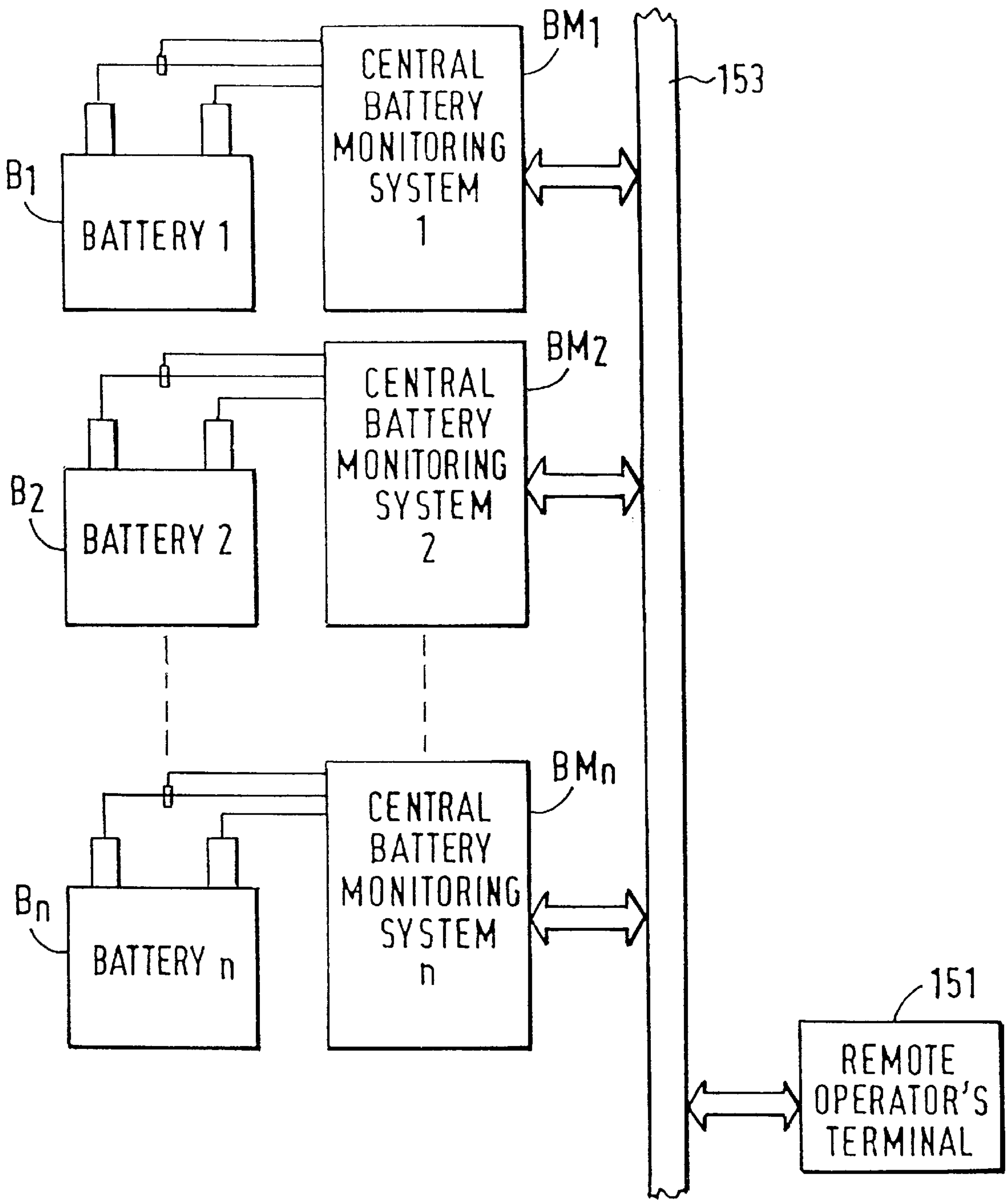

9
CM1a
CM2a
CM3a
CM4a
CMna
C1a
C2a
C3a
C4a
Cna
9
9
9
9
9
9
9
9
9
CM1b
C1b
C2b
CM
C3b
CM
C4b
CM4b
Cnb
CMnb

FIG. 15



BM1
153
CENTRAL
BATTERY
MONITORING
SYSTEM
1
B1
BATTERY 1
BM2
CENTRAL
BATTERY
MONITORING
SYSTEM
2
B2
BATTERY 2
BMn
CENTRAL
BATTERY
MONITORING
SYSTEM
n
Bn
BATTERY n
151
REMOTE
OPERATOR'S
TERMINAL

SIGNALLING SYSTEM

FIELD OF THE INVENTION

The present invention relates to a signalling system. The invention is applicable for use in a system for monitoring and/or controlling the cells of an industrial battery.

BACKGROUND OF THE INVENTION

Industrial batteries comprise a number of rechargeable battery cells which can be electrically connected in various series and series-parallel combinations to provide a rechargeable battery having a desired output voltage. To recharge the battery, a current is passed through the cells in the opposite direction of current flow when the cells are working. There are many different types of battery cells available, but those most commonly used in industrial applications are lead acid battery cells, each of which provides 2 volts, and nickel-cadmium (Nicad) battery cells, each of which provides 1.2 volts.

The batteries are usually used as a back-up power supply for important systems in large industrial plants, such as off-shore oil rigs, power stations and the like. Since the batteries are provided as back-up in the event of a fault with the main generators, they must be constantly monitored and maintained so that they can provide power to the important systems for a preset minimum amount of time.

Many battery monitoring systems have been proposed which monitor the battery as a whole and provide an indication of the battery voltage. However, only a few systems have been proposed which can also monitor the individual cells which make up the battery. These systems use a number of monitoring devices, some of which are powered by the battery cell or cells which they monitor and send status information indicative of the cell voltage back to a central battery monitory system which monitors the battery as a whole.

However, since the cells are connected in series and since each cell monitoring device is powered by the cell which it is monitoring, the ground or reference voltage of each cell monitoring device is different. For example, in an industrial battery which has sixty lead acid cells connected in series, the negative terminal, i.e. the ground, of the fifth cell will be at a potential of approximately 8 volts and the positive terminal will be at a potential of approximately 10 volts, whereas the negative terminal of the seventh cell will be at a potetial of approximately 12 volts and the positive terminal will be at a potential of approximately 14 volts. This has lead to the common misconception in the art that the cell monitoring devices have to be electrically isolated from each other and from the central battery monitoring system.

In one known cell monitoring system, each cell is independently linked to its own electrically isolated input at the central monitoring system. The problem with this system is that a large number of connectors are needed to link the individual cell monitoring devices to the central monitoring system. Consequently, in practice, it is seldom used for permanent real-time monitoring of the battery cells.

In another known cell monitoring system, each cell monitoring device is serially linked to its neighbours in a daisy-chain configuration, either by using optical links between the monitoring devices or by using transformers which have no DC path. The problem with this system is that to operate,

each of the cell monitoring devices requires either an electrical to optical and an optical to electrical converter or a modulator and a demodulator, which makes them relatively expensive and inefficient since this additional circuitry requires more power from the cell.

There is therefore a need to provide a simple cell monitoring device which can monitor and report on the status of the cells of the battery, but which consumes minimal power from the cell which it is monitoring.

As mentioned above, existing battery monitoring systems monitor the battery and provide an indication of the battery voltage. However, battery voltage is not an indication of the capacity of the battery, i.e. the ability of the battery to provide energy. There is therefore also a need to provide a battery monitoring system which can give the user a fairly accurate estimate of how much load he can place on a battery and over what period of time.

SUMMARY OF THE INVENTION

The inventor has realised that it is possible to overcome the problem of having the cell monitoring devices operating at different voltages using simple electronic components and that therefore, there is no need for electrical isolation between the individual cell monitoring devices and the central monitoring system.

According to a first aspect, the present invention provides a signalling system for use with a plurality of series connected battery cells, comprising: a plurality of cell signalling devices, each to be powered by a respective one or more of the plurality of battery cells; and a communication link connecting the plurality of cell signalling devices in series; wherein each cell signalling device comprises a level shift circuit which is operable to receive signals transmitted from an adjacent cell signalling device to shift the level of the received signal and to output the level shifted signal for transmission to the communication link. By providing a level shift circuit in each cell signalling device, the cell signalling devices can be linked together in a communication link without the need for electrical isolation between the signalling devices.

The signalling system can be used as part of a battery monitoring and/or control system which is used to monitor and/or control the series connected battery cells. By providing the level shift circuit in each cell signalling device, the signalling system obviates the need for electrical isolation between individual cell signalling devices. Consequently, the communication link can be a simple one-wire communication bus.

Preferably each of the cell signalling devices is able to receive communications from and transmit communications to the communication link so that they can communicate with, for example, the battery monitoring and/or control system. In which case, each cell signalling device can comprise two DC level shift circuits, one for increasing the level of the received signals for transmission to a cell signalling device having a higher ground potential than that of the receiving cell signalling device, and one for reducing the level of the received signals for transmission to a cell signalling device which has a lower ground potential than that of the receiving cell signalling device.

Each level shift circuit can comprise a simple electronic device, such as a comparator, which consumes a relatively small amount of power from the battery cell which powers the cell signalling device.

The first aspect of the present invention also provides a cell signalling device for use in the above defined signalling system, comprising: a power input terminal connectable to the cell or cells which is or are to power the cell signalling device; and at least one DC level shift circuit for receiving signals from an adjacent cell signalling device, for shifting the level of the received signal, and for outputting the level shifted signal for transmission to the communication link.

The first aspect of the present invention also provides a signalling kit comprising a plurality of the cell signalling devices defined above. The kit may also comprise the communication link for connecting the cell signalling devices in series.

The first aspect of the present invention also provides a signalling method using a plurality of series connected battery cells, comprising the steps of: providing a plurality of cell signalling devices and powering them with a respective one or more of the plurality of battery cells; providing a communication link which connects the plurality of cell signalling devices in series; receiving signals transmitted from an adjacent cell signalling device; shifting the level of the received signals; and outputting the level shifted signals to the communication link.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will now be described, by way of example only, with reference to the accompanying drawings, in which:

FIG. **1** schematically shows a battery comprising a number of battery cells connected in series, a central battery monitoring system for monitoring the condition of the battery as a whole and individual cell monitoring devices for monitoring the cells of the battery;

FIG. **2** is a schematic diagram showing more detail of the central battery monitoring system shown in FIG. **1**;

FIG. **3** is a schematic diagram of one of the cell monitoring devices shown in FIG. **1**;

FIG. **4** is a plot showing the battery-cell voltage distribution;

FIG. **5***a* is a circuit diagram of a first comparator forming part of the cell monitoring device shown in FIG. **3**;

FIG. **5***b* is a circuit diagram of a second comparator forming part of the cell monitoring device shown in FIG. **3**;

FIG. **5***c* is a schematic representation showing part of the battery-cell staircase voltage distribution and example data pulses which are applied to the input of the comparators shown in FIGS. **5***a* and **5***b;*

FIG. **6** is a schematic diagram of one of the cell monitoring devices according to a second embodiment of the present invention;

FIG. **7** schematically illustrates the way in which signals are passed between adjacent cell signalling devices in the second embodiment of the invention;

FIG. **8** schematically illustrates the form of a cell monitoring device according to a third embodiment and the way in which it is connected to neighbouring cell monitoring devices;

FIG. **9** schematically illustrates an alternative way in which signals can be transmitted between adjacent cell signalling devices;

FIG. **10** is a schematic diagram of a battery cell monitoring device for use in a battery monitoring system according to a second embodiment of the present invention;

FIG. **11** schematically shows a battery comprising a number of battery cells connected in series, a central battery control system for controlling the battery as a whole and individual battery cell controllers for controlling the cells of the battery;

FIG. **12** is a schematic diagram of one of the battery cell control devices shown in FIG. **11**;

FIG. **13** is a schematic diagram of a battery cell monitoring and control device for use in a battery monitoring and control system embodying the present invention;

FIG. **14** is a schematic representation of an industrial battery in which the cells of the battery are connected in a series-parallel configuration; and

FIG. **15** is a schematic diagram of a system for monitoring a plurality of industrial batteries.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

A first embodiment of the present invention will now be described with reference to FIGS. **1** to **5**. FIG. **1** schematically shows an industrial battery, generally indicated by reference numeral **1**, comprising a number of lead acid battery cells $C_1, C_2, C_3 \ldots C_n$ connected so that the negative terminal C_i^- of cell C_i is connected to the positive terminal C_{i-1}^+ of preceding cell C_{i-1} and the positive terminal C_i^+ of cell C_i is connected to the negative terminal C_{i+1}^- of the succeeding cell C_{i+1}, whereby the negative terminal C_{i+1}^- of the first cell C_1 is the negative terminal of the battery and the positive terminal C_n^+ of the last cell C_n is the positive terminal of the battery. Since the battery cells are lead acid, they each provide approximately 2 volts and the voltage of the battery as a whole will be approximately 2n volts. For industrial applications a voltage of 120 volts is often required. Therefore, 60 series connected lead acid or 100 series connected Nicad battery cells would be required. Sometimes, each cell in the series connection is connected in parallel with one or more similar cells, so as to provide redundancy, so that the battery will not fail if a single cell fails.

FIG. **1** also shows a central battery monitoring system **3** which is powered by the battery **1** via connectors **4** and **6,** which connect the central battery monitoring system **3** to the negative terminal C_1^- and the positive terminal C_n^+ of the battery **1**, respectively. The battery monitoring system **3** monitors the status of the industrial battery **1** as a whole, based on charging and discharging characteristics of the battery (determined by monitoring the battery voltage from connectors **4** and **6** and the current being drawn from or supplied to the battery **1**, which is sensed by current sensor **8**, whilst the battery is being charged and subsequently discharged), the ambient temperature (input from temperature sensor **5**) and on information relating to the efficiency characteristics of the battery cells (provided by the battery cell manufacturer). The monitoring results can be stored in the central battery monitoring system **3** or they can be transmitted to a remote user (not shown) via the telephone line **7**.

Each of the battery cells C_i, shown in FIG. **1**, also has a battery cell monitoring device CM_i mounted on top of the cell between its positive and negative terminals Ci+and C_i^- respectively, which monitors the status of the cell C_i. Each cell monitoring device CM_i is powered by the cell C_i which it monitors and communicates with the central battery monitoring system **3** via a simple one-wire communication link **9**. The communication link **9** links the cell monitoring devices CM_i. in series in a daisy chain configuration to the central battery monitoring system **3,** so that communications from the central battery monitoring system **3** to the cell monitoring devices CM_i pass from left to right along the communication link **9** and communications from the cell monitoring devices CM_i to the central battery monitoring system 3 pass from right to left along the communication link 9. Each cell monitoring device CM_i has its own cell identification or address, which, in this embodiment, is set in advance using DIP-switches mounted in the device. This allows communications from the central battery monitoring system 3 to be directed to a specific cell monitoring device and allows the central battery monitoring system 3 to be able to identify the source of received communications.

The battery monitoring system shown in FIG. 1 operates in two modes. In the first mode, the central battery monitoring system 3 monitors the condition of the industrial battery 1 as a whole and polls each of the cell monitoring devices CM_i in turn. During this mode, each of the cell monitoring devices CM_i listens to communications from the central battery monitoring system 3 on the communication link 9 and responds when it identifies a communication directed to it. When polled, each cell monitoring device CM_i performs a number of tests on the corresponding battery cell C_i and returns the results of the tests back to the central battery monitoring system 3 via the communication link 9.

In the second mode of operation, the central battery monitoring system 3 listens for communications on the communication link 9 from the cell monitoring devices CM_i indicating that there is a faulty condition with one of the battery cells C_i. In this second mode of operation, each cell monitoring device CM_i continuously monitors the corresponding battery cell C_i and, upon detection of a faulty condition, checks that the communication link 9 is free and then sends an appropriate message back to the central battery monitoring system 3 via the communication link 9.

FIG. 2 is a schematic diagram of the central battery monitoring system 3 shown in FIG. 1. As shown, the central battery monitoring system 3 comprises a CPU 11 for controlling the operation of the central battery monitoring system 3. The CPU 11 is connected, via data bus 12, to a main memory 13 where data from the input sensors is stored and where test programs are executed, to a display 15 which displays the battery's current status and to a mass storage unit 17 for storing the sensor data and the results of the battery tests. The mass storage unit 17 can be fixed within the central battery monitoring system 3, but is preferably a floppy disk or a PCMIA memory card which can be withdrawn and input into an operator's personal computer for analysis. An operator can also retrieve the stored data and results and control the set up and initialisation of the central battery monitoring system 3 via the RS-232 serial interface 18. As mentioned above, instead of storing the test results in the mass storage unit 17, they can be transmitted via a modem 21 and telephone line 7 to a remote computer system (not shown) for display and/or analysis.

The central battery monitoring system measures the total battery capacity in Amp-hours (Ahr) or Watt-hours (Whr), the actual or remaining battery capacity as a percentage of the total battery capacity and the internal resistance of the battery 1 as a whole. The cental battery monitoring system 3 can also measure the internal resistance of the individual cells from the data received from the individual cell monitoring devices CM_i received via the communication link 9 and the communication circuit 19.

In order to be able to measure the total battery capacity, i.e. the maximum amount of charge which can be stored in the battery, and the actual or remaining battery capacity at a given time point as a percentage of the total battery capacity, the central battery monitoring system 3 monitors how much charge is fed into the battery and how much charge is drawn from the battery. Unfortunately, since the charging and discharging characteristics of the battery are not one hundred percent efficient. Therefore, the estimated capacity derived by monitoring the charge alone is not very accurate. In fact, various factors affect the amount of charge which is input to or drawn from a battery during charging/discharging, including the ambient temperature, the magnitude of the charging/discharging current, the algorithm used for charging etc. Fortunately, many of these characteristics are known to the battery manufacturer and, in this embodiment the specific characteristics of the battery 1 are programmed into the central battery monitoring system 3. With this information, it is possible to determine more accurately how much charge has been stored in or withdrawn from the battery 1.

For example, if the battery 1 is charged with a charging current of 10 amps over a period of two hours at an ambient temperature of 20° C., and it is known that the efficiency characteristic of the battery is 95% for such a level of charging current and for that ambient temperature, then the total charge supplied to the battery is 19 Ahr. In the general case, for a current (I(t)) drawn from or supplied to the battery, the capacity (CP) added to or removed from (depending on whether the current is negative or positive) the battery from time t_0 to time t_1 is given by:

$$CP[t_0, t_1] = (k_1 \times k_2 \times k_3) \cdot \int_{t_0}^{t_1} I(t)\,dt \qquad (1)$$

where k_i are the efficiency characteristics for the battery 1 for the sensed conditions and where I(t) is negative when the current is being drawn from the battery 1.

In order to determine the initial total battery capacity (TCP), the battery 1 is initially fully charged by charging the battery for a long period of time using a small charging current. Then the battery 1 is discharged through a load (not shown) until the battery voltage drops below an end of discharge voltage limit (EODV) which is specified by the battery manufacturer. During this discharging period, the central battery monitoring system 3 monitors the discharge current via current sensor 8, and once the EODV limit is reached, it calculates the capacity (in Amp-hours) which has been removed from the battery using equation 1 above, with to being the time that the discharge is initiated and time t, is the time that the EODV limit is reached. This capacity represents the total battery capacity (TCP).

In this embodiment, the central battery monitoring system 3 periodically determines the remaining battery capacity (RCP) as a percentage of the total battery capacity (TCP) by monitoring the amount of current which is drawn from and/or supplied to the battery 1 since the last time the remaining battery capacity was determined and then by using the following equation:

$$RCP[t_1] = RCP[t_0] + \frac{100 \cdot CP[t_0, t_1]}{TCP} \qquad (2)$$

Where $CP[t_0,t_1]$ is calculated using equation 1 above. The initial estimate for the remaining battery capacity is set equal to the total working capacity of the battery after the battery has been fully charged.

To determine the internal resistance of the battery as a whole, the battery is connected to two different loads and the central battery monitoring system 3 monitors the current through the loads from which it determines the internal resistance of the whole battery.

As mentioned above, in addition to determining the total battery capacity, the remaining battery capacity and the battery internal resistance, the central battery monitoring system **3** also monitors data received from the cell monitoring devices CM_i via the communication circuit **19** and the communication link **9**. If there is a fault with one of the battery cells C_i or if there is some other faulty condition, the CPU **11** can trigger a local alarm **23** to alert a technician that there is a fault with the battery **1** or with one or more of the battery cells C_i. In this embodiment, the conditions which define a fault and their thresholds are user definable and set in advance.

Although the central battery monitoring system **3** continuously monitors the battery **1**, the sensor data and the other battery data, i.e. the remaining battery capacity etc., are only stored periodically in the mass storage unit **17** in order to save storage space. The period is specified in advance by the user and in this embodiment is set at ten seconds. Furthermore, when the samples are stored, they are time and date stamped so that the battery charging and discharging behaviour can be monitored and used to detect the cause of an eventual battery failure. In this embodiment, the data which is to be stored is also filtered in order to try to identify and highlight important events, and the filtered data is also stored in the mass storage unit **17**. What counts as an important event is user definable, but can be, for instance, a temperature increase of 2° C. or a change in remaining battery capacity of greater than 1% of the total battery capacity.

As mentioned above, the status data of the battery, i.e. the battery voltage, the discharge/charge current, the battery temperature and the remaining and total battery capacities, are displayed on display **15**. For simplicity, since the display **15** does not need to be continuously updated, it is only updated using the samples of the status data which are to be stored in mass storage unit **17**. Therefore, in this embodiment, the display **15** is updated every ten seconds.

In this embodiment, the central battery monitoring system **3** is also used to control the battery charger (not shown) which is used to charge the battery **1**. In particular, the central battery monitoring system **3** monitors the charging current, the remaining battery capacity, the ambient temperature etc. and controls the operation of the charger (not shown) so that the battery charging is in accordance with the specific charging procedures recommended by the battery manufacturer for the battery **1**.

Since the total battery capacity also decreases with time (due to ageing), the central battery monitoring system **3** is programmed to perform regular (for example daily or monthly) automated measurements of the total battery capacity and the battery internal resistance using the procedures outlined above. This allows the central battery monitoring system **3** to be able to build up a picture of the battery life characteristics and to be able to predict the battery end of life and the early detection of faulty conditions.

FIG. **3** is a schematic diagram showing, in more detail, one of the cell monitoring devices CM_i. As shown, cell monitoring device CM_i comprises a microcontroller **31** for controlling the operation of the cell monitoring device CM_i and for analysing sensor data received from voltage interconnection sensor **33**, cell voltage sensor **35**, temperature sensor **37** and electrolyte level/PH sensor **39**.

The voltage interconnection sensor **33** measures the voltage drop between the cell being monitored and its neighbouring cells, by measuring the potential difference between each terminal of the cell C_i and the respective terminal connections which connects cell C_i with its neighbouring cells. Ideally, there should be no voltage drop between each terminal and the corresponding terminal connection. However, due to chemical deposits accumulating at the cell terminals with time, or because of cell malfunction, a difference in potential between the cell terminals and the corresponding connectors sometimes exists, indicating that there is a fault, either with the battery cell C_i or with the interconnection with a neighbouring cell.

The cell voltage sensor **35** is provided for sensing the potential difference between the positive terminal C_i^+ and the negative terminal C_i^- of the cell C_i which it is monitoring. The temperature sensor **37** senses the cell temperature locally at the cell C_i. By monitoring the local temperature at each cell C_i, it is possible to identify quickly faulty cells or cells which are not operating efficiently. The electrolyte level/PH sensor senses the electrolyte level and/or the electrolyte PH of the battery cell C_i which it is monitoring.

The microcontroller **31** analyses the data input from the sensors and monitors for faulty conditions and reports to the central battery monitoring system **3** via the communication link **9**. Since the microcontroller **31** processes digital data, and since the signals received from the sensors and the messages received from the battery monitoring system **3** are analogue signals, the microcontroller **31** has a built-in analogue to digital convertor (not shown) so that it can convert the sensor data and the received messages into corresponding digital signals.

Since the cell monitoring devices are connected in series by the communication link **9**, each cell monitoring device CM_i will either receive communications originating from the central battery monitoring system **3**, from the left hand side of the communication link **9** for transmission to the next cell monitoring device CM_{i+1}, or they will receive communications from cell monitoring device CM_{i+1} from the right hand side of the communication link **9** for transmission back to the central battery monitoring system **3**. In order to compensate for the difference in reference voltages between each of the cell monitoring devices CM_i, each cell monitoring device CM_i has an up-link **41** for transmitting data received from cell monitoring device CM_{i-1} to cell monitoring device CM_{i+1}, and a down-link **43** for transmitting data received from cell monitoring device CM_{i+1} to cell monitoring device CM_{i-1}.

The up-link **41** has a transceiver **45** for increasing the reference voltage of the data signal so that it can be received by the next cell monitoring device CM_{i+1}, while the down-link **43** has a transceiver **47** which reduces the reference voltage of the received data so that it can be received by the cell monitoring device CM_{i-1}. The up-link **41** and the down-link **43** are connected to the one wire communication link **9** via switches **49** and **51** which are controlled by microcontroller **31**, as represented by arrows **52**. The way in which the microcontroller **31** controls the position of the switches **49** and **51** for the above described two modes of operation will be apparent to those skilled in the art and will not be described here. The microcontroller **31** is connected to the up-link **41** by connection **53** so that it can listen for communications sent from the central battery monitoring system **3** which are directed to it. Similarly, the microcontroller **31** is connected to the down-link **43** by connection **55** so that the microcontroller **31** can send messages back to the central battery monitoring system **3**, either upon being polled or upon detection of a fault.

In order to power the cell monitoring device CM_i, the positive terminal C_i^+ and the negative terminal C_i^- of cell C_i are connected to the input of a DC to DC convertor **57**, which generates, relative to the ground or reference voltage V_{REF}^1 of cell C_i (which equals the voltage potential of the negative terminal C_i^- of cell C_i) the voltages $V_{REF}^i \pm 5V$, which are used to power the microcontroller **31** and the transceivers **45** and **47**.

FIG. **4** shows the voltage characteristic of the industrial battery showing each cell's terminal potential versus the cell's position in the series. As shown in FIG. **4**, this voltage characteristic has a staircase shape, with each stair having a height equal to the voltage V_{CELL} of the respective battery cell C_i. Each cell monitoring device CM_i uses the fact that there is only a small difference between the reference voltages of adjacent cells and that therefore the transceivers **45** and **47** only have to increase or decrease the reference voltage of the received data by this voltage difference.

In this embodiment, the transceivers **45** and **47** comprise voltage comparators and the messages transmitted to and from the central battery monitoring system **3** are encoded within the transitions of a square wave signal. FIG. **5***a* is a circuit diagram of a voltage comparator **61** forming part of the transceiver **45** provided in the up-link **41** shown in FIG. **3**. The limits of the comparator **61** are V_{REF}^i+5V and V_{REF}^i−5V, which are generated by the DC to DC converter **57**. FIG. **5***b* is a circuit diagram of a voltage comparator **63** forming part of the transceiver **47** provided in the down-link **43** shown in FIG. **3**. As with comparator **61**, the limits of comparator **63** are V_{REF}^i+5V and V_{REF}^i−5V.

FIG. **5***c* shows part of the battery-cell voltage distribution shown in FIG. **4** and, superimposed thereon, data pulses for illustrating the way in which data is passed along the communication link **9**. The left-hand side of FIG. **5***c* shows the ground or reference voltage V_{REF}^{i-1} for cell C_{i-1} and shows that data pulses **65** output by cell monitoring device CM_{i-1}, vary between V_{REF}^{i-1}+5V and V_{REF}^{i-1}−5V. In this embodiment, when the data is originally transmitted from the central battery monitoring system **3**, the data pulses **65** will be transmitted from cell C_i^{-1} to cell C_i and will be applied to the positive input of the comparator **61** on the up-link **41** of cell monitoring device CM_i via switch **49**. As shown in FIG. **5***a*, the received pulses are compared with V_{REF}^i−2V (which is an approximation of the reference voltage V_{REF}^{i-1} of the cell C_i^{-1} which generated the received pulses **65**, since the cells are lead acid battery cells which provide approximately 2 volts each) and the data pulses **67** output by comparator **61** will correspond with the received data pulses **65** but will vary between V_{REF}^i+5V and V_{REF}^i−5V, as shown in the middle of FIG. **5***c*. Therefore, the DC level of the square wave pulses has been increased by passing it through the comparator **61**.

The output data pulses **67** are transmitted to the next cell monitoring device CM_{i+1} via switch **51** and communications link **9**. The data pulses **67** output from comparator **61** are also input to the microcontroller **31** via connection **53**, so that the microcontroller **31** can identify whether or not the communication from the central battery monitoring system **3** is directed to it. If the communication is directed to it, the microcontroller **31** processes the request, performs the necessary tests and transmits the appropriate data back to the central battery monitoring system **3**.

When data pulses **69** are transmitted to cell monitoring device CM_i from cell monitoring device CM_{i+1} for transmitting back to the central battery monitoring system **3**, the received data pulses **69**, which vary between V_{REF}^{i+1}+5V and V_{REF}^{i+1}−5V, are applied to the positive input of comparator **63** on the down-link **43** of cell monitoring device CM_i via switch **51**. As shown in FIG. **5***b*, the received pulses **69** are compared with V_{REF}^i+2V (which is an approximation of the reference voltage V_{REF}^{i+1} of the cell C_{i+1} which generated the received pulses **69**, since the cells are lead acid battery cells which provide approximately 2 volts each). As shown in FIG. **5***c*, this comparison results in a series of pulses **67** corresponding to the received pulses **65** but which vary between V_{REF}^i±5V which are transmitted to cell C_{i-1} via switch **49**. Therefore, the DC level of the square wave pulses has been reduced by passing it through the comparator **63**.

Each of the cell monitoring devices CM_i operate in a similar manner. However, it should be noted that the first cell monitoring device CM_i has the same ground or reference voltage as the central battery monitoring system **3**. Therefore, it is not necessary to use a transceiver **45** in the up-link **41** of the first cell monitoring device CM_i, although one is usually used in order to buffer the received signals and in order to standardise each of the cell monitoring devices CM_i. Similarly, the last cell monitoring device CM_n will not receive data pulses from a subsequent cell monitoring device and therefore, does not need a transceiver **47** in its down-link. However, one is provided so that all the cell monitoring devices CM_i are the same, and is used for buffering the data sent from microcontroller **31** of cell monitoring device CM_n back to the central battery monitoring device **3**.

The battery monitoring system described above has the following advantages:

(1) There is no need for voltage isolation between the cell monitoring devices CM_i or between the first cell monitoring device CM_1 and the central battery monitoring system **3**. Therefore, each cell monitoring device CM_i will only consume a few milli-amps and only requires very inexpensive and readily available DC to DC converters for converting the battery cell voltage to the supply voltage needed by the microcontroller **31** and the transceivers **45** and **47**.

(2) Since electrical isolation is not required between the cell monitoring devices CM_i, there is no longer a need for relatively expensive voltage isolated links between the cell monitoring devices. In the embodiment described, each cell monitoring device CM_i is linked to its neighbours by a simple wire. The cost of the battery monitoring system is therefore low and system installation is simplified.

(3) Continuous monitoring of all the cells C_i in battery **1** becomes economical and practical, and the user can be informed in real-time if one or more of the battery cells C_i is under performing or is faulty.

(4) The internal resistance of each cell C_i can be determined in real-time and without having to disconnect the cell from the battery, since the central battery monitoring system **3** is capable of measuring battery charging and discharging current (which is the same as the cell current) and can correlate it with individual cell voltages (determined by the cell monitoring devices) in order to calculate each cell's internal resistance.

(5) Each cell monitoring device CM_i is able to measure the voltage drop on cell to cell interconnections and indicate a faulty interconnection condition, usually due to chemical deposits accumulating at the cell terminals with time or because of cell malfunction.

(6) Since each cell monitoring device CM_i is able to measure the cell voltage and the cell temperature, it is possible to increase the probability of detecting a faulty cell. Therefore, the industrial battery need only be serviced when required.

(7) Since each cell monitoring device CM_i can read the corresponding cell voltage, cell temperature etc. at the same time as the other cell monitoring devices, the data produced by each cell monitoring device is less likely to be corrupted by changes in load and/or changes in ambient temperature which occur with time, as compared with prior art systems which take readings from the individual cells one at a time.

A number of alternative embodiments will now be described, which operate in a similar manner to the first embodiment. Accordingly, the description of these alternative embodiments will be restricted to features which are different to those of the first embodiment.

FIG. **6** is a schematic diagram showing, in more detail, one of the cell monitoring devices CM_i shown in FIG. **1** according to a second embodiment of the present invention. As shown, cell monitoring device CM_i comprises a microcontroller **31** for controlling the operation of the cell monitoring device CM_i and for analysing sensor data received from voltage interconnection sensor **33**, cell voltage sensor **35**, temperature sensor **37** and electrolyte level/PH sensor **39**, which all operate in the same manner as in the first embodiment.

In order to power the cell monitoring device CM_i, the positive terminal C_i^+ and the negative terminal C_i^- of cell C_i are connected to the input of a DC to DC convertor **57**, which generates, relative to the ground of cell C_i (which equals the voltage potential of the negative terminal C_i^- of cell C_i) the voltage V_{cc}^i, which is used to power the microcontroller **31** and the other components in the device and which in this embodiment is C_i^-+3 Volts.

Since the cell monitoring devices are connected in series by the communication link **9**, each cell monitoring device CM_i is operable (i) to receive up-link communications originating from the central battery monitoring system **3** on wire **9***a* of the communication link **9** for reception by itself and/or for onward transmission to the next cell monitoring device CM_{i+1}; (ii) to receive down-link communications from cell monitoring device CM_{i+1} on wire **9***b* of the communication link **9** for transmission back to the central battery monitoring system **3**; and (iii) to transmit down-link communications generated by itself back to the central battery monitoring system **3** on wire **9***b* of the communication link **9**.

As shown in FIG. **6**, in this embodiment, the microcontroller **31** receives up-link communications originating from the central battery monitoring system **3** via wire **9***a*, potential divider **41** and comparator **43**. The microcontroller **31** identifies whether or not the received message from the central battery monitoring system is for it or if it is for onward transmission to the next cell monitoring device CM_{i+1}. If the message is for the current cell monitoring device CM_i, then the microcontroller **31** decodes the message and takes the appropriate action. If the received message is for onward transmission, then the microcontroller **31** regenerates the message and outputs it to wire **9***a* via output block **45**. In this embodiment, the messages transmitted are square-wave signals representing digital data. The signals are encoded for error correction purposes and the microcontroller **31** checks for errors in the received messages. Since the microcontroller **31** regenerates the messages for transmission to the next cell monitoring device CM_{i+1}, the timing between the transitions in the signal levels can be resynchronised, thereby reducing any errors caused by the transmission of the pulses along the communication link **9**.

In a similar manner, down-link messages received from cell monitoring device CM_{i+1} on wire **9***b* are passed via potential divider **47** and comparator **49** to the microcontroller **31**. In this embodiment, all down-link communications are for transmission back to the central battery monitoring system **3**. Therefore, the micro controller **31** checks for any errors in the received data and, if possible, corrects them. The microprocessor **31** then regenerates the message and outputs it to wire **9***b* via output block **51** for onward transmission back to the central battery monitoring system **3**.

The way in which the messages are transmitted between the cell monitoring devices will now be described in more detail with reference to FIG. **7**. Up-link messages originating from the central battery monitoring system **3** which are re-transmitted by the microcontroller **31** of cell monitoring device CM_{i-1} are applied on line **32** to the gate electrode of the MOSFET Q_1^{i-1}. The source electrode of the MOSFET Q_1^{i-1} is connected to the ground C_{i-1}^- of cell monitoring device CM_{i-1} and the drain electrode is connected, via resistors R_a^i, R_b^i and R_c^{i-1}, to V_{cc}^i output by the DC/DC converter **57** in cell monitoring device CM_i. In operation, when the microcontroller **31** in the cell monitoring device CM_{i-1} outputs a voltage low (representing a binary 0) on line **32**, the MOSFET Q_1^{i-1} does not allow current to flow from the drain electrode to the source electrode and therefore effectively open circuits the connection between V_{cc}^i and C_{i-1}^-. Therefore, when a voltage low is applied to the gate electrode of MOSFET Q_1^{i-1}, a voltage of approximately V_{cc}^i is applied on line **34** to the comparator **43**, where it is compared with reference voltage V_{ref1}^i. When the microprocessor **31** of cell monitoring device CM_{i-1} outputs a voltage high (representing a binary 1) on line **32**, the MOSFET Q_1^{i-1} is switched on and current can flow from the drain electrode to the source electrode. Therefore, current will flow from V_{cc}^i through resistors R_a^i, R_b^i and R_c^{i-1} through the MOSFET Q_1^{i-1} to the ground C_{i-1}^- of cell monitoring device CM_{i-1}. As a result, V_{cc}^i–X volts will be applied on line **34** to the comparator **43**, where it is compared with the reference voltage V_{ref1}^i. The value of X depends upon the difference between V_{cc}^i and C_{i-1}^- and the values of the resistors R_a^i, R_b^i and R_c^{i-1}. Provided the value of the reference voltage V_{ref1}^i is between the voltage levels applied to the comparator **43** on line **34** when the MOSFET Q_1^{i-1} is switched on and when it is switched off, the output of the comparator **43** will be a square-wave signal **36** varying between the ground potential C_i^- and V_{cc}^i of cell monitoring device CM_i in synchronism with the variation of the square-wave signal **38** applied to the gate electrode of MOSFET Q_1^{i-1} of cell monitoring device CM_{i-1}. Therefore, messages encoded within the variation of the signal applied to the MOSFET Q_1^{i-1} in cell monitoring device CM_{i-1} are transferred from cell monitoring device CM_{i-1} to cell monitoring device CM_i.

In a similar manner, down-link messages output by the microcontroller **31** in cell monitoring device CM_i for transmission back to the central battery monitoring system **3** are applied to the gate electrode of MOSFET Q_2^i on line **40**. The drain electrode of MOSFET Q_2^i is raised to the potential V_{cc}^i and the source is connected, via resistors R_d^i, R_e^{i-1} and R_f^{i-1}, to the ground potential C_{i-1}^- of cell monitoring device CM_{i-1}. In operation, when the microcontroller **31** in the cell monitoring device CM_i outputs a voltage low on line **40**, the MOSFET Q_2^i does not allow current to flow from the drain electrode to the source electrode and therefore effectively open circuits the connection between V_{cc}^i and C_{i-1}^-. Therefore, when a voltage low is applied to the gate electrode of MOSFET Q_2^i, approximately zero volts is applied on line **42** to the comparator **49**, where it is compared with reference voltage V_{ref2}^{i-1} When the microcontroller **31** of cell monitoring device CM_i outputs a voltage high on line **40**, the MOSFET Q_2^i is switched on and current flows from V_{cc}^i through resistors R_d^i, R_e^{i-1} and R_f^{i-1} to the ground C_{i-1}^- of the cell monitoring device CM_{i-1}. As a result, V_{cc}^i–Y volts will be applied on line **42** to the comparator **49**, where it is compared with the reference voltage V_{ref2}^{i-1}. The value of Y depends upon the difference between V_{cc}^i and C_{i-1}^- and the values of resistors R_d^i, R_e^{i-1} and R_f^{i-1}. Again, provided the value of the reference voltage V_{ref2}^{ii-1} is between the voltage levels applied to the comparator **49** on line **42** when the MOSFET Q_2^i is switched on and when it is switched off, the output of the comparator **49** will be a square-wave signal **44** varying between the ground potential C_{i-1}^- and V_{cc}^{i-1} of cell monitoring device CM_{i-1} in synchronism with the variation of the signal **46** applied to the gate electrode of MOSFET Q_2^i of cell monitoring device CM_i. Therefore, messages encoded within the variation of the signal applied to MOSFET Q_2^i are transferred from cell monitoring device CM_i to cell monitoring device CM_{i-1}.

The values of the resistors R_a^i to R_f^i in each cell monitoring device CM_i are chosen in order (i) to buffer the input and output terminals of the cell monitoring devices CM_i; (ii) to reduce power consumption of the cell monitoring devices CM_i; and (iii) to provide the necessary voltage division with respect to the difference in voltage between adjacent cell monitoring devices.

As those skilled in the art will appreciate, the above technique for transferring up-link and down-link data between cell monitoring devices CM_{i-1} and CM_i will only work provided the difference between V_{cc}^i and C_{i-1}^- does not exceed the operating range of the MOSFET switches Q_1^{i-1} and Q_2^i. In this embodiment, each battery cell C_i is provided with a cell monitoring device CM_i, the difference in operating potentials of adjacent cell monitoring devices is approximately two volts and V_{cc}^i is three volts more than the ground potential of the cell monitoring device. Therefore, in this embodiment, the difference between V_{cc}^i and C_{i-1}^- is approximately five volts. MOSFET transistors Q which can operate with such a loading are readily available. Indeed, there are some commercially available MOSFETs which can operate with a loading of up to sixty volts. Therefore, this technique of transmitting data between adjacent cell monitoring devices can be used in most practical situations, even in an embodiment where, for example, one cell monitoring device is provided for every tenth battery cell C_i.

Each of the cell monitoring devices CM_i operate in a similar manner. However, it should be noted, that in this embodiment, the first cell monitoring device CM_1 has the same ground or reference voltage as the central battery monitoring system **3**. Therefore, in this embodiment, it is not necessary to use the potential divider **41** and the comparator **43** of the up-link nor the output block **51** in the down-link of the first cell monitoring device CM_1, although these are usually provided in order to standardise each of the cell monitoring devices CM_i. Similarly, the last cell monitoring device CM_n will not transmit data to nor receive data from a subsequent cell monitoring device. Therefore, cell monitoring device CM_n does not need the output block **45** in the up-link nor the potential divider **47** and the comparator **49** in the down-link. However, these are usually provided so that all the cell monitoring devices CM_i are the same.

As those skilled in the art will appreciate, in the above embodiment, solid state switches were used to, effectively, shift the DC level of the received signals for onward transmission. FIG. **8** illustrates a further embodiment which uses analogue switches to transmit messages uplink as well as downlink between adjacent cell monitoring devices CM_i, via a single communication wire **9** which connects the cell monitoring devices in series. As shown in FIG. **8**, each cell monitoring device CM_i has the same potential dividers **41** and **49**, comparators **43** and **47**, and output blocks **45** and **51** as in the second embodiment. The difference between this embodiment and the second embodiment is that the uplink and the downlink between adjacent cell monitoring devices share a common communication wire **9**. This is achieved by connecting, at connection **62**, the output of block **51** in cell monitoring device CM_i to the connection between potential divider **41** in cell monitoring device CM_i and the output block **45** in cell monitoring device CM_{i-1} and by connecting, at connection **64**, the potential divider **49** in cell monitoring device CM_{i-1} to the connection between potential divider **41** in cell monitoring device CM_i and the output block **45** in cell monitoring device CM_{i-1}.

Since both the uplink and the downlink connection between adjacent cell monitoring devices is via the same wire **9**, communications between cell monitoring devices can be in one direction only at any given time. To achieve this, during a downlink communication, MOSFET Q_1^{i-1} is switched off so that messages transmitted by switching the state of MOSFET Q_2^i pass via the potential divider **49** and the comparator **47** into the microcontroller (not shown) in cell monitoring device CM_{i-1}. Similarly, for uplink communications from, for example, cell monitoring device CM_i to cell monitoring device CM_{i+1}, the MOSFET Q_2^{i+1} is switched off so that the output block **51** has a high impedance and does not affect the operation of the potential divider **41**. Further, as those skilled in the art will appreciate, in order for the potential dividers and output blocks to operate in the same way as in the second embodiment, the resistances of resistors R_a, R_b, R_e and R_f must be relatively large compared to the resistances of resistors R_c and R_d. In this embodiment, with 2 volt battery cell voltages, $R_a=R_b=R_e=R_f=10K$ ohms, $R_d=R_c=2K$ ohms, $V_{ref1}^i=V_{ref2}^i=V_{cc}^i/2$ and $V_{cc}^i=C_i^-+5V$. As those skilled in the art will appreciate, the cell monitoring device of this embodiment can easily be adapted to operate with any battery cell voltage, the only changes that are required are the resistor values, the reference voltage values and the maximum allowable drain to source voltage of the MOSFETs.

As those skilled in the art will appreciate, in the above embodiments, data was transmitted between adjacent cell monitoring devices by varying the output impedance of an output block in the cell monitoring device which is to transmit the message and by detecting this variation in the cell monitoring device which is to receive the message. For example, when up-link message data is to be transmitted from cell monitoring device CM_{i-1} to cell monitoring device CM_i, the impedance of output block **45** in cell monitoring device CM_{i-1} is varied in dependence upon the data to be transmitted—when a voltage low is to be transmitted, the impedance of output block **45** is made to be very high, whereas when a voltage high is to be transmitted, the impedance of output block **45** is made to be relatively low. This variation of the impedance of output block **45** is detected by the potential divider **41** and the comparator **43** in the cell monitoring device CM_i which is to receive the transmitted up-link message. As those skilled in the art will appreciate, there are various ways of varying an output impedance of a cell monitoring device in dependence upon the data to be transmitted and various ways of detecting that variation in the adjacent cell monitoring device. FIG. **9** shows one of these alternative embodiments.

In the embodiment shown in FIG. **9**, the output impedance of cell monitoring device CM_{i-1} is varied in the same way as it was varied in the second embodiment but this variation is detected in cell monitoring device CM_1 in a different manner. In particular, in this embodiment, a current detector **48** is used to detect the changes in current flowing between the V_{cc}^i terminal in cell monitoring device CM_i to the ground potential C_{i-1}^- in cell monitoring device CM_{i-1}. In operation, when a voltage low is applied to the gate electrode of MOSFET Q_1^{i-1}, the MOSFET is open and no current flows down line **50**. However, when a voltage high is applied to the gate electrode of MOSFET Q_1^{i-1}, the MOSFET opens and current is drawn down line **50**. This change in current is detected by the current sensor **48**. More specifically, each time there is a transition from a voltage high to a voltage low (or vice versa) applied to the gate electrode of MOSFET Q_1^{i-1}, a voltage spike is induced in the current detector **48**. As illustrated in FIG. **9**, in response to up-link message data **52** being applied to the MOSFET Q_1^{i-1}, a train of voltage spikes **53** are induced in the current detector **48** and passed to a spike detector **54** which regenerates and outputs the up-link message data **52** for transmission to the microcontroller (not shown). The resistors R_1 and R_2 are provided in order to reduce the power consumed by each of the cell monitoring devices CM_i and in order to buffer the input and output of the respective cell monitoring devices.

In the last three embodiments, MOSFET switches were used as a device whose impedance can be varied in dependence upon the message data to be transmitted. As those skilled in the art will appreciate, these MOSFETs can be replaced by any electronic switches (solid-state relays, electromechanical relays, J-FETs, transistors etc.) and, in embodiments where the up-link and the down-link messages are received and re-transmitted by a microcontroller, can be omitted altogether. This is because the output impedance of the output pin of the microcontroller varies in dependence upon whether it is outputting a voltage high or a voltage low. Therefore, for example, the output pin from the microcontroller in cell monitoring device CM_{i-1} could be directly connected to the potential divider **41** in cell monitoring device CM_i. However, such an embodiment is not preferred, because the microcontroller can be damaged by the voltage applied to the output pin from the adjacent cell monitoring device.

In the above embodiments, each cell monitoring device CM_i has a microcontroller **31** for receiving messages from the central battery monitoring system **3**, for analysing data from various sensors and for sending data back to the central battery monitoring system **3** via the communication link **9**. FIG. **10** schematically shows an alternative cell monitoring device CM_i of an alternative embodiment which does not use a microcontroller **31**.

In particular, as shown in FIG. **10**, each cell monitoring device CM_i comprises a signal generator **71** which receives sensor signals from the cell voltage sensor **35** and the temperature sensor **37** and outputs, on line **73**, a signal which varies in dependence upon the received sensor signals. The signal generator **71** may comprise a voltage controlled oscillator which outputs an alternating signal whose frequency varies in dependence upon an input voltage from, for example, the cell voltage sensor **35**. The signal output from the signal generator **71** is applied to an output terminal **75** for transmission to the central battery monitoring system **3**, via the communication link **9**. In this embodiment, each cell monitoring device CM_i only transmits signals back to the central battery monitoring system **3**, they can not receive messages from the central battery monitoring system. Therefore, only a down-link is required to receive signals at input terminal **77**, transmitted from cell monitoring device CM_{i+1}.

As in the first embodiment, each cell monitoring device CM_i is powered by the cell C_i which it is monitoring. This is illustrated in FIG. **6** by the connections C_i^+ and C_i^- which are connected to input terminals **74** and **76** respectively. Since the communication link **9** connects each of the cell monitoring devices CM_i in series in a daisy chain configuration, cell monitoring device CM_i will receive signals, at input terminal **77**, from cell monitoring device CM_{i+1}. The received signals are applied to a DC level shift circuit **79** which reduces the DC level of the received signals and supplies them to the output terminal **75** for transmission to the next cell monitoring device CM_{i-1} in the communication link **9**.

In the above embodiments, the system described was a battery monitoring system. FIG. **11** schematically shows an embodiment which is a control system for controlling the cells of an industrial battery. As shown, the control system has a similar architecture to the battery monitoring system shown in FIG. **1**, except that the central battery monitoring system **3** is now a central battery control system **80** and the cell monitoring devices CM_i are now battery cell control devices CC_i. As in the monitoring system of FIG. **1**, the central battery control system **80** communicates with each of the cell controlling devices CC_i via the communication link **9**.

FIG. **12** schematically shows an example of one of the battery cell control devices CC_i shown in FIG. **11**. In this example, each cell controlling device CC_i is used to control the topping up of acid and water in the respective battery cell C_i, in response to an appropriate control signal received from the central battery control system **80**. As in the above embodiments, each cell control device CC_i is powered by the cell which it is to control, as represented by inputs C_i^+ and C_i^- applied to input power terminals **81** and **85** respectively. In this embodiment, each cell controlling device CC_i is arranged to receive messages from the central battery controlling system (not shown), but not to transmit messages back. Accordingly, signals received at the input terminal **85** from cell controller CC_{i-1} are applied to DC level shift circuit **87**, which-increases the DC level of the received signals and outputs them to output terminal **89** for transmission to the next cell controlling device CC_{i+1}. The microcontroller **91** monitors the received signals via connection **93** and outputs appropriate control signals to output terminals **95** and **97** when the received signals are directed to it. The control signals output to terminals **95** and **97** are used to control the position of valves **99** and **101** respectively, so as to control the amount of water and acid to be added to the battery cell C_i from the water tank **103** and the acid tank **105**. The microcontroller **91** determines the amount of water and acid to add with reference to the sensor signals received from the electrolyte level/PH sensor **39**.

In the above embodiments, a central battery monitoring system or a central battery control system was provided which monitored or controlled the system as a whole. FIG. **13** schematically shows a cell monitoring and control device $CM\&C_i$ which can be used in a combined battery control and monitoring system in which there is no central battery monitoring and control system and in which each cell monitoring and control device $CM\&C_i$ communicates directly with the other cell monitoring and control devices. As in the other embodiments, each cell monitoring and control device $CM\&C_i$ is powered by the cell which it is monitoring and controlling, as represented by inputs C_i^+ and C_i^- applied to input power terminals **115** and **117** respectively.

As shown in FIG. **13**, each cell monitoring and control device $CM\&C_i$ comprises a microcontroller **111** which receives sensor data from temperature sensor **37** and which outputs control data to output terminal **113** for controlling, for example, a liquid crystal display (not shown) mounted on the respective cell C_i.

In this embodiment, the communication link comprises two wires **9***a* and **9***b* and therefore, switches **49** and **51** are not required to connect the up-link and the down-link to the communication link **9**. Wire **9**a is used for passing communications up the series communication link **9** from cell monitoring and control device CM&C_i to cell monitoring and control device CM&C_{i+1} and wire **9**b is used for transmitting signals down the series communication link **9** from cell monitoring and control device CM&C_i to cell monitoring and control device CM&C_{i-1}. Accordingly, the signals received by cell monitoring and control device CM&C_i at input terminal **119** are applied to DC level shift circuit **121** which increases the DC level of the received signals and outputs them to output terminal **123** for transmission to cell monitoring and control device CM&C_{i+1}. Similarly, signals received at input terminal **125** are applied to DC level shift circuit **127** which decreases the DC level of the received signals and outputs them to output terminal **129** for transmission to cell monitoring and control device CM&C_{i-1}. As shown, microcontroller **111** can receive data from and transmit data to both the up-link **9**a and the down-link **9**b via connections **131** and **133** respectively.

Various modifications which can be made to the above described embodiments will now be described.

In the first embodiment, the transceivers **45** and **47** used in the up-link and the down-link within each cell monitoring device CM_i comprises a voltage comparator. Other types of transceivers could be used. For example, voltage to current and current to voltage comparators could be used. In such an embodiment, the voltage to current comparators and the current to voltage comparators would be arranged alternatively along the communication link **9** so that a voltage to current comparator is connected to the input of a current to voltage comparator, and vice-versa.

In the first embodiment the data transmitted between cells and between the first cell and the central battery monitoring systems varies between $V_{REF}{}^i\pm5V$. The value of 5 volts was chosen for convenience since the normal operating voltage for the microcontroller **31** is 5 volts above the ground voltage for that cell. Theoretically, where the data transmitted between cells is given by $V_{REF}{}^i\pm X$ volts, X must be greater than half the cell voltage V_{CELL} in order for the comparator to be able to regenerate the received data pulses at the increased or decreased potential. Practically, since the battery cells and the comparators are not ideal, X should be at least two and a half times the cell voltage V_{CELL}.

In the first embodiment, a cell monitoring device was used to monitor each cell of the battery. In a cheaper implementation, each cell monitoring device CM_i could be used to monitor two or three series connected battery cells C_i. However, in such an embodiment, where the data transmitted between cell monitoring device is given by $V_{REF}{}^i\pm X$ volts, X should be at least two and a half times the difference in the reference potentials between adjacent cell monitoring devices.

In the first embodiment, the received data pulses are compared with an approximation of the ground or reference voltage of the cell which sent the data pulses. Alternatively, the received data pulses could simply be compared with the reference voltage of the cell monitoring device which receives the data pulses.

In the embodiments described, the cells are connected in series. It is possible to connect the battery cells C_i in a series-parallel or ladder configuration. FIG. **14** shows such an interconnection of battery cells, in which cell C_{ia} is connected in parallel with cell C_{ib} and the parallel combinations C_{ia} and C_{ib} are connected in series for i=1 to n. In the configuration shown in FIG. **14**, a single cell monitoring device CM_i is provided for monitoring each of the battery cells and the communication link **9** connects CM_{ia} to CM_{ib} and CM_{ib} to CM_{i+1a} etc. Alternatively, a single cell monitoring device could be used to monitor each parallel combination of battery cells C_{ia} and C_{ib}. Additionally, more than two battery cells can be connected in parallel.

In the above embodiments, the central battery monitoring and/or control system was provided at the zero volt reference voltage end of the communication link **9**. Alternatively, the central battery monitoring and/or control system could be connected at the high reference voltage end of the communication link **9**. Alternatively still, the central battery monitoring and/or control system could be connected at both ends, thereby forming a circular communications path in which messages which are transmitted to and received from the battery monitoring/controlling system are passed in one direction through the cell monitoring/controlling devices. Therefore, each cell monitoring/controlling device only needs either an up-link or a down-link for increasing or decreasing the DC level of the received signals, depending on whether the messages are transmitted up or down the communication staircase.

In the above described embodiments, the communication link **9** comprised either one or two wires. As those skilled in the art will appreciate, the communication link **9** may comprise any number of wires along which data can be transmitted in parallel.

In the above embodiments, a separate central battery monitoring system or a central battery control system was provided. In an alternative embodiment, a combined battery monitoring and control system could be used to both monitor and control the battery.

In the above described embodiments, a single battery comprising a plurality of battery cells, is monitored and/or controlled by a central battery monitoring and/or controlling system. FIG. **15** shows an alternative embodiment where a plurality of batteries B_i are provided, and wherein each battery B_i is monitored by its own central battery monitoring system BM_i which communicates with a remote operator's terminal **151** via a data bus **153**. The data bus **153** may be a proprietary data link or can be the public telephone exchange. In operation, each of the central battery monitoring systems BM_i monitors the respective battery B_i and reports its status back to the remote operator's terminal **151**, where the condition of each of the batteries is monitored by a human operator. A similar system could also be provided for controlling or for monitoring and controlling a plurality of batteries.

In the first embodiment, a cell monitoring device was used to monitor each cell of the battery. In an alternative less expensive implementation, each cell monitoring device CM_i could be used to monitor two or more series connected battery cells C_i.

In the above embodiments which employ MOSFET switches, the cell signalling devices were connected in series in a daisy-chain configuration, with the position of each cell signalling device in the series communication link corresponding with the position of the cell or cells which are to power the cell signalling device in the series connection of battery cells. This is not essential. The cell signalling devices can be connected in any arbitrary series configuration relative to the series connection of battery cells. This is because the MOSFET switches Q_1 and Q_2 operate in the same manner irrespective of the voltage loading applied across their drain and source electrodes. However, in this case, the values of the resistors R_a to R_f in each cell monitoring/control device will be different and will be chosen so as to provide the necessary voltage division having regard to the difference in voltage between adjacent cell monitoring devices in the communications link.

The present invention is not limited by the exemplary embodiments described above, and various other modifications and embodiments will be apparent to those skilled in the art.

What is claimed is:

1. A signalling system for use with a plurality of series connected battery cells, comprising:

first and second cell signalling devices, each to be powered by a respective one or more of said plurality of battery cells; and

a communication link for connecting an output terminal of said first cell signalling device to an input terminal of said second cell signalling device;

characterised in that at least one of said first and second cell signalling devices comprises a DC level shift circuit which is operable (i) to receive signals transmitted from an adjacent cell signalling device; (ii) to shift the DC level of the received signals; and (iii) to output the level shifted signals for transmission to said communication link.

2. A signalling system according to claim **1**, wherein said DC level shift circuit is operable (i) to receive signals from an adjacent cell signalling device which is to be powered by a cell having a higher ground potential than that of the receiving cell signalling device; (ii) to decrease the DC level of the received signals; and (iii) to output the level shifted signals for transmission to said communication link.

3. A signalling system according to claim **1**, wherein said DC level shift circuit is operable (i) to receive signals from an adjacent cell signalling device which is to be powered by a cell having a lower ground potential than that of the receiving cell signalling device; (ii) to increase the DC level of the received signals; and (iii) to output the level shifted signals for transmission to said communication link.

4. A signalling system according to claim **1**, wherein each cell signalling device comprises at least one sensor input terminal operable to receive a signal from a sensor, which signal is indicative of a condition of the cell or cells which are to power the cell signalling device.

5. A signalling system according to claim **4**, wherein each of said cell signalling devices comprises a sensor input terminal operable to receive a signal from an electrolyte level and/or electrolyte pH sensor, which signal is indicative of the electrolyte level and/or the electrolyte pH of the cell or cells which are to power the cell signalling device.

6. A signalling system according to claim **4**, wherein each cell signalling device comprises a sensor input terminal operable to receive a signal from a voltage sensor, which signal is indicative of the voltage of the cell or cells which are to power the cell signalling device.

7. A signalling system according to claim **4**, wherein each cell signalling device comprises a sensor input terminal which is operable to receive a signal from a temperature sensor, which signal is indicative of the temperature of the cell or cells which are to power the cell signalling device.

8. A signalling system according to claim **4**, wherein each cell signalling device comprises a sensor input terminal operable to receive a signal from a voltage interconnection sensor, which signal is indicative of the voltage drop between the cell which is to power said cell signalling device and its adjacent cells.

9. A signalling system according to claim **1**, wherein each cell signalling device comprises two of said DC level shift circuits, one of which is operable (i) to receive signals from an adjacent cell signalling device which is to be powered by

a cell having a higher ground potential than that of the receiving cell signalling device; (ii) to decrease the DC level of the received signals; and (iii) to output the level shifted signals for transmission to said communication link; and the other one of which is operable (i) to receive signals from an adjacent cell signalling device which is to be powered by a cell having a lower ground potential than that of the receiving cell signalling device; (ii) to increase the DC level of the received signals; and (iii) to output the level shifted signals for transmission to said communication link.

10. A signalling system according to claim **9**, wherein said communication link comprises a single wire communication bus, and wherein said two DC level shift circuits lie on two separate data transfer paths which are connectable to said single wire communication bus by a switch.

11. A signalling system according to claim **9**, wherein said two DC level shift circuits are located on separate data transfer paths, and wherein said communication link comprises a two wire communication bus for connecting the respective data transfer paths with corresponding data transfer paths of an adjacent cell signalling device.

12. A signalling system according to claim **1**, further comprising a central battery monitoring system for monitoring the battery as a whole, and wherein each of said cell signalling devices is operable to communicate, via said communication link, with said central battery monitoring system.

13. A signalling system according to claim **12**, wherein each cell signalling device comprises:

at least one sensor input terminal operable to receive a signal from a sensor, which signal is indicative of a condition of the cell or cells which are to power the cell signalling device; and

a signal generator operable to generate a signal in dependence upon said sensor signal and to output said generated signal for transmission to said central battery monitoring system.

14. A signalling system according to claim **13**, wherein said central battery monitoring system is operable to poll each of said plurality of cell signalling devices in turn, and wherein upon being polled, each cell signalling device is operable to return a signal back to said central battery monitoring system via said communication link, which is indicative of said condition of the cell which is to power said cell signalling device.

15. A signalling system according to claim **13**, wherein said condition is the cell voltage and wherein said central battery monitoring system is operable to measure the battery charging and discharging current and to calculate the internal resistance of each battery cell by correlating said charging and discharging current with the cell voltages determined by the respective cell signalling devices.

16. A signalling system according to claim **13**, wherein said central battery monitoring system is operable to monitor the battery voltage, the battery temperature, the total battery current and the total level of charge.

17. A signalling system according to claim **1**, wherein each of said cell signalling devices is operable to receive a control signal from said communication link and comprises a signal generator operable to generate an actuation signal in dependence upon said received control signal and to output said generated actuation signal for controlling an actuator.

18. A signalling system according to claim **17**, further comprising a central battery control system for transmitting said control signal to said communication link.

19. A signalling system according to claim **17**, wherein each cell signalling device comprises a sensor input terminal operable to receive a signal from an electrolyte level and/or electrolyte pH sensor, which signal is indicative of the electrolyte level and/or the electrolyte pH of the cell or cells which are to power the cell signalling device, and wherein upon receiving said control signal said cell signalling device is operable to output an actuation signal in dependence upon said sensor signal for controlling the addition of water and acid to the cell in order to control its electrolyte level and/or its electrolyte pH.

20. A signalling system according to claim **17**, wherein said actuation signal is for controlling a display.

21. A signalling system according to claim **13**, wherein said signal generator comprises a microcontroller which is operable to receive communications from and to transmit communications to said communication link.

22. A signalling system according to claim **21**, wherein the microcontrollers of said signalling devices are independently addressable so that communications can be directed to a selected one or more of said cell signalling devices via said communication link.

23. A signalling system according to claim **22**, wherein the microcontrollers of said cell signalling devices are operable to communicate with each other.

24. A signalling system according to claim **1**, wherein said DC level shift circuit comprises a comparator.

25. A signalling system according to claim **24**, wherein said comparator comprises a voltage comparator.

26. A signalling system according to claim **25**, wherein the communications transmitted over said communication link comprise square wave signals, and wherein each of said comparators is arranged to compare said square wave signals with a reference signal which is an approximation of the ground potential of the adjacent cell signalling device which transmitted the received square wave signals and to output a square wave signal in dependence upon whether or not the received square wave signal is greater or less than said reference signal.

27. A signalling system according to claim **24**, wherein said comparator comprises a current comparator.

28. A signalling system according to claim **24**, wherein alternate voltage to current comparators and current to voltage comparators are used in adjacent cell signalling devices.

29. A signalling system according to claim **1**, wherein said DC level shift circuit comprises a switch and wherein said signalling devices comprises means for opening and closing said switch in dependence upon the signal to be transmitted.

30. A signalling system according to claim **29**, wherein said switch comprises a transistor.

31. A signalling system according to claim **30**, wherein a source electrode of said switch is connected to a ground potential of one of said first and second cell signalling devices, wherein a drain electrode of said switch is connected to a positive terminal of the other one of said first and second cell signalling devices, wherein said means for opening and closing said switch operates on a gate electrode of the switch in dependence upon the signal to be transmitted to the other cell signalling device and wherein said other cell signalling device comprises means for sensing the change in impedance of said transistor switch.

32. A signalling system according to claim **31**, wherein said sensing means comprises a current sensor for sensing the variation of current drawn by said switch as it is opened and closed.

33. A signalling system according to claim **31**, wherein said sensing means comprises a voltage divider connected in series with said switch for sensing the change in voltage across the switch as it is opened and closed.

34. A signalling system according to claim **1**, wherein each cell signalling device comprises a DC to DC convertor which is operable to convert the cell voltage of the cell which is to power the cell signalling device, to supply voltages and a ground voltage for powering the cell signalling device.

35. A signalling system according to claim **1**, wherein a cell signalling device is provided for each of said series connected battery cells.

36. A signalling system according to claim **1**, wherein one or more of said series connected battery cells are connected in parallel with one or more additional battery cells.

37. A cell signalling device for use in a signalling system according to claim **1**, comprising:

a power input terminal connectable to the cell or cells which is or are to power said cell signalling device; and

at least one DC level shift circuit which is operable (i) to receive signals transmitted from an adjacent cell signalling device; (ii) to shift the DC level of the received signals; and (iii) to output the level shifted signals for transmission to the communication link forming part of said signalling system.

38. A signalling kit for use in a signalling system according to claim **1**, comprising a plurality of cell signalling devices each of which comprises:

a power input terminal connectable to the cell or cells which is or are to power said cell signalling device; and

at least one DC level shift circuit which is operable (i) to receive signals transmitted from an adjacent cell signalling device; (ii) to shift the DC level of the received signals; and (iii) to output the level shifted signals for transmission to the communication link forming part of said signalling system.

39. A signalling kit according to claim **38**, further comprising a communication link for connecting said plurality of cell signalling devices in series.

40. A signalling system according to claim **1** in combination with a plurality of series connected battery cells, wherein one or more of said battery cells are connected to a respective one of said plurality of cell signalling devices, for powering said cell signalling devices.

41. A cell signalling device according to claim **37** in combination with a battery cell, wherein the terminals of said battery cell are connectable to said cell signalling device.

42. A signalling method using a plurality of series connected battery cells, comprising the steps of:

providing a plurality of cell signalling devices and powering them with a respective one or more of said plurality of battery cells;

providing a communication link for connecting said plurality of cell signalling devices in series;

receiving signals transmitted from an adjacent cell signalling device;

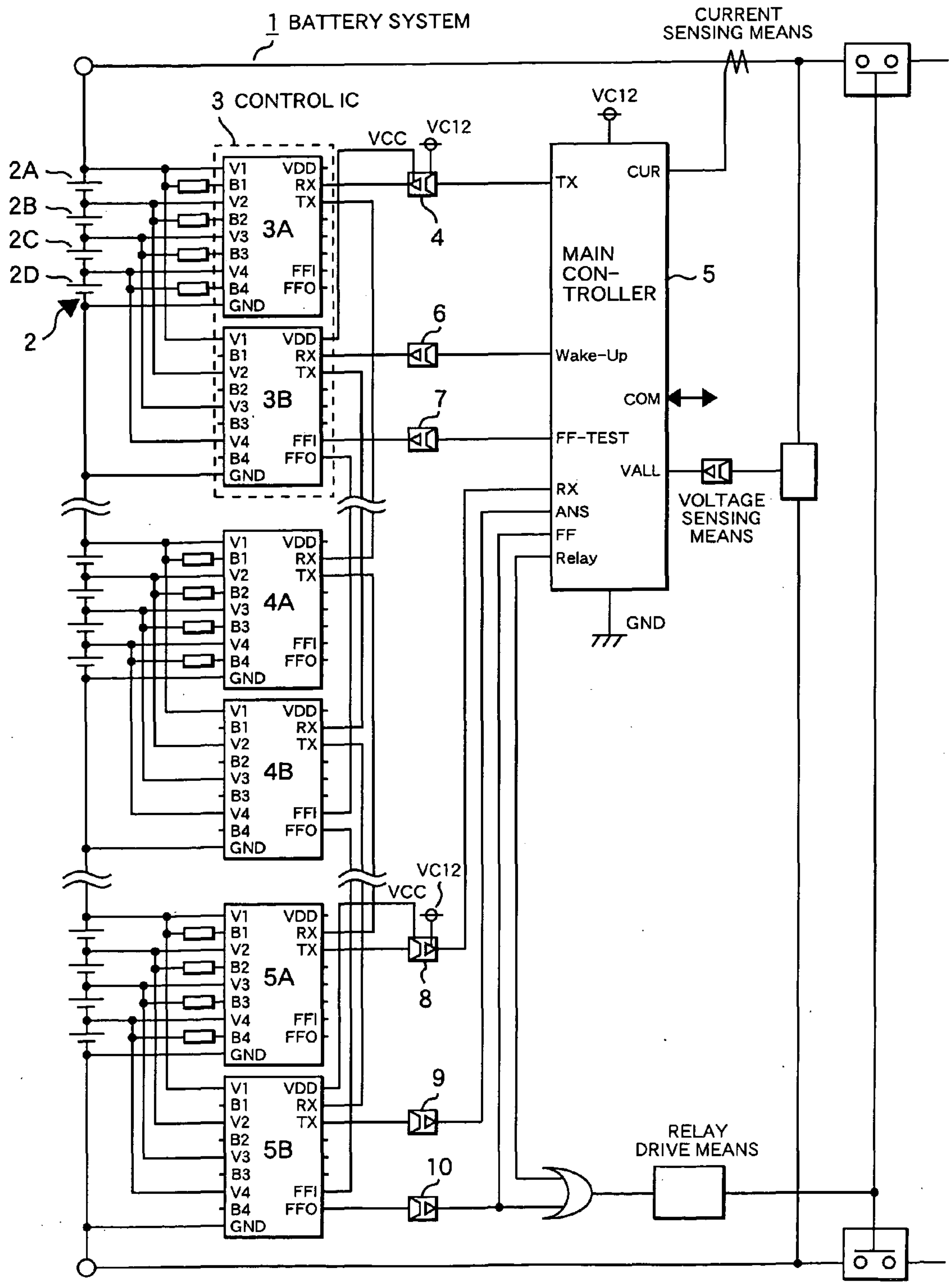
shifting the DC level of the received signals; and

outputting the level shifted signals to the communication link.

* * * * *

IE3

FIG. 1



1 BATTERY SYSTEM
CURRENT SENSING MEANS
3 CONTROL IC
VCC
VC12
2A
2B
2C
2D
2
3A
3B
4A
4B
5A
5B
V1
B1
V2
B2
V3
B3
V4
B4
GND
VDD
RX
TX
FFI
FFO
4
6
7
8
9
10
MAIN CON-TROLLER
5
TX
CUR
Wake-Up
COM
FF-TEST
VALL
RX
ANS
FF
Relay
GND
VOLTAGE SENSING MEANS
RELAY DRIVE MEANS

FIG. 2

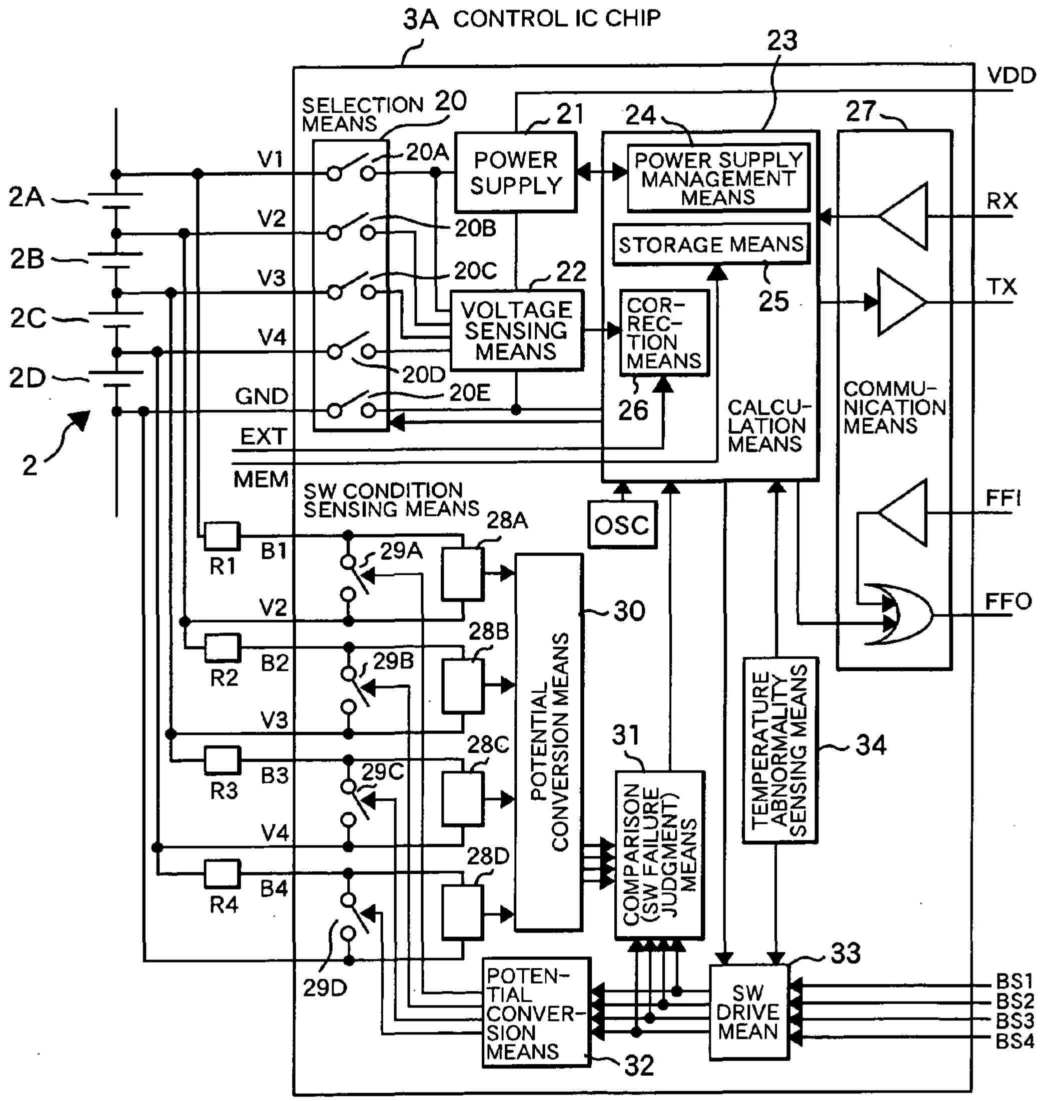

3A CONTROL IC CHIP
SELECTION MEANS 20
20A
20B
20C
20D
20E
21
POWER SUPPLY
22
VOLTAGE SENSING MEANS
23
24
POWER SUPPLY MANAGEMENT MEANS
STORAGE MEANS
25
COR-REC-TION MEANS
26
CALCU-LATION MEANS
27
COMMU-NICATION MEANS
VDD
RX
TX
FFI
FFO
2A
2B
2C
2D
2
V1
V2
V3
V4
GND
EXT
MEM
SW CONDITION SENSING MEANS
OSC
R1
R2
R3
R4
B1
B2
B3
B4
28A
28B
28C
28D
29A
29B
29C
29D
POTENTIAL CONVERSION MEANS
30
31
COMPARISON (SW FAILURE JUDGMENT) MEANS
TEMPERATURE ABNORMALITY SENSING MEANS
34
POTEN-TIAL CONVER-SION MEANS
32
SW DRIVE MEAN
33
BS1
BS2
BS3
BS4

FIG. 3

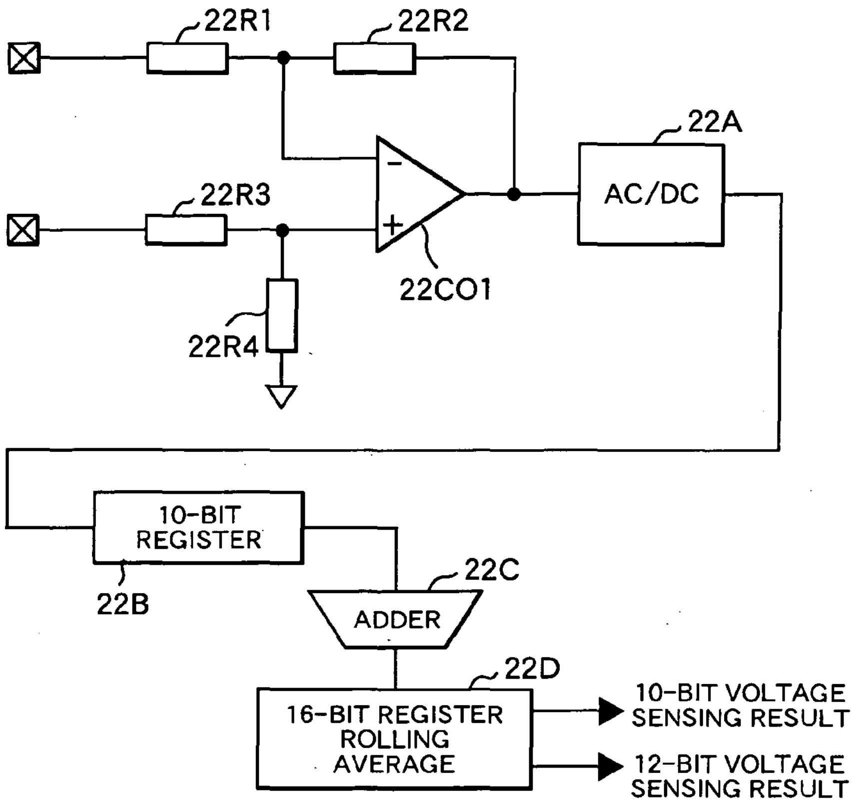

22R1
22R2
22A
AC/DC
22R3
22CO1
22R4
10-BIT
REGISTER
22B
22C
ADDER
22D
16-BIT REGISTER
ROLLING
AVERAGE
10-BIT VOLTAGE
SENSING RESULT
12-BIT VOLTAGE
SENSING RESULT

FIG. 4

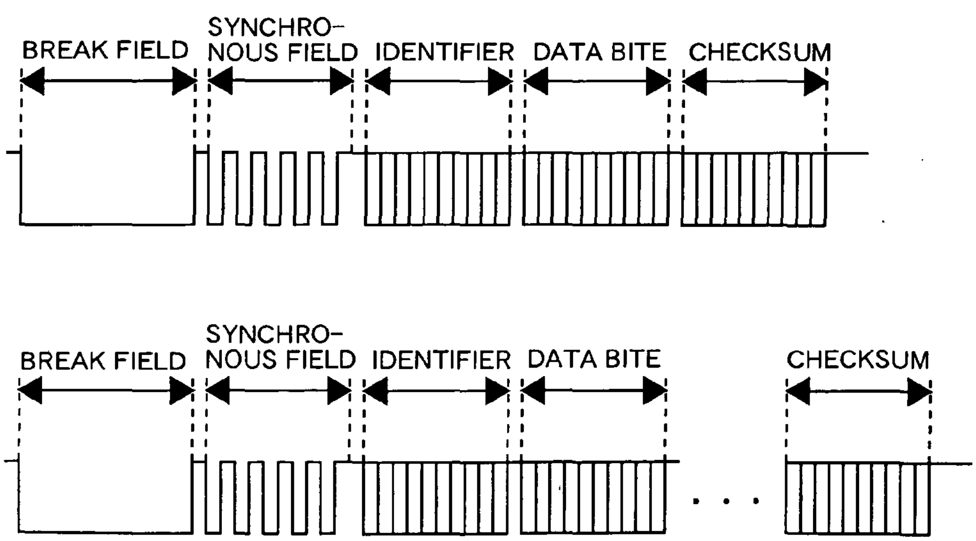
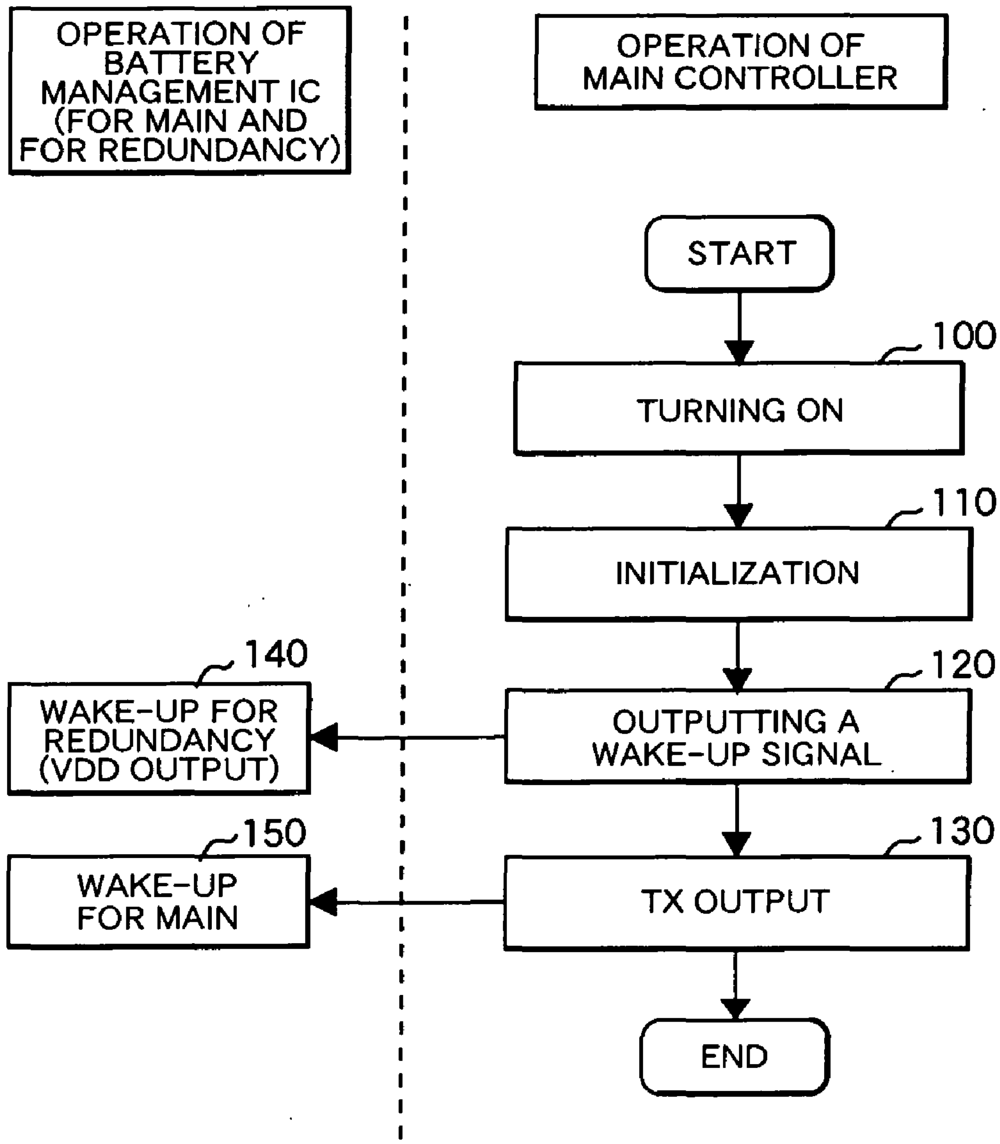

BREAK FIELD
SYNCHRO-
NOUS FIELD
IDENTIFIER
DATA BITE
CHECKSUM
BREAK FIELD
SYNCHRO-
NOUS FIELD
IDENTIFIER
DATA BITE
CHECKSUM

FIG. 5



OPERATION OF BATTERY MANAGEMENT IC (FOR MAIN AND FOR REDUNDANCY)
OPERATION OF MAIN CONTROLLER
START
100
TURNING ON
110
INITIALIZATION
120
OUTPUTTING A WAKE-UP SIGNAL
140
WAKE-UP FOR REDUNDANCY (VDD OUTPUT)
130
TX OUTPUT
150
WAKE-UP FOR MAIN
END

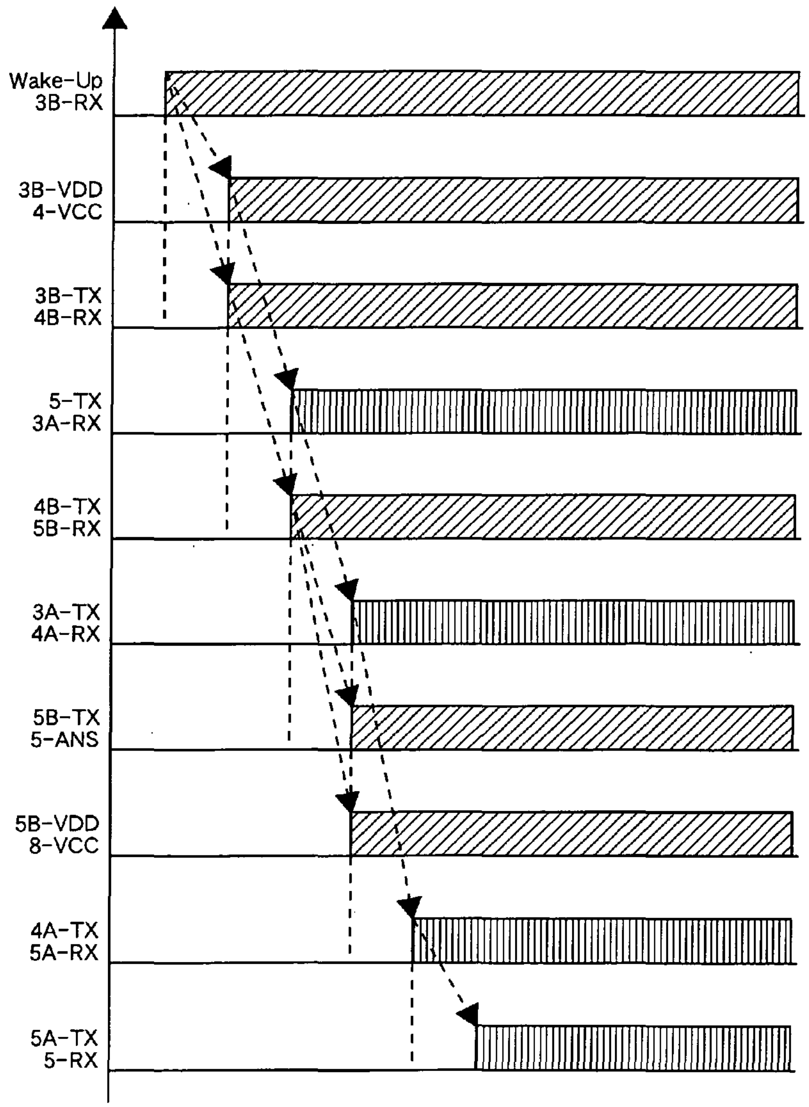


FIG. 6A

FIG. 6B

FIG. 6C

FIG. 6D

FIG. 6E

FIG. 6F

FIG. 6G

FIG. 6H

FIG. 6I

FIG. 6J

FIG. 7

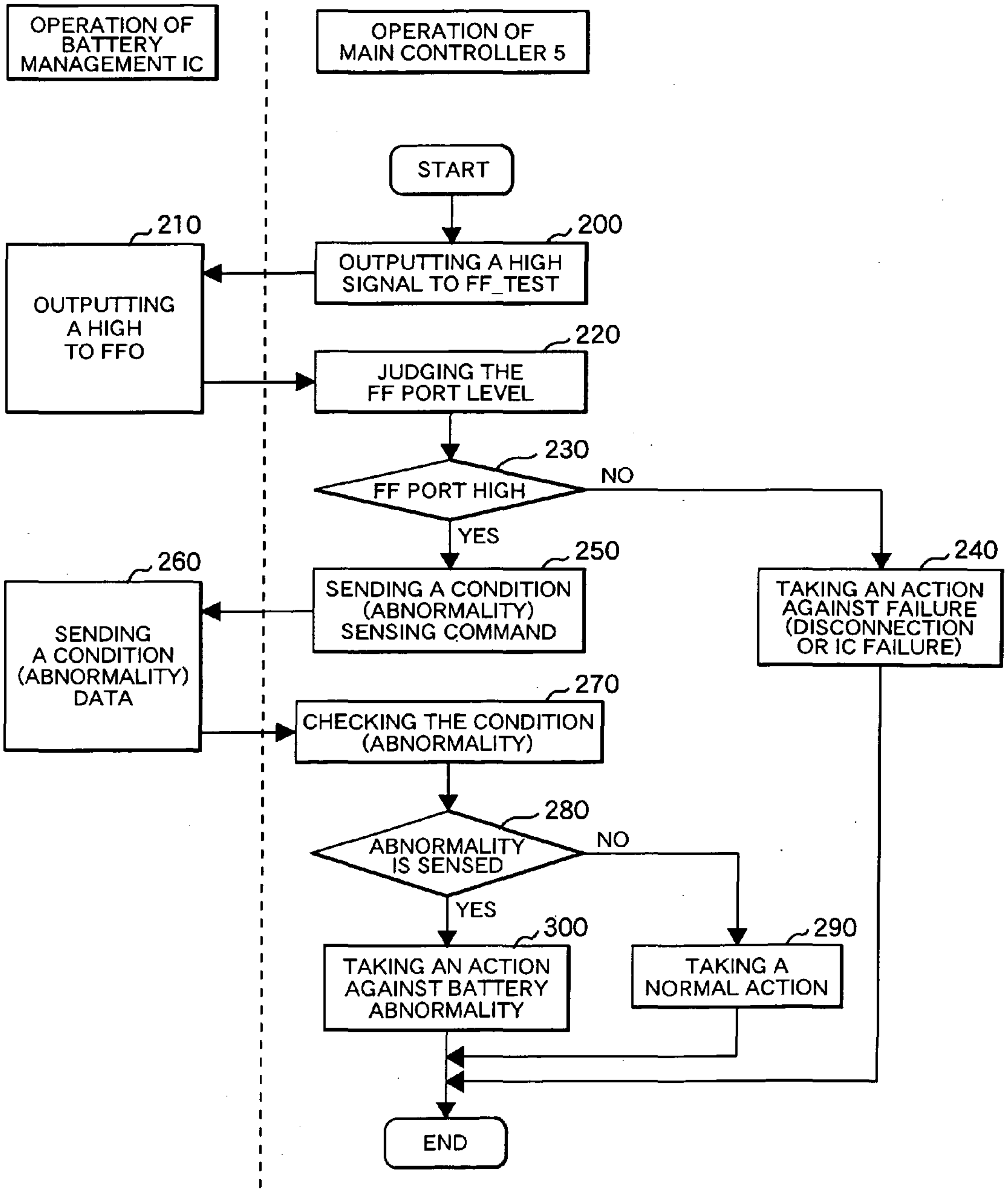
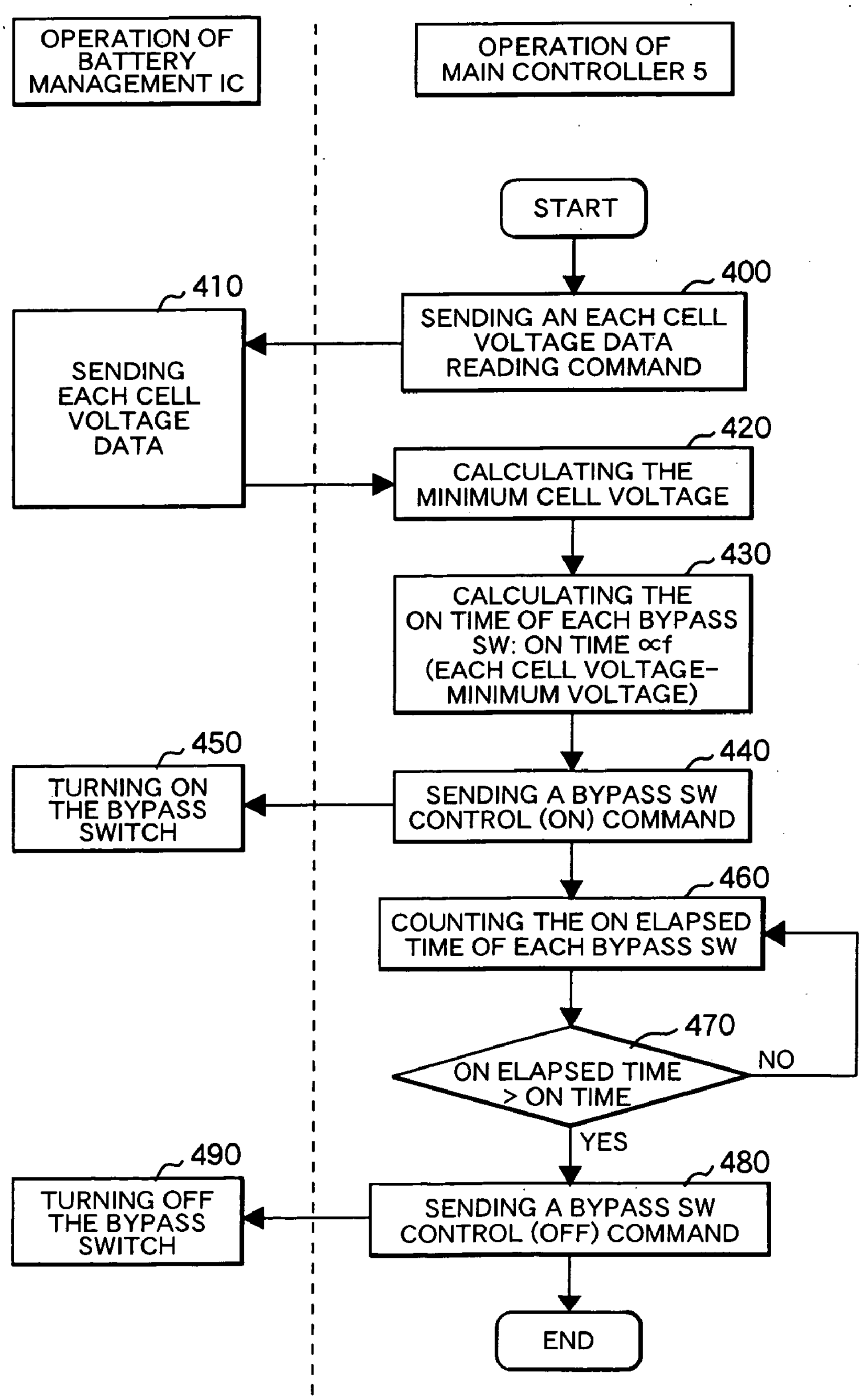

OPERATION OF BATTERY MANAGEMENT IC
OPERATION OF MAIN CONTROLLER 5
START
200
OUTPUTTING A HIGH SIGNAL TO FF_TEST
210
OUTPUTTING A HIGH TO FFO
220
JUDGING THE FF PORT LEVEL
230
FF PORT HIGH
NO
YES
240
TAKING AN ACTION AGAINST FAILURE (DISCONNECTION OR IC FAILURE)
250
SENDING A CONDITION (ABNORMALITY) SENSING COMMAND
260
SENDING A CONDITION (ABNORMALITY) DATA
270
CHECKING THE CONDITION (ABNORMALITY)
280
ABNORMALITY IS SENSED
NO
YES
290
TAKING A NORMAL ACTION
300
TAKING AN ACTION AGAINST BATTERY ABNORMALITY
END

FIG. 8



OPERATION OF BATTERY MANAGEMENT IC
OPERATION OF MAIN CONTROLLER 5
START
400
SENDING AN EACH CELL VOLTAGE DATA READING COMMAND
410
SENDING EACH CELL VOLTAGE DATA
420
CALCULATING THE MINIMUM CELL VOLTAGE
430
CALCULATING THE ON TIME OF EACH BYPASS SW: ON TIME ∝f (EACH CELL VOLTAGE−MINIMUM VOLTAGE)
440
SENDING A BYPASS SW CONTROL (ON) COMMAND
450
TURNING ON THE BYPASS SWITCH
460
COUNTING THE ON ELAPSED TIME OF EACH BYPASS SW
470
ON ELAPSED TIME > ON TIME
NO
YES
480
SENDING A BYPASS SW CONTROL (OFF) COMMAND
490
TURNING OFF THE BYPASS SWITCH
END

FIG. 9

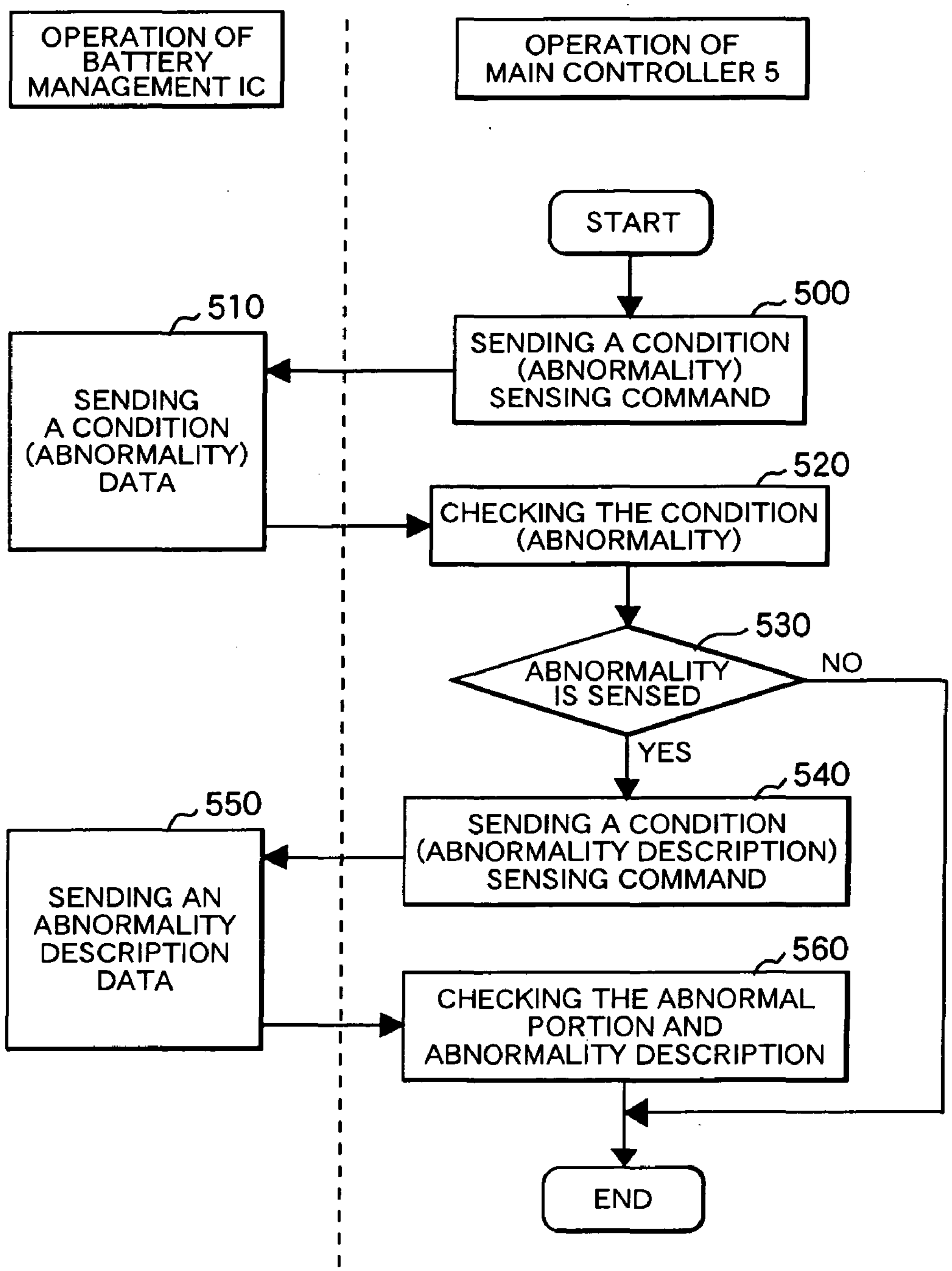
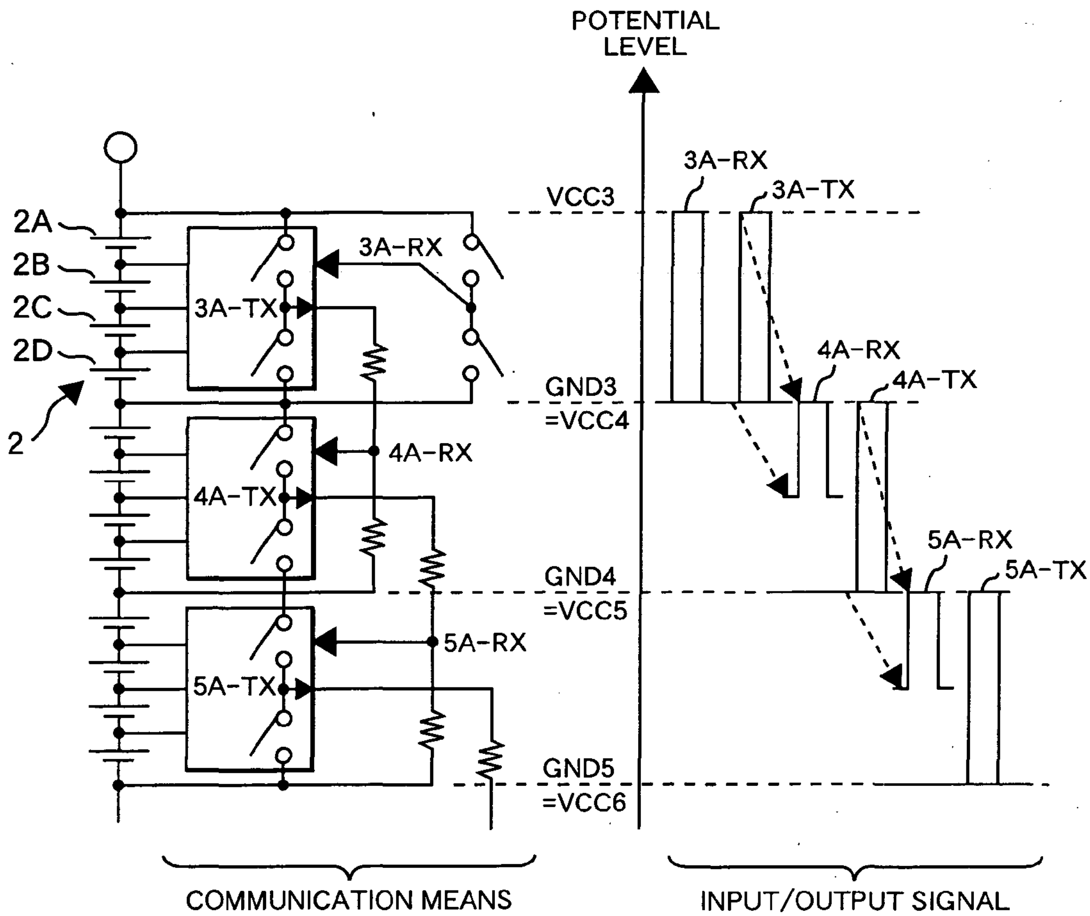
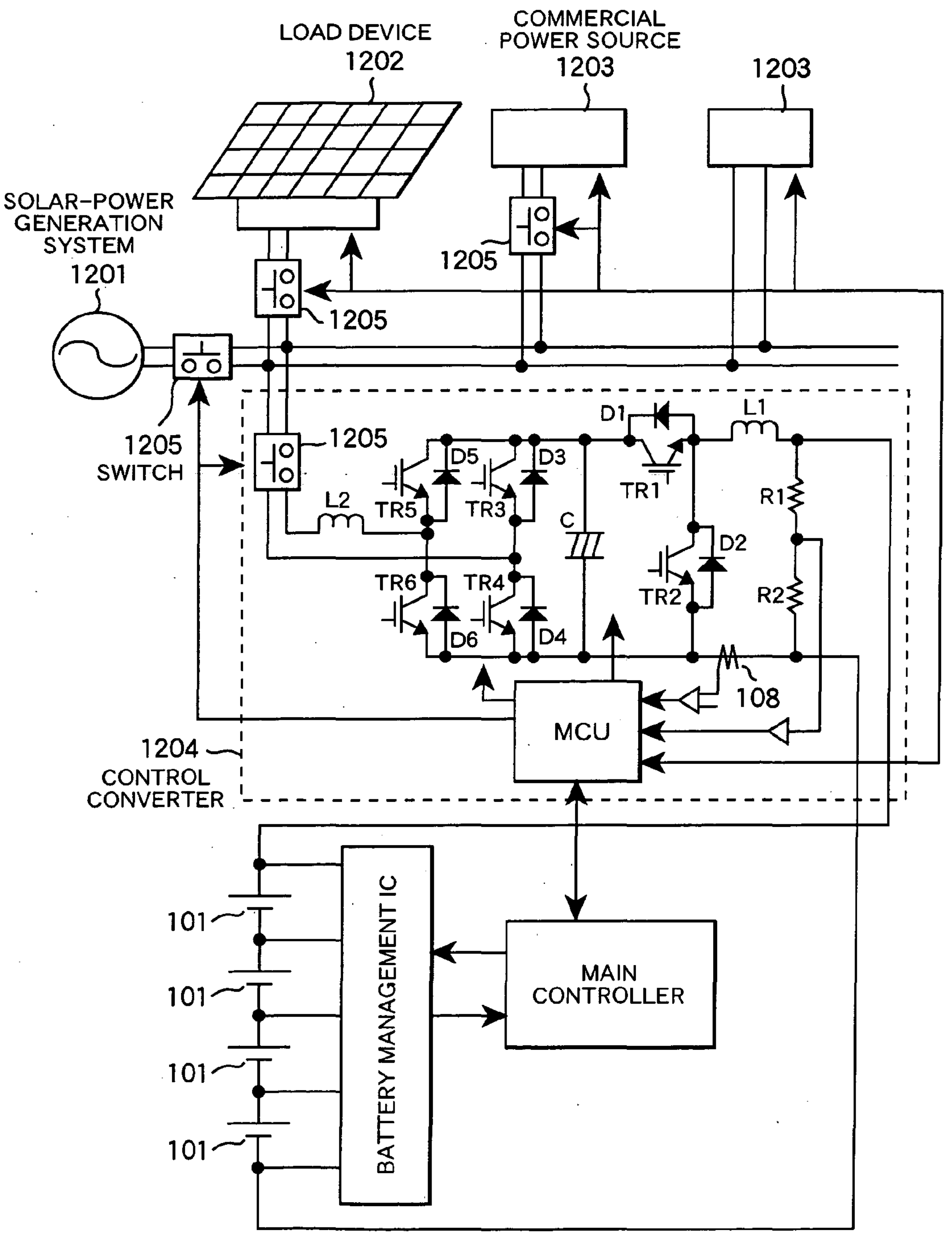

OPERATION OF BATTERY MANAGEMENT IC
OPERATION OF MAIN CONTROLLER 5
START
500
SENDING A CONDITION (ABNORMALITY) SENSING COMMAND
510
SENDING A CONDITION (ABNORMALITY) DATA
520
CHECKING THE CONDITION (ABNORMALITY)
530
ABNORMALITY IS SENSED
NO
YES
540
SENDING A CONDITION (ABNORMALITY DESCRIPTION) SENSING COMMAND
550
SENDING AN ABNORMALITY DESCRIPTION DATA
560
CHECKING THE ABNORMAL PORTION AND ABNORMALITY DESCRIPTION
END

FIG. 10



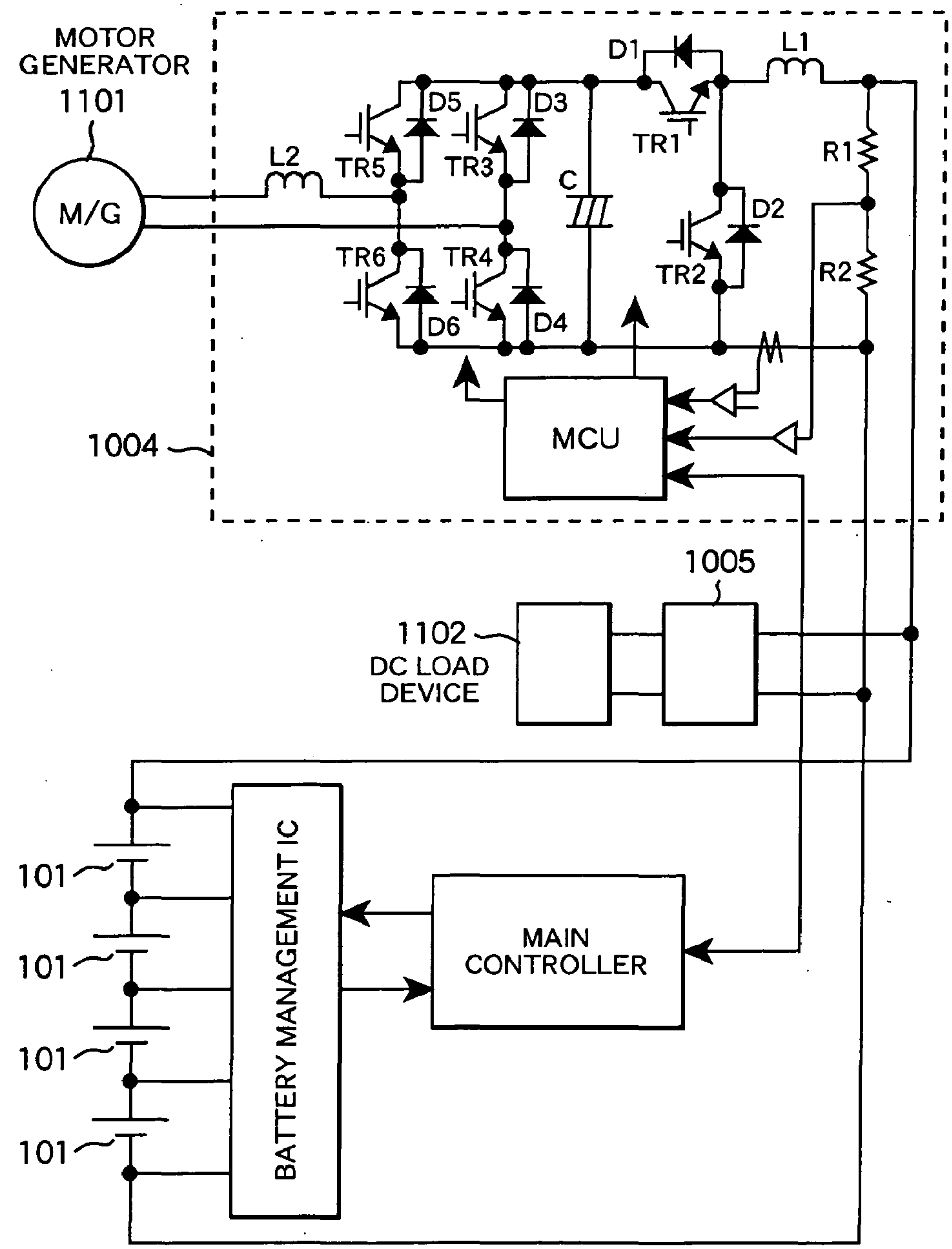
POTENTIAL
LEVEL
2A
2B
2C
2D
2
3A-RX
3A-TX
4A-RX
4A-TX
5A-RX
5A-TX
VCC3
GND3
=VCC4
GND4
=VCC5
GND5
=VCC6
3A-RX
3A-TX
4A-RX
4A-TX
5A-RX
5A-TX
COMMUNICATION MEANS
INPUT/OUTPUT SIGNAL

FIG. 11



LOAD DEVICE
1202
COMMERCIAL
POWER SOURCE
1203
1203
SOLAR-POWER
GENERATION
SYSTEM
1201
1205
1205
1205
SWITCH
1205
D1
L1
D5
D3
TR5
TR3
TR1
L2
R1
C
D2
TR6
TR4
TR2
R2
D6
D4
108
MCU
1204
CONTROL
CONVERTER
101
101
101
101
BATTERY MANAGEMENT IC
MAIN
CONTROLLER

FIG. 12


MOTOR GENERATOR
1101
M/G
L2
TR5
D5
TR3
D3
D1
TR1
L1
R1
C
D2
TR2
R2
TR6
TR4
D6
D4
MCU
1004
1005
1102
DC LOAD DEVICE
101
101
101
101
BATTERY MANAGEMENT IC
MAIN CONTROLLER

MULTI-SERIES BATTERY CONTROL SYSTEM

CLAIM OF PRIORITY

[0001]

BACKGROUND OF THE INVENTION

[0002] The present invention relates to secondary battery (lithium battery) for vehicle or for power supply, particularly to a multi-series battery control system for managing the condition of the secondary battery (lithium battery).

[0003] In order to solve a problem that higher precision voltage sensing involves cost increase of insulation means installed for each of multiple lower control units, there has been proposed a storage battery unit aiming at cost reduction by reducing the number of insulation means, for example, refer to Japanese Patent Laid-open 2003-70179, especially pages 3-4, FIG. 1. This Patent Document aims to lower the effect of disturbance such as noise and thereby improve reliability and enable higher precision voltage sensing.

SUMMARY OF THE INVENTION

[0004] A conventional storage battery unit is so constructed as to comprise multiple series-connected battery modules, each consisting of multiple series-connected storage batteries, multiple lower control units that are provided corresponding respectively to the multiple battery modules and control the multiple storage batteries constituting the battery module, and upper control unit that controls the multiple lower control units, wherein there are provided an input terminal of the lower control unit positioned at the maximum potential among the multiple lower control units and output terminal of the lower control unit positioned at the minimum potential, insulation means or potential conversion means that connects the upper control unit, and cutout device that is installed between the output terminal of the lower control unit and storage battery in the battery module on the lower potential side and cuts out the discharge current from the storage battery in the battery module, and signal input/output terminals of the multiple lower control units are connected with each other, electrically not insulated.

[0005] This conventional storage battery unit is not satisfactory in view of high reliability.

[0006] An object of the present invention is to offer a multi-series battery control system that can realize high reliability.

[0007] In an aspect of the invention, a multi-series battery control system comprising: a plurality of unit battery cells of which unit consists of multiple battery cells connected in series; a plurality of control ICs each comprising a control circuit for controlling the unit battery cell; a main controller that sends and receives signal to/from the control ICs via an insulation; means for sending an abnormality signal, which represents the existence or the absence of abnormality of the control ICs or the battery cells, to the main controller from the control ICs, responding to the first signal outputted from the main controller via the insulation; and means for sending an abnormality contents signal of the control ICs or the battery cells, to the main controller from the control ICs, responding to the second signal outputted from the main controller via the insulation.

[0008] In another aspect of the invention, A multi-series battery control system comprising: a plurality of unit battery cells of which unit consists of multiple battery cells connected in series; a plurality of control IC chips comprising a control circuit for controlling the unit battery cell; a plurality of cell monitor IC chips each monitoring the voltage of the unit battery cell; a plurality of control ICs each consisting of the control IC chip and the cell monitor IC chip; a main controller that sends and receives signal to/from the control IC chips via an insulation; means for sending an abnormality signal, which represents the existence or the absence of abnormality of the control IC chips or the battery cells, to the main controller from the control IC chips, responding to the first signal outputted from the main controller via the insulation; and means for sending the abnormality contents signal of the control IC chip or the battery cells, to the main controller from the control IC chips, responding to the second signal outputted from the main controller via the insulation.

[0009] According to a preferred embodiment of the present invention, a high reliability multi-series battery control system can be realized.

[0010] Other objects and features of the present invention are described hereunder along with preferred embodiments.

BRIEF DESCRIPTION OF DRAWINGS

[0011] **FIG. 1** is a diagram showing an embodiment of the multi-series battery control system of the present invention.

[0012] **FIG. 2** is a detailed circuit diagram of the control IC chip shown in **FIG. 1**.

[0013] **FIG. 3** is a block diagram showing a concrete embodiment of the voltage sensing means shown in **FIG. 2**.

[0014] **FIG. 4** is a diagram showing an embodiment of communication command.

[0015] **FIG. 5** is a chart showing the wake-up sequence in starting up the system.

[0016] **FIG. 6** is a chart showing the sent/received wake-up signals on each control IC shown in **FIG. 5**.

[0017] **FIG. 7** is a chart showing an FF-TEST subroutine.

[0018] **FIG. 8** is a chart showing a balancing subroutine for switching the balancing switch.

[0019] **FIG. 9** is a flow chart showing an operation flow for testing abnormality of battery cell or IC chip.

[0020] **FIG. 10** is a chart for explaining how communication signal is sensed in each control IC.

[0021] **FIG. 11** is a diagram showing a case where the invention is employed in combination with a commercial power source.

[0022] **FIG. 12** is a diagram showing a case where the invention is applied to a motor generator.

DETAILED DESCRIPTION OF THE INVENTION

[0023] The present invention can be realized by monitoring multiple series-connected battery cells as a unit and managing the condition of a battery so as to sense abnormality of IC chip circuit or battery cell and take appropriate measures.

EMBODIMENT 1

[0024] An embodiment of the multi-series battery control system according to the present invention is described hereunder in detail.

[0025] **FIG. 1** shows the construction of the multi-series battery control system of the present invention.

[0026] In **FIG. 1**, a battery system **1** is so constructed that a unit battery cell **2** comprising four series-connected battery cells **2**A, **2**B, **2**C, **2**D is provided with a corresponding paired control IC **3** (control IC chip **3**A and cell monitor IC chip **3**B). The paired control IC **3** consists of two ICs: one is the control IC chip **3**A that contains a control circuit and the other is the cell monitor IC chip that monitors the unit battery cell. One end of the control IC chip **3**A is connected with each terminal of the battery cells **2**A, **2**B, **2**C, **2**D of the unit battery cell **2**. The other end of the control IC chip **3**A is connected with a main controller **5** via a high-speed insulation means **4**. The main controller **5** is connected with one end of the cell monitor IC chip **3**B via insulation means **6** and **7**. The other end of the cell monitor IC chip **3**B is connected with each terminal of the battery cells **2**A, **2**B, **2**C, **2**D.

[0027] The paired control IC **3** is provided for each unit battery cell comprising four battery cells. Although **FIG. 1** shows only three paired ICs, the number of paired ICs **3** is the same number of units of all battery cells of a lithium battery where one unit comprises four battery cells.

[0028] **FIG. 2** shows a detailed circuit of the control IC chip **3**A. Although the figure shows the control IC chip **3**A only, the other control IC chip **4**A, **5**A . . . have the same construction. Moreover, the cell monitor IC chips **3**B-**5**B in **FIG. 1** can also completely be constituted using the same IC chip. Then, in the following explanation, **FIG. 2** is referred to also to explanation of the cell monitor IC chips **3**B-**5**B.

[0029] In **FIG. 2**, the (+) terminal of the battery cell **2**A of the unit battery cell **2** is connected with a selection means **20** via the V1 input terminal. This selection means **20** is a multiplexer, for example. The selection means is provided with switches **20**A, **20**B, **20**C, **20**D, **20**E. One end of the switch **20**A is connected with the V1 input terminal and the other end of the switch **20**A is connected with a power supply **21** and voltage sensing means **22**. In addition, the (–) terminal of the battery cell **2**A of the unit battery cell **2**, which is the (+) terminal of the battery cell **2**B, is connected with one end of the switch **20**B of the selection means **20** via the V2 input terminal and the other end of the switch **20**B is connected with the voltage sensing means **22**.

[0030] In addition, the (–) terminal of the battery cell **2**B of the unit battery cell **2**, which is the (+) terminal of the battery cell **2**C, is connected with one end of the switch **20**C of the selection means **20** via the V3 input terminal and the other end of the switch **20**C is connected with the voltage sensing means **22**. Furthermore, the (–) terminal of the battery cell **2**C of the unit battery cell **2**, which is the (+) terminal of the battery cell **2**D, is connected with one end of the switch **20**D of the selection means **20** via the V4 input terminal and the other end of the switch **20**D is connected with the voltage sensing means **22**.

[0031] The (–) terminal of the battery cell **2**D of the unit battery cell **2** is connected with one end of the switch **20**E of the selection means **20** via the GND (ground) terminal and the other end of the switch **20**E is connected with the voltage sensing means.

[0032] The power supply **21** is constructed for example as a DC/DC converter, which is made using the unit battery cells so as to convert the power of the unit battery cell **2** to a specified voltage and supply to the outside through the VDD terminal and also to supply drive power to each circuit in the control IC chip **3**A.

[0033] The voltage sensing means **22** senses each terminal-to-terminal voltage between the battery cells **2**A, **2**B, **2**C, **2**D of the unit battery cell **2**, and the sensed terminal-to-terminal voltage between the battery cells **2**A, **2**B, **2**C, **2**D is outputted to a calculation means **23**. The calculation means comprises a power supply management means **24**, storage means **25** and correction means **26**. The power supply management means **24** controls ON/OFF of the power supply **21**.

[0034] The storage means **25** stores each terminal-to-terminal voltage between the battery cells **2**A, **2**B, **2**C, **2**D of the unit battery cell **2** sensed by the voltage sensing means **22** separately for each battery cell **2**A, **2**B, **2**C, **2**D. To be concrete, the storage means **25** is constructed as a shift register. The correction means **26** corrects each terminal-to-terminal voltage between the battery cells **2**A, **2**B, **2**C, **2**D of the unit battery cell **2** sensed by the voltage sensing means **22**.

[0035] The calculation means **23** is connected with a communication means **27**. The communication means **27** receives through the RX terminal via the high-speed insulation means **4** a communication command (such as 8-bit, 10-bit or 12-bit ON/OFF signal) sent from the main controller **5**. That is to say, the main controller **5** sends out a command for operating a specified control IC chip **3**A to the high-speed insulation means **4**, including a communication command for reading the voltage between each battery cell **2**A, **2**B, **2**C, **2**D or communication command for adjusting the voltage between each battery cell **2**A, **2**B, **2**C, **2**D of a specified unit battery cell **2**. The high-speed insulation means **4** does not send out the communication command received from the main controller **5** directly to the communication means **27** but via the insulation means.

[0036] The high-speed insulation means **4** is a transformer type and as small as an IC. Being a transformer type, the high-speed insulation means **4** needs power and is driven by power supplied from the cell monitor chip **3**B.

[0037] The communication means **27** generates a communication command (such as 10-bit or 12-bit ON/OFF signal), corresponding to the communication command sent from the main controller **5** via the high-speed insulation means **4**, by the voltage of eight battery cells, that is, two series-connected unit battery cells and outputs it to the calculation means **23**.

[0038] How communication signal is sensed in each control IC chip **3**A, **4**A, . . . **5**A is described hereunder, using **FIG. 10**.

[0039] In FIG. 10, among the control IC chip 3A, control IC chip 4A, . . . control IC chip 5A, communication signal is judged by the control IC chip 3A and control IC chip 4A, and the control IC chip 4A and control IC chip 5A. In the control IC chip 3A in FIG. 10, a VCC3 voltage level signal (Hi/Low signal of the VCC3 voltage level), of which Hi is the total voltage of the sum of each voltage of battery cells 2A, 2B, 2C, 2D of the unit battery cell 2 and Low is the GND (ground) level, is inputted into the RX terminal of the control IC chip 3A. The VCC3 voltage level signal inputted into the RX terminal of the control IC chip 3A is outputted from the TX terminal of the control IC chip 3A but the voltage is divided by a resistor, and so a divided VCC3 voltage level signal (Hi/Low signal of the VCC3 voltage level divided to ½ for example) is inputted into the RX terminal of the control IC chip 4A. That is, the communication signal is inputted into the RX terminal of the control IC chip 4A as a signal for example repeating Hi/Low of the VCC3 voltage level divided to ½. If the control IC chip 4A attempts to judge the signal outputted from the TX terminal of the control IC chip 3A using the same threshold as for the control IC chip 3A based on each voltage of the unit battery cell 2 under its control, judgment is impossible because the Low level of the signal outputted from the TX terminal of the control IC chip 3A is half the total voltage applied to the control IC chip 4A.

[0040] That is to say, in FIG. 10, the RX terminal voltage of the control IC chip 3A ranges VCC3 to GND3. The RX terminal voltage of the control IC chip 4A ranges (VCC3 to GND4)×R/2R because the voltage outputted from the TX terminal of the control IC chip 3A is divided to ½ by a resistor. The TX terminal voltage of the control IC chip 4A ranges VCC4 to GND4. The RX terminal voltage of the control IC chip 5A ranges (VCC4 to GND5)×R/2R because the voltage outputted from the TX terminal of the control IC chip 4A is divided to ½ by a resistor.

[0041] Accordingly, both input and output (RX and TX) of the highest control IC chip 3A ranges VCC to GND. The threshold of the highest control IC chip 3A for judging Hi/Low of the input (RX) is therefore ½ VCC. The output (TX) of other control IC chips (4A, . . . 5A) than the highest control IC chip 3A ranges VCC to ½ VCC. Accordingly, for smooth operation, the threshold of each control IC chip 4A, . . . 5A for judging Hi/Low of the input (RX) shall be nothing but ¾ VCC.

[0042] In addition, the (+) terminal of the battery cell 2A of the unit battery cell 2 is connected with the B1 terminal via a resistor R1. This B1 terminal is connected with one end of the SW condition sensing means 28A and the other end of the SW condition sensing means 28A is connected with the (−) terminal of the battery cell 2A of the unit battery cell 2 via the V2 terminal. And, a balancing switch 29A series-connected with the resistor R1 is inserted between the two terminals of the battery cell 2A of the unit battery cell 2.

[0043] In addition, the (+) terminal of the battery cell 2B of the unit battery cell 2 is connected with the B2 terminal via a resistor R2. This B2 terminal is connected with one end of the SW condition sensing means 28B and the other end of the SW condition sensing means 28B is connected with the (−) terminal of the battery cell 2B of the unit battery cell 2 via the V3 terminal. And, a balancing switch 29B series-connected with the resistor R2 is inserted between the two terminals of the battery cell 2B of the unit battery cell 2.

[0044] In addition, the (+) terminal of the battery cell 2C of the unit battery cell 2 is connected with the B3 terminal via a resistor R3. This B3 terminal is connected with one end of the SW condition sensing means 28C and the other end of the SW condition sensing means 28C is connected with the (−) terminal of the battery cell 2C of the unit battery cell 2 via the V4 terminal. And, a balancing switch 29C series-connected with the resistor R3 is inserted between the two terminals of the battery cell 2C of the unit battery cell 2.

[0045] Furthermore, the (+) terminal of the battery cell 2D of the unit battery cell 2 is connected with the B4 terminal via a resistor R4. This B4 terminal is connected with one end of the SW condition sensing means 28D and the other end of the SW condition sensing means 28D is connected with the (−) terminal of the battery cell 2D of the unit battery cell 2. And, a balancing switch 29D series-connected with the resistor R4 is inserted between the two terminals of the battery cell 2D of the unit battery cell 2.

[0046] These SW condition sensing means 28A, 28B, 28C, 28D sense the voltage between both ends of the balancing switches 29A to 29D, respectively. They also sense abnormality of the balancing switches 29A, 29B, 29C, 29D. That is to say, if the terminal voltage of the battery cells 2A, 2B, 2C, 2D is outputted while the balancing switches 29A, 29B, 29C, 29D are ON, the balancing switches 29A, 29B, 29C, 29D can be judged abnormal. These SW condition sensing means 28A, 28B, 28C, 28D are a voltage sensing circuit comprising a differential amplifier.

[0047] These balancing switches 29A, 29B, 29C, 29D are switches that short-circuits each battery cell via the resistor R1, resistor R2, resistor R3, and resistor R4 respectively so as to discharge the series-connected battery cells 2A, 2B, 2C, 2D constituting the unit battery cell 2 and match the battery cell voltage of the four battery cells 2A, 2B, 2C, 2D constituting the unit battery cell with each other. To be concrete, they are constructed as a MOS type FET. In addition, the SW condition sensing means 28A senses whether the balancing switch 29A is operating correctly, SW condition sensing means 28B senses whether the balancing switch 29B is operating correctly, SW condition sensing means 28C senses whether the balancing switch 29C is operating correctly, and SW condition sensing means 28D senses whether the balancing switch 29D is operating correctly. That is, the SW condition sensing means 28A to 28D continuously monitor the voltage of the balancing switches 29A to 29D, and when the balancing switches 29A, 29B, 29C, 29D are turned ON, the SW condition sensing means 28A, 28B, 28C, 28D sense a voltage near 0 (zero), respectively.

[0048] A potential conversion means 30 is connected with these SW condition sensing means 28A, 28B, 28C, 28D. The potential conversion means 30 convert the voltage between each battery cell 2A, 2B, 2C, 2D sensed by the SW condition sensing means 28A, 28B, 28C, 28D to a specific potential (potential suitable for processing) and output it to a comparison means 31. That is, since the potential levels between each battery cell 2A, 2B, 2C, 2D are different, the potential conversion means 30 converts them to such potential levels that can be compared with each other.

[0049] The comparison means 31, into which a drive signal of a SW drive means 33 is inputted, compares the drive signal with the voltage, which is the voltage between each balancing switches **29**A, **29**B, **29**C, **29**D sensed by the SW condition sensing means **28**A, **28**B, **28**C, **28**D, and converted into a specific voltage (potential suitable for processing) and outputted from the potential conversion means **30**, and judges whether the balancing switches **29**A, **29**B, **29**C, **29**D are normal or abnormal.

[**0050**] On the other hand, a signal for driving the balancing switch **29**A is inputted via the BS**1** terminal, signal for driving the balancing switch **29**B is inputted via the BS**2** terminal, signal for driving the balancing switch **29**C is inputted via the BS**3** terminal, and signal for driving the balancing switch **29**D is inputted via the BS**4** terminal from the main controller **5** into the SW drive means **33**, respectively. The SW drive means **33** converts the switch signal sent from the main controller **5** into each switch drive signal and outputs it to the comparison means **31** connected with the SW drive means and potential conversion means **32**.

[**0051**] The potential conversion means **32** receives the switch drive signal sent from the SW drive means **33**, converts it to a drive voltage signal (to be concrete, a gate signal) for turning ON/OFF the balancing switches **29**A, **29**B, **29**C, **29**D, and supplies it (to be concrete, supplies a gate voltage) to the balancing switches **29**A, **29**B, **29**C, **29**D

[**0052**] When abnormality of the balancing switches **29**A, **29**B, **29**C, **29**D is sensed by the comparison means **31**, it identifies which balancing switch **29**A, **29**B, **29**C, **29**D is abnormal based on the switch drive signal outputted from the SW drive means **33** and outputs the result to the calculation means **23**. When abnormality is sensed by the comparison means **31**, the calculation means **23** identifies an abnormal balancing switch and sends a signal informing the abnormality is sent to the main controller **5** from the FFO terminal of the communication means **27** or TX terminal of the communication means **27**.

[**0053**] In **FIG. 2**, the BS**1** to BS**4** terminals in the SW drive means **33** are used to input a signal for turning ON the balancing switches **19**A to **19**D from the outside, and the signal inputted from these terminals BS**1** to BS**4** drives the SW drive means **33** and the SW drive means **33** sends out an ON signal of the balancing switches **19**A to **19**D to the potential conversion means **32**. The potential conversion means **32** receives the switch drive signal sent from the SW drive means **33**, converts it to a drive voltage signal (to be concrete, a gate signal) for turning ON the balancing switches **29**A, **29**B, **29**C, **29**D, and supplies it (to be concrete, supplies a gate voltage) to the balancing switches **29**A, **29**B, **29**C, **29**D.

[**0054**] **34** in **FIG. 2** is a temperature abnormality sensing means, and the temperature abnormality sensing means **34** senses the temperature of the control IC chip **3**A, checking whether it reaches a preset temperature. If the temperature abnormality sensing means **34** senses a temperature in excess of the preset temperature, it sends out a signal to the SW drive means **33** so as to stop supplying current to the balancing switches **29**A to **29**D and terminate the charging control by the balancing switches **29**A, **29**B, **29**C, **29**D so that no more heat is generated.

[**0055**] **FIG. 3** shows a concrete embodiment of the voltage sensing means **22** shown in **FIG. 2**.

[**0056**] The voltage sensing means **22** in **FIG. 3** is connected with the selection means **20**. The voltage sensing means **22** is provided with a resistor **22R1** connected with the (+) terminal of the battery cells **2**A, **2**B, **2**C, **2**D of which connection is switched by the switches **20**A, **20**B, **20**C, **20**D, **20**E of the selection means **20**. The other end of the resistor **22R1** is connected with one end of a resistor **22R2** and the (−) input terminal of the operation amplifier **22OP1**. The other end of the resistor **22R2** is connected with an AC/DC converter **22**A.

[**0057**] On the other hand, there is provided a resistor **22R3** connected with the (−) terminal of the battery cells **2**A, **2**B, **2**C, **2**D of which connection is switched by the switches **20**A, **20**B, **20**C, **20**D, **20**E of the selection means **20**, and the other end of the resistor **22R3** is connected with one end of a resistor **22R4** and the (+) input terminal of the operation amplifier **22OP1**. The output terminal of the operation amplifier **22OP1** is connected with the AC/DC converter **22**A. The other end of the resistor **22R4** is connected with the ground.

[**0058**] The output terminal of the AC/DC converter **22**A is connected with an adder **12**C via a 10-bit resistor **22**B, and the adder **12**C is connected with a 16-bit resistor rolling average **22**D.

[**0059**] Because a duplex integration type is employed as explained above, noise content in the input voltage can be filtered. In addition, because a 16-bit resistor rolling average is employed, resolution can be improved and sensed value can be filtered.

[**0060**] **FIG. 4** shows an embodiment of communication command. This communication command is sent from the main controller **5** and inputted to the RX terminal of the communication means **27** shown in **FIG. 2**. A unit data of this communication command comprises 8 bits and a communication command contains 5 bytes. The first 8 bits of the communication command are a break field informing an incoming signal, second 8 bits are a synchronous field as a signal for synchronization, third 8 bits are an identifier equivalent to an address showing which control IC chip **3**A applies, fourth 8 bits are a data byte showing the communication detail (control detail), and fifth 8 bits are a checksum. These communication commands consisting of 5 bytes are sent in series.

[**0061**] **FIG. 5** shows the wake-up sequence in starting up the system. That is, this wake-up sequence is the operation flow for actuating the control IC chip **3**A and cell monitor IC chip **3**B in turning on the main controller **5**.

[**0062**] In **FIG. 5**, when the main controller **5** shown in **FIG. 2** is turned on (key-switch is turned on) in step **100**, the main controller **5** is initialized in step **110**. After the initialization of the main controller **5** in step **110**, a wake-up signal shown in **FIG. 6** (A) is outputted from the wake-up terminal of the main controller **5** to the RX terminal of the cell monitor IC chip **3**B via the insulation means **6** in step **120**. The RX terminal of the cell monitor IC chip **3**B is for waking up the cell monitor IC chip **3**B and so, when a wake-up signal is inputted to the RX terminal of the cell monitor IC chip **3**B, the cell monitor IC chip **3**B is actuated (wakes up). When this cell monitor IC chip **3**B wakes up, the power VCC supplied from the battery cells **2**A, **2**B, **2**C, **2**D as shown in **FIG. 6** (B) is outputted from the VDD terminal of the cell monitor IC chip **3**B.

[**0063**] When a wake-up signal shown in **FIG. 6** (A) is outputted from the wake-up terminal of the main controller

5 to the RX terminal of the cell monitor IC chip **3**B via the insulation means **6** in step **120**, the cell monitor IC chip **3**B supplies the power VCC shown in **FIG. 6** (B) from the VDD terminal to the high-speed insulation means **4** (VDD output) in step **140**. When the power VCC shown in **FIG. 6** (B) is supplied from the VDD terminal of the cell monitor IC chip **3**B to the high-speed insulation means **4**, the high-speed insulation means **4** wakes up. When the high-speed insulation means **4** wakes up, the wake-up signal shown in **FIG. 6** (D) outputted from the TX terminal of the main controller **5** can be outputted to the RX terminal of the control IC chip **3**A.

[**0064**] As explained above, the cell monitor IC chip **3**B wakes up when a wake-up signal shown in **FIG. 6** (A) outputted from the wake-up terminal of the main controller **5** via the insulation means **6** is received at the RX terminal in step **120**, and a wake-up signal shown in **FIG. 6** (D) for waking up the control IC chip **3**A is outputted from the TX terminal of the main controller **5** to the RX terminal of the control IC chip **3**A via the high-speed insulation means **4** in step **130**. In step **130**, a wake-up signal shown in **FIG. 6** (D) for waking up the control IC chip **3**A is outputted from the TX terminal of the main controller **5** to the RX terminal of the control IC chip **3**A via the high-speed insulation means **4** in step **130**, and when it is received at the RX terminal of the control IC chip **3**A, the control IC chip **3**A wakes up in step **150**.

[**0065**] When the cell IC chip **3**B is woken up by a wake-up signal shown in **FIG. 6** (A) outputted from the wake-up terminal of the main controller **5** to the RX terminal of the cell monitor IC chip **3**B via the insulation means **6**, the cell IC chip **3**B copies the wake-up signal shown in **FIG. 6** (A) as a wake-up signal shown in **FIG. 6** (C) and outputs it from the RX terminal of the cell monitor IC chip **3**B to the RX terminal of the cell monitor IC chip **4**B in the next stage. The cell IC chip **4**B is woken up by a wake-up signal shown in **FIG. 6** (C) outputted from the TX terminal of the cell monitor IC chip **3**B, and the cell IC chip **4**B copies the wake-up signal shown in **FIG. 6** (C) outputted from the TX terminal of the cell monitor IC chip **3**B and outputs it as a wake-up signal shown in **FIG. 6** (E) from the TX terminal of the cell monitor IC chip **4**B to the RX terminal of the cell monitor IC chip **5**B in the last stage. There are multiple cell IC chips provided between the cell monitor IC chip **4**B and the cell monitor IC chip **5**B in the last stage, but they are omitted in **FIG. 1**.

[**0066**] On the other hand, the power supplied from the battery cells **2**A, **2**B, **2**C, **2**D is outputted from the VDD terminal of the cell monitor IC chip **3**B to the high-speed insulation means **4**, the high-speed insulation means **4** is turned on, and a wake-up signal shown in **FIG. 6** (D) is outputted from the TX terminal of the main controller **5** to the RX terminal of the control IC chip **3**A via the high-speed insulation means **4**. When this wake-up signal shown in **FIG. 6** (D) is inputted to the RX terminal of the control IC chip **3**A, the control IC chip **3**A wakes up. When the control IC chip **3**A wakes up, the control IC chip **3**A copies the wake-up signal shown in **FIG. 6** (D) sent from the TX terminal of the main controller **5** and outputs it as a wake-up signal shown in **FIG. 6** (F) from the TX terminal of the control IC chip **3**A to the RX terminal of the control IC chip **4**A in the next stage.

[**0067**] The cell IC chip **4**A is woken up by a wake-up signal shown in **FIG. 6** (F) outputted from the TX terminal of the cell monitor IC chip **3**A, and the cell IC chip **4**A copies the wake-up signal shown in **FIG. 6** (F) outputted from the TX terminal of the cell monitor IC chip **3**A and outputs it as a wake-up signal shown in **FIG. 6** (I) from the TX terminal of the cell monitor IC chip **4**A to the RX terminal of the cell monitor IC chip **5**A in the last stage. There are multiple cell IC chips provided between the cell monitor IC chip **4**A and the cell monitor IC chip **5**A in the last stage, but they are omitted in **FIG. 1**.

[**0068**] The control IC chip **3**A, control IC chip **4**A, . . . control IC chip **5**A and the cell monitor IC chip **3**B, cell monitor IC chip **4**B, . . . cell monitor IC chip **5**B wake up as explained above, and the battery management IC for managing the battery cells **2**A to **2**N wakes up. In addition, there is provided a VDD terminal on each control IC chip **3**A, control IC chips **4**A to **5**A, cell monitor IC chip **3**B, and cell monitor IC chips **4**B to **5**B, and so power can be supplied to the outside by appropriate utilization of these VDD terminals.

[**0069**] After the cell monitor IC chip **3**B wakes up as above, the cell monitor IC chip **4**B and remaining cell monitor IC chips wake up by repeating a similar operation. The cell IC chip **5**B wakes up as it receives a wake-up signal shown in **FIG. 6** (E) outputted from the TX terminal of the cell monitor IC chip **4**B at the RX terminal. When the cell monitor IC chip **5**B wakes up as it receives a wake-up signal shown in **FIG. 6** (E) outputted from the TX terminal of the cell monitor IC chip **4**B to the RX terminal of the cell monitor IC chip **5**B, the cell monitor IC chip **5**B copies the wake-up signal shown in **FIG. 6** (E) and outputs it as a wake-up signal shown in **FIG. 6** (G) from the TX terminal of the cell monitor IC chip **5**B to the ANS terminal of the main controller **5**.

[**0070**] When the cell monitor IC chip **5**B wakes up, it supplies the power VCC shown in **FIG. 6** (H) from the VDD terminal to the high-speed insulation means **8** (VDD output). When the power VCC shown in **FIG. 6** (H) is supplied from the VDD terminal of the cell monitor IC chip **5**B to the high-speed insulation means **8**, the high-speed insulation means **8** wakes up. When the high-speed insulation means **8** wakes up, the high-speed insulation means **8** is turned ON and so the TX terminal of the control IC chip **5**A can communicate with the RX terminal of the main controller **6**. That is, when the high-speed insulation means **8** wakes up, a wake-up signal shown in **FIG. 6** (J) is sent from the TX terminal of the control IC chip **5**A to the RX terminal of the main controller **5**. When the wake-up signal shown in **FIG. 6** (J) from the TX terminal of the control IC chip **5**A is received at the RX terminal of the main controller **5**, the main controller **5** confirms that the control IC chip **3**A, control IC chip **4**A, . . . control IC chip **5**A and the cell monitor IC chip **3**B, cell monitor IC chip **4**B, . . . cell monitor IC chip **5**B have woken up and the battery management IC for managing the battery cells **2**A to **2**N has woken up correctly. Whether the cell monitor IC chip **3**B, cell monitor IC chip **4**B, . . . cell monitor IC chip **5**B have woken up is judged by confirming that the high-speed insulation means **8** is turned ON and a wake-up signal shown in **FIG. 6** (J) is sent from the TX terminal of the control IC chip **5**A to the RX terminal of the main controller **5** is the cell monitor IC chip **5**B has woken up.

[0071] The battery management IC is provided with a high-speed insulation means **4** on its top stage and high-speed insulation means **8** on its bottom stage for the purpose of insulation and so it is not grounded to chassis (power supply is lifted from the chassis).

[0072] **FIG. 7** shows an FF-TEST subroutine. That is, the FF-TEST subroutine is a processing flow for inputting a test signal from the FFI of the cell monitor IC chip **3**B and sensing abnormality in the circuits of the cell monitor IC chips **3**B to **5**B.

[0073] In **FIG. 7**, a High signal is sent from the FF-TEST terminal of the main controller **5** as shown in **FIG. 1** to the FFI terminal of the communication means of the cell monitor IC chip **3**B shown in **FIG. 1** via an insulation means **7** in step **200**. When a High signal is sent to the FFI terminal of the communication means of the cell monitor IC chip **3**B in step **200**, the cell monitor IC chip **3**B outputs the High signal, without adding any processing, from the FFO terminal to the FFI terminal of the cell monitor IC chip **4**B in the next stage. Similarly, when a High signal is sent to the FFI terminal of the communication means of the cell monitor IC chip **4**B, the cell monitor IC chip **4**B outputs the High signal, without adding any processing, from the FFO terminal to the FFI terminal of the cell monitor IC chip **5**B in the next stage. Then, when a High signal is sent to the FFI terminal of the communication means of the cell monitor IC chip **5**B, the cell monitor IC chip **5**B outputs the High signal, without adding any processing, from the FFO terminal to the main controller **5**. When a signal is outputted from the FFO terminal of the communication means **27**, the FF port level is judged based on the signal sent from the FFO terminal to the main controller **5** in step **220**. When the FF port level is judged based on the signal outputted from the FFO terminal and sent to the main controller **5** in step **220**, the main controller **5** judges whether the FF port level is High or not in step **230**.

[0074] If the main controller **5** judges that the FF port level is not High (is Low) in step **230**, it takes an action needed in a case the circuit is disconnected somewhere or the cell monitor IC chip itself is abnormal.

[0075] If the main controller **5** judges the FF port level is High in step **230**, it is necessary in step **250** to check if the returned High signal is a signal representing normality (High signal) that has been inputted by chance in spite of over-charging or over-discharging. That is, in step **250**, it sends a condition (abnormality) sensing command, which is a command for sensing other abnormality (abnormality of battery cell), to the RX terminal of the communication means **27** provided on the control IC chip **3**A. When this condition (abnormality) sensing command is sent to the controller **5** and RX terminal of the communication means **27** of the control IC chip **3**A, a condition (abnormality) data, which is a data showing the current condition, is sent from the TX terminal of the communication means **27** of the control IC chip **3**A to the main controller **5** in step **260**. When this condition (abnormality) data is sent from the TX terminal of the communication means **27** to the main controller **5**, the main controller **5** checks the condition (abnormality) in step **270** and judges whether the condition (abnormality) data sent from the TX terminal of the communication means **27** is a signal indicating abnormality in step **280**. In a similar manner, it checks the condition (abnormality) of the control IC chip **4**A and control IC chip **5**A and judges whether the condition (abnormality) data sent from the TX terminal of the communication means **27** is a signal indicating abnormality. If the condition (abnormality) data sent from the TX terminal of the communication means **27** is judged to be a signal indicating no abnormality in step **280**, it takes a normal action and finishes the flow. If the condition (abnormality) data sent from the TX terminal of the communication means **27** is judged to be a signal indicating abnormality in step **280**, it takes an action against battery abnormality and finishes the flow.

[0076] **FIG. 8** shows a balancing subroutine for switching the balancing switches **29**A, **29**B, **29**C, **29**D. That is, this balancing subroutine is a processing flow for discharging the series-connected battery cells **2**A, **2**B, **2**C, **2**D constituting the unit battery cell **2** and matching the battery cell voltage of the four battery cells **2**A, **2**B, **2**C, **2**D constituting the unit battery cell with each other.

[0077] In step **400** in **FIG. 8**, the main controller **5** sends each battery cell voltage reading command, which is a command for reading the voltage data of each battery cell **2**A to 2D, to the RX terminal of the communication means **27** in **FIG. 2**. When the each battery cell voltage reading command is sent in step **400**, the each battery cell voltage reading command judges control particulars and reads the battery cell voltage of each battery cell **2**A, **2**B, **2**C, **2**D, periodically updated and stored in the storage means, in the calculation means **23** of the control IC chip **3**A and sends in series each battery cell voltage data from the TX terminal to the main controller **5**. When each battery cell voltage data from the control IC chip **3**A is received, the main controller **5** finds the minimum battery cell voltage out of each battery cell voltage data received and calculates the minimum cell voltage so as to calculate the discharging time of each battery cell in step **420**. After calculating the minimum cell voltage in step **420**, it calculates the ON time of each balancing switch **29**A, **29**B, **29**C, **29**D in step **430**. The ON time of each balancing switch **29**A, **29**B, **29**C, **29**D is calculated by subtracting the minimum cell voltage from each battery cell voltage.

[0078] In step **440**, a bypass SW control (ON) command for ON control of each balancing switch **29**A, **29**B, **29**C, **29**D is sent from the main controller **5** to the RX terminal of the communication means **27** shown in **FIG. 2**. When the bypass SW control (ON) command is sent in step **440**, the bypass control (ON) command judges control particulars in the calculation means **23** of the control IC chip **3**A and drives the SW drive means **33** so that a switch drive signal (a signal specifying which switch to drive) is outputted from the SW drive means **33** to the potential conversion means **32**, and a selected balancing switch out of **29**A, **2529**B, **29**C, **29**D is turned ON in step **450**. When the selected balancing switch out of **29**A, **29**B, **29**C, **29**D is turned ON, one of the battery cells **2**A, **2**B, **2**C, **2**D discharges.

[0079] When the selected balancing switch out of **29**A, **29**B, **29**C, **29**D is turned ON in step **450**, the main controller **5** counts the ON elapsed time of each bypass SW (balancing switch) **29**A, **29**B, **29**C, **29**D in step **460**. When the ON elapsed time of each bypass SW is counted in step **460**, whether the ON elapsed time of each bypass SW (balancing switch) **29**A, **29**B, **29**C, **29**D becomes greater than the ON time in step **470**. That is, in step **470**, the main controller waits until the ON elapsed time of each bypass SW (balancing switch) **29**A, **29**B, **29**C, **29**D becomes greater than the ON time.

[**0080**] When the ON elapsed time of each bypass SW (balancing switch) **29**A, **29**B, **29**C, **29**D is judged greater than the ON time in step **470**, a bypass SW control (OFF) command for OFF control of each balancing switch **29**A, **29**B, **29**C, **29**D is sent from the main controller **5** to the RX terminal of the communication means **27** shown in **FIG. 2** in step **480**. When the bypass SW control (OFF) command is sent in step **480**, the bypass control (OFF) command judges control particulars in the calculation means **23** of the control IC chip **3**A and controls the SW drive means **33** so that a switch drive signal (a signal specifying which switch to drive) is outputted from the SW drive means **33** to the potential conversion means **32**, and a selected balancing switch out of **29**A, **29**B, **29**C, **29**D is turned OFF in step **490**. When the selected balancing switch out of **29**A, **29**B, **29**C, **29**D is turned OFF, one of the battery cells **2**A, **2**B, **2**C, **2**D stops discharging. A similar operation applies to the control IC chip **4**A and control IC chip **5**A.

[**0081**] **FIG. 9** shows an operation flow for checking whether the control IC chips **3**A to **5**A or each battery cell is normal or not.

[**0082**] To start with, in step **500**, a condition (abnormality) sensing command (the first signal) is sent from the TX terminal of the main controller **5** to the RX terminal of the control IC chip **3**A. When a condition (abnormality) sensing command is sent from the TX terminal of the main controller **5**, the control IC chip **3**A receives the condition (abnormality) sensing command.

[**0083**] When the condition (abnormality) sensing command is sent from the TX terminal of the main controller **5** in step **500**, the control IC chip **3**A, control IC chip **4**A, . . . control IC chip **5**A receives it in turn and the cell monitor IC chip **5**B on the last stage sends it to the main controller **5**.

[**0084**] That is, the control IC chip **3**A that has received the condition (abnormality) sensing command adds an abnormality signal representing the existence or the absence of abnormality in own range, and sends the condition (abnormality) sensing command to the RX terminal of the next control IC chip **4**A. When the condition (abnormality) sensing command is outputted from the TX terminal of the control IC chip **3**A, the control IC chip **4**A receives the condition (abnormality) sensing command and sends the condition (abnormality) sensing command to the TX terminal of the next control IC chip **5**A. Consequently, when the control IC chip **5**A on the last stage receives the condition (abnormality) sensing command sent from the TX terminal of the control IC chip **4**A, it sends the condition (abnormality) sensing command received through the TX terminal of the control IC chip **5**A to the RX terminal of the main controller **5** via the insulation means **10**.

[**0085**] When the control IC chip **3**A, control IC chip **4**A, . . . control IC chip **5**A receives the command in turn and the cell monitor IC chip **5**B on the last stage sends it to the main controller **5** in step **510**, the main controller **5** that has received the condition (abnormality) sensing command from the control IC chip **5**A checks the condition (abnormality) in step **520**. Which of the control IC chip **3**A, control IC chip **4**A, . . . control IC chip **5**A or corresponding battery cells is abnormal can be judged from the condition (abnormality) sensing command returned to the main controller **5**.

[**0086**] After checking the condition (abnormality) of the control IC chip **3**A, control IC chip **4**A, . . . control IC chip **5**A in step **520**, the main controller **5** judges whether abnormality is found on any of the control IC chips or corresponding battery cells in step **530**. If it judges no abnormality is found on any of the control IC chips or corresponding battery cells in step **530**, it finishes the flow. If the main controller **5** judges abnormality is found on any of the control IC chip **4**A, . . . control IC chip **5**A in step **530**, a condition (abnormality detail) sensing command (the second signal) for specifying the address of the control IC chip on which abnormality is sensed and identifying the abnormality detail is sent from the TX terminal of the main controller **5** to the RX terminal of the control IC chip **3**A via the insulation means **7** in step **540**.

[**0087**] When the condition (abnormality detail) sensing command is sent from the TX terminal of the main controller **5** in step **540**, the control IC chip **3**A receives it in step **550** and then a control IC chip having different address than the specified sends the condition (abnormality detail) sensing command as it is to the control IC chip on the next stage. This sending and receiving is performed sequentially as follows: the control IC .chip **3**A receives the condition (abnormality detail) sensing command through the RX terminal and sends it from the TX terminal to the RX terminal of the control IC chip **4**A, and the control IC chip **4**A sends it from the TX terminal to the RX terminal of the control IC chip **5**A, and the control IC chip **5**A sends the condition (abnormality detail) sensing command received from the control IC chip **4**A from the TX terminal of the control IC chip **5**A to the RX terminal of the main controller **5** via the insulation means **10**.

[**0088**] When abnormality is sensed based on the condition (abnormality detail) sensing command that is received from the control IC chip **4**A and sent from the TX terminal of the control IC chip **5**A to the RX terminal of the main controller **5** via the insulation means **9**, a signal is outputted from the Relay terminal of the main controller **5** so as to drive a relay drive circuit and turn OFF the relay.

[**0089**] When the control IC chip **3**A, control IC chip **4**A, . . . control IC chip **5**A receives the command in turn and the cell monitor IC chip **5**A on the last stage sends it to the main controller **5** in step **550**, the main controller **5** having received the condition (abnormality detail) sensing command from the control IC chip **5**A checks the abnormal portion and abnormality detail in the control IC chip **3**A, control IC chip **4**A, . . . control IC chip **5**A in step **560** and finishes the flow.

[**0090**] The main controller **5** first sends an alert signal for sending a signal (break field) from the TX terminal of the main controller **5** to the RX terminal of the control IC chip **3**A and then sends a synchronous signal for receiving an incoming signal synchronously, and after that, sends out the first signal for sensing abnormality continuously. Responding to the first signal for sensing abnormality, an abnormality sensed signal showing abnormality is sensed on one of the control IC chip **3**A, control IC chip **4**A, . . . control IC chip **5**A or corresponding battery cells is sent back with an identified address of abnormal control IC chip. When this abnormality sensed signal which represents the existence or the absence of abnormality of the control IC chip or the battery cells is received, the main controller **5** sends out the second signal for identifying the abnormality detail based on the abnormal sensed signal. This signal for identifying the abnormality detail specifies which control IC chip shall send what type of information, and the abnormality detail specifies the address and type of data (overcharging, battery cell voltage, etc.).

[**0091**] As explained above, the main controller **5** collects individual voltage of the battery cells and performs cell balancing control upon start-up, and then sends a signal for sensing abnormality of each control IC chip and, if abnormality is sensed, sends a signal for identifying the abnormality detail.

[**0092**] In this embodiment, a multi-series battery control system comprises a plurality of unit battery cells (**2**) of which unit consists of multiple battery cells (**2**A-**2**D) connected in series; a plurality of control IC chips (**3**A-**5**A) comprising a control circuit for controlling the unit battery cell (**2**); a plurality of cell monitor IC chips (**3**B-**5**B) each monitoring the voltage of the unit battery cell (**2**); a plurality of control ICs (**3**) each consisting of the control IC chip (**3**A-**5**A) and the cell monitor IC chip (**3**B-**5**B); a main controller (**5**) that sends and receives signal to/from the control IC chips (**3**A-**5**A) via an insulation (**4**,**8**); means (process in **510**) for sending an abnormality signal, which represents the existence or the absence of abnormality of the control IC chips or the battery cells, to the main controller (**5**) from the control IC chips (**3**A-**5**A), responding to the first signal (abnormality sensing command) outputted from the main controller (**5**) via the insulation (**4**,**8**); means (process in **540**) for sending the abnormality contents signal of the control IC chip or the battery cells, to the main controller (**5**) from the control IC chips (**3**A-**5**A), responding to the second signal (condition sensing command) outputted from the main controller (**5**) via the insulation (**4**,**8**); and means (process in **410**) for sending voltage signals of the battery cells, to the main controller (**5**) from the control IC chips (**3**A-**5**A), responding to a voltage sensing command outputted from the main controller (**5**) via the insulation (**4**,**8**).

[**0093**] The main controller **5** periodically senses the total voltage of the battery cells by the voltage sensing means and collects it through the VALL terminal of the main controller **5** via the insulation means. It also senses the total current through the battery cells by the current sensing means and collects it through the CUR terminal of the main controller **5**. In addition, the main controller **5** periodically sums up each cell voltage and compares the total voltage so as to accomplish conformity diagnosis by checking if the differential voltage is within a specified range. Since whether this differential voltage is within a specified range or not is always checked, nothing more is needed to adjust the balancing but turning ON/OFF the balancing switches according to the voltage of each battery cell.

[**0094**] **FIG. 11** shows a case where this embodiment is employed in combination with a commercial power source.

[**0095**] In the figure, **1201** is a commercial power source, **1202** is a solar-power generation system, **1203** is a load device, **1204** is a control converter, and **1205** is a switch.

[**0096**] Multiple battery cells **101** are connected in series, a battery management IC is connected with each battery cell **101**, and the output of the battery management IC is connected with the main controller **5** via an insulation coupler. In addition, the control converter **1204** is connected to both ends of the row of the battery cells **101**, and the main controller **5** is connected with the MCU in the control converter **1204**.

[**0097**] Furthermore, the solar-power generation system **1202**, load device **1203** and control converter **1204** are connected with the common commercial power source **1201** each via a switch **1205**. At the same time, the solar-power generation system **1202**, load device **1203**, control converter **1204**, switch **1205** and main controller **5** are connected with each other in both directions.

[**0098**] The solar-power generation system **1202** is a system that converts the sunlight to DC current using solar cells and outputs AC current using an inverter.

[**0099**] The load device **1203** includes home electric appliances such as air-conditioner, refrigerator, microwave range, and lighting, and electric appliances such as motor, computer, and medical devices. The control converter **1204** is a charging/discharging device that converts AC current to DC current or DC current to AC current. This converter also functions as a controller for controlling the charging and discharging as well as for controlling the above solar-power generation system **1202** and load device **1203**.

[**0100**] In the construction as above, if power needed for the load device **1203** cannot be fully supplied by the commercial power source **1201** and solar-power generation system **1202**, power is supplied from the battery cell **101** via the control converter **1204**. When the power supplied from the commercial power source **1201** and solar-power generation system **1202** becomes excessive, it is stored in the battery cell **101** via the control converter **1204**.

[**0101**] If the terminal-to-terminal voltage of the battery cell **101** reaches a level requiring charging or discharging to be ceased in the course of the above operation, the main controller **5** sends a relevant signal to the control converter **1204** and the control converter **1204** controls charging and discharging accordingly.

[**0102**] With the above construction, it becomes possible to lower the contract demand and power demand of the commercial power source **1201** and generation rating of the solar-power generation system **1202**, and hence equipment cost and running cost decrease.

[**0103**] In addition, if power is supplied from the battery cell **101** to the commercial power source **1201** when the power demand concentrates to a specific time zone and stored into a storage battery when the power demand is low, the concentration of power demand can be moderated and the power demand can be leveled

[**0104**] Furthermore, since the control converter **1204** monitors the power demand of the load device **1203** and controls the load device **1203** accordingly, energy saving and effective utilization of power can be realized.

[**0105**] **FIG. 12** shows a case where the embodiment is applied to a motor generator.

[**0106**] If the figure, **1101** is a motor generator, **1004** is a control converter, **1005** is a voltage regulator, and **1102** is a

DC load device (for example, power steering, electric brake, and suction/exhaust valve timing device).

[**0107**] Multiple battery cells **101** are connected in series, a battery management IC is connected with each battery cell **101**, and the output of the battery management IC is connected with the main controller **5** via an insulation coupler. In addition, the main controller **5** is connected with the MCU in the control converter **1004**.

[**0108**] The motor generator **1101** is a motor that converts the generated AC power to DC power and outputs.

[**0109**] With the above construction, while an automobile is driven by engine and is moving, power is generated by the motor generator **1101** that is driven by the automobile movement via a drive belt or directly driven by actuating an electromagnetic clutch. The power generated by the motor generator **1101** is supplied and charged into the battery cell **101** via the control converter **1004**. Charging and discharging of the battery cell **101** is controlled by the motor generator **1101** through the battery management IC and via the main controller **5**. In case of discharging, power is supplied through the battery management IC to the motor to drive the tires to rotate. The MCU in the control converter **1004** and the system are also connected with each other.

[**0110**] The main controller **5** is grounded with the ground (chassis ground) but both ends of the battery cells **2**A, **2**B, **2**C, **2**D of the unit battery cell **2** are lifted from the ground. The control converter **1004** is not grounded, either but lifted from the ground. In short, the power related circuit is lifted from the ground.

[**0111**] If the system is actually abnormal while the main controller **5** becomes out of control and mistakenly judges normal, the relay cannot be turned off because the main controller **5** is out of control. If this happens, a signal is outputted from an analog system so as to drive the relay drive circuit and turn OFF the relay.

[**0112**] With this embodiment, the number of components constituting the multi-series battery control system can be decreased.

[**0113**] In addition, with this embodiment, lower cost can be realized in constructing the multi-series battery control system.

[**0114**] Furthermore, with this embodiment, higher reliability of the multi-series battery control system can be realized.

[**0115**] Furthermore, with this embodiment, operability of the multi-series battery control system can be improved.

[**0116**] Furthermore, with this embodiment, the multi-series battery control system can be further generalized.

[**0117**] With this embodiment, higher-speed communication in the multi-series battery control system can also be realized.

[**0118**] In addition, with this embodiment, the multi-serial battery control system can be easily constructed and can be simplified.

[**0119**] According to the proper embodiments of the present invention, high reliability can be achieved.

What is claimed is:

1. A multi-series battery control system comprising:

a plurality of unit battery cells of which unit consists of multiple battery cells connected in series;

a plurality of control ICs each comprising a control circuit for controlling the unit battery cell;

a main controller that sends and receives signal to/from the control ICs via an insulation;

abnormality sensing means for sending an abnormality signal, which represents the existence or the absence of abnormality of the control ICs or the battery cells, to the main controller from the control ICs, responding to an abnormality sensing command outputted from the main controller via the insulation; and

voltage sensing means for sending voltage signals of the battery cells, to the main controller from the control ICs, responding to a voltage sensing command outputted from the main controller via the insulation.

2. A multi-series battery control system according to claim 1, wherein the control ICs each comprising:

a balancing circuit which discharges so that the voltage of each cell constituting the unit battery cell connected with the control IC becomes stable at a specified voltage.

3. A multi-series battery control system according to claim 1, wherein the control ICs each comprising:

means for sensing the voltage of each cell constituting the unit battery cell connected with the control IC; and

means for controlling the supply of power from the unit battery cell.

4. A multi-series battery control system according to claim 1, wherein the main controller is grounded with chassis but the unit battery cells and the control ICs are not grounded.

5. A multi-series battery control system according to claim 2, wherein the balancing circuit in the control IC is driven when the voltage variation of each cell constituting the unit battery cell sensed on the control IC is greater than a specified voltage.

6. A multi-series battery control system comprising:

a plurality of unit battery cells of which unit consists of multiple battery cells connected in series;

a plurality of control ICs each comprising a control circuit for controlling the unit battery cell;

a main controller that sends and receives signal to/from the control ICs via an insulation;

means for sending an abnormality signal, which represents the existence or the absence of abnormality of the control ICs or the battery cells, to the main controller from the control ICs, responding to the first signal outputted from the main controller via the insulation; and

means for sending an abnormality contents signal of the control ICs or the battery cells, to the main controller from the control ICs, responding to the second signal outputted from the main controller via the insulation.

7. A multi-series battery control system according to claim 6, wherein the control ICs each comprising:

a balancing circuit which discharges so that the voltage of each cell constituting the unit battery cell connected with the control IC becomes stable at a specified voltage.

8. A multi-series battery control system according to claim 6, wherein the control ICs each comprising:

means for sensing the voltage of each cell constituting the unit battery cell connected with the control IC; and

means for controlling the supply of power from the unit battery cell.

9. A multi-series battery control system according to claim 6, wherein communication between the main controller and the control ICs are made duplex communication system so as to send the first signal for requesting abnormality of the control ICs or the battery cells and send the second signal for requesting abnormality contents to the control ICs in case the existence of abnormality is sensed by the abnormality requesting.

10. A multi-series battery control system according to claim 6, wherein the main controller is grounded with chassis but the unit battery cells and the control ICs are not grounded.

11. A multi-series battery control system according to claim 7, wherein the balancing circuit in the control IC is driven when the voltage variation of each cell constituting the unit battery cell sensed on the control IC is greater than a specified voltage.

12. A multi-series battery control system comprising:

a plurality of unit battery cells of which unit consists of multiple battery cells connected in series;

a plurality of control IC chips each comprising a control circuit for controlling the unit battery cell;

a plurality of cell monitor IC chips each monitoring the voltage of the unit battery cell;

a plurality of control ICs each consisting of the control IC chip and the cell monitor IC chip;

a main controller that sends and receives signal to/from the control IC chips via an insulation;

means for sending an abnormality signal, which represents the existence or the absence of abnormality of the control IC chips or the battery cells, to the main controller from the control IC chips, responding to the first signal outputted from the main controller via the insulation; and

means for sending the abnormality contents signal of the control IC chip or the battery cells, to the main controller from the control IC chips, responding to the second signal outputted from the main controller via the insulation.

13. A multi-series battery control system according to claim 12, wherein the cell monitor IC chips each comprising:

a balancing circuit which discharges so that the voltage of each cell constituting the unit battery cell connected with the control IC chip becomes stable at a specified voltage.

14. A multi-series battery control system according to claim 12, wherein the control IC chips each comprising:

means for sensing the voltage of each cell constituting the unit battery cell connected with the control IC chip; and

means for controlling the supply of power from the unit battery cell.

15. A multi-series battery control system according to claim 12, wherein communication between the main controller and the control IC chips are made duplex communication system so as to send the first signal for requesting abnormality of the control IC chips or the battery cells and send the second signal for requesting abnormality contents to the control IC chips in case the existence of abnormality is sensed by the abnormality requesting.

16. A multi-series battery control system according to claim 12, wherein the main controller is grounded with chassis but the unit battery cells, the control IC chips and the cell monitor IC chips are not grounded.

17. A multi-series battery control system according to claim 13, wherein the balancing circuit in the cell monitor IC chip is driven based on a command from the control IC chip when the voltage variation of each cell constituting the unit battery cell sensed on the control IC chip is greater than a specified voltage.

18. A multi-series battery control system according to claim 13, wherein the cell monitor IC chips each comprising:

means for driving the balancing circuit independently even without receiving a command for driving the balancing circuit from the control IC chip when the voltage variation of each cell constituting the unit battery cell is greater than a specified voltage.

* * * * *

IE4

FIG.1

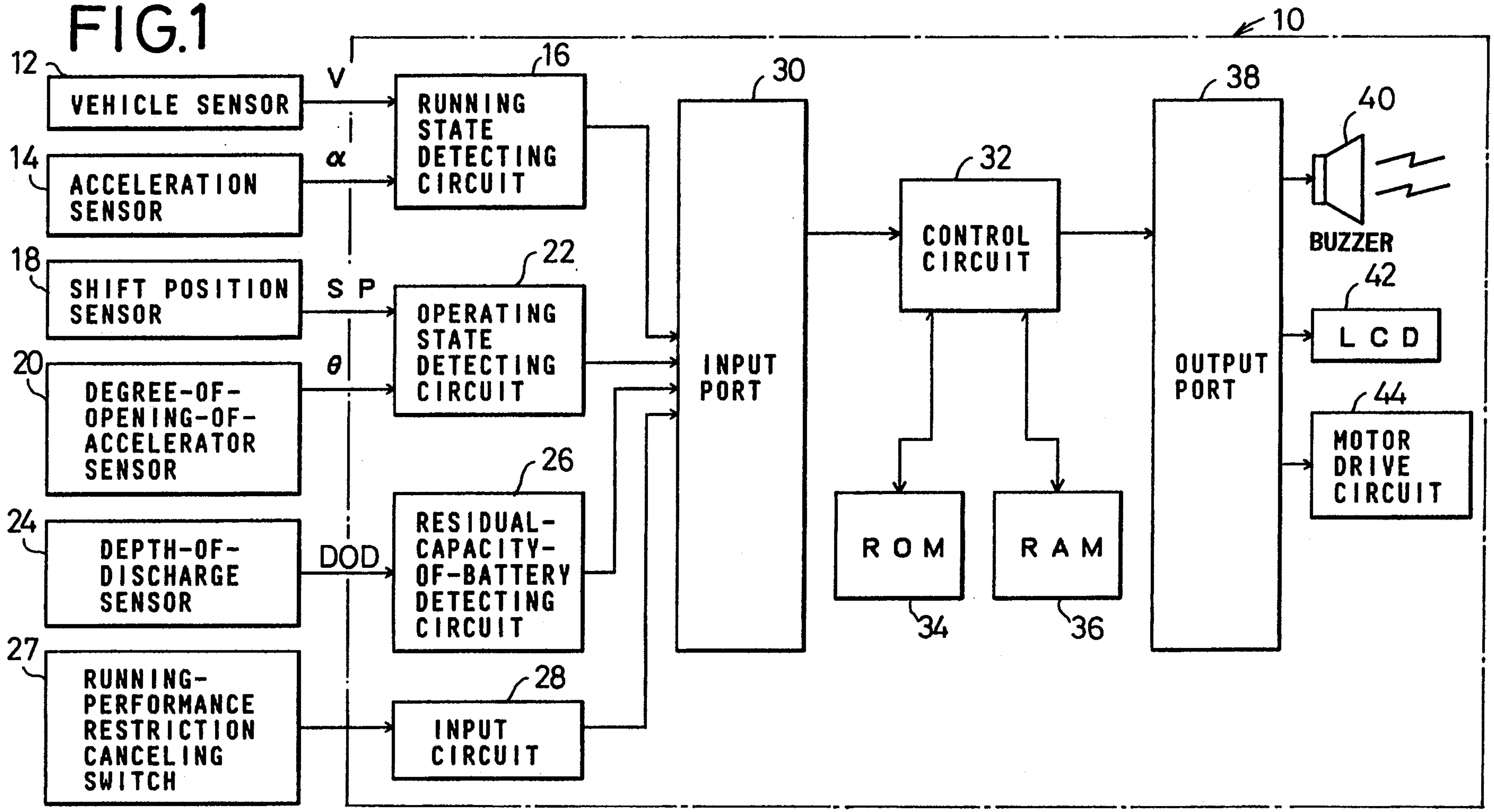

10
12
VEHICLE SENSOR
14
ACCELERATION SENSOR
18
SHIFT POSITION SENSOR
20
DEGREE-OF-OPENING-OF-ACCELERATOR SENSOR
24
DEPTH-OF-DISCHARGE SENSOR
27
RUNNING-PERFORMANCE RESTRICTION CANCELING SWITCH
V
α
S P
θ
DOD
16
RUNNING STATE DETECTING CIRCUIT
22
OPERATING STATE DETECTING CIRCUIT
26
RESIDUAL-CAPACITY-OF-BATTERY DETECTING CIRCUIT
28
INPUT CIRCUIT
30
INPUT PORT
32
CONTROL CIRCUIT
R O M
34
R A M
36
38
OUTPUT PORT
40
BUZZER
42
L C D
44
MOTOR DRIVE CIRCUIT

FIG.2

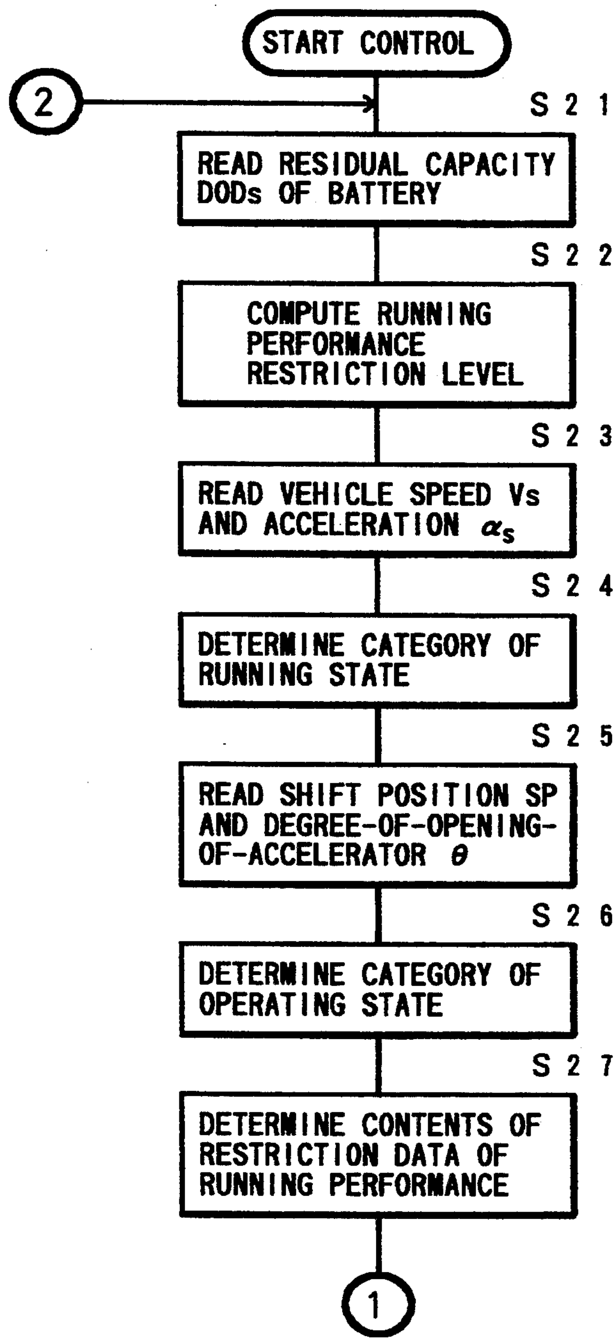
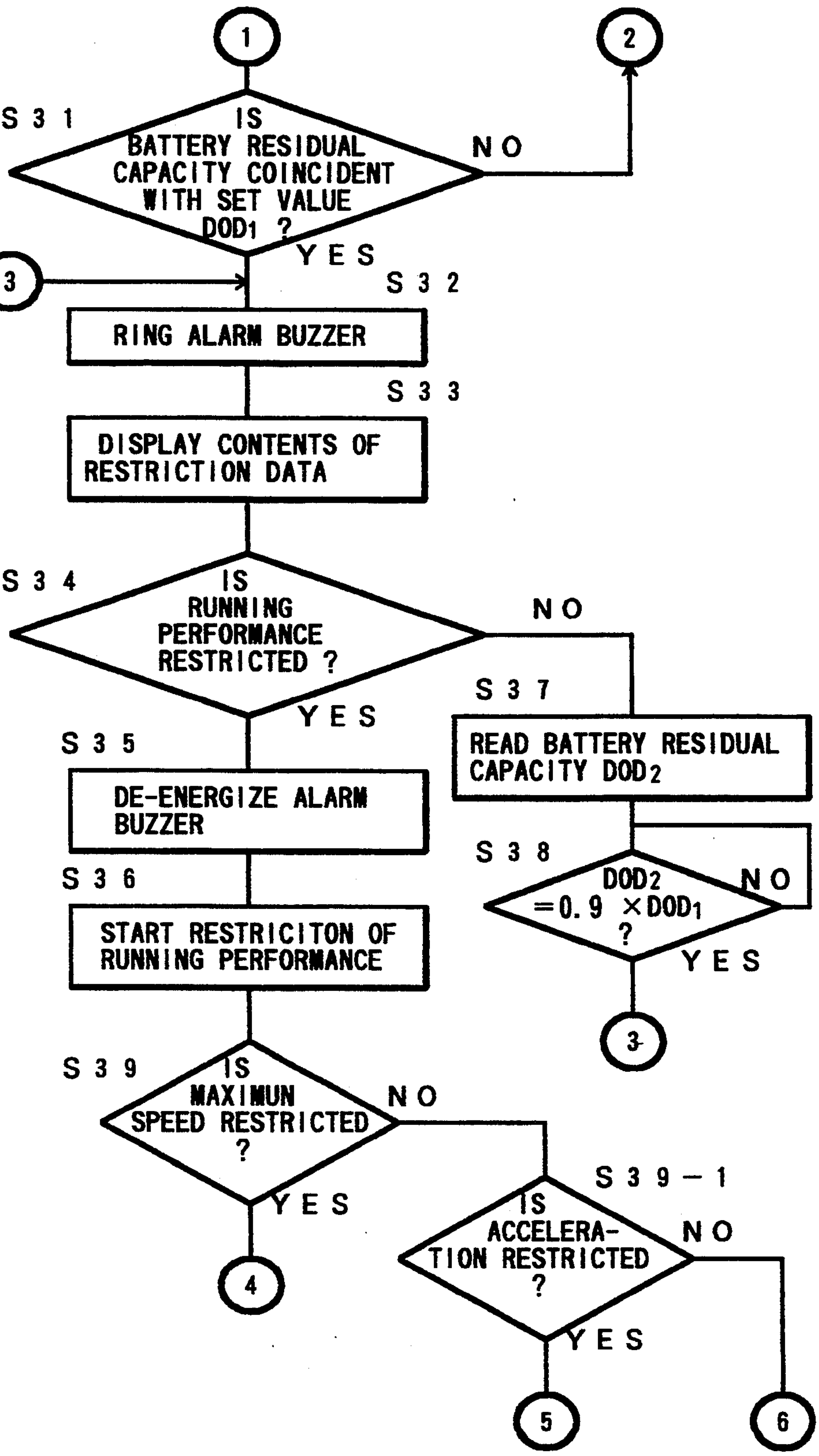
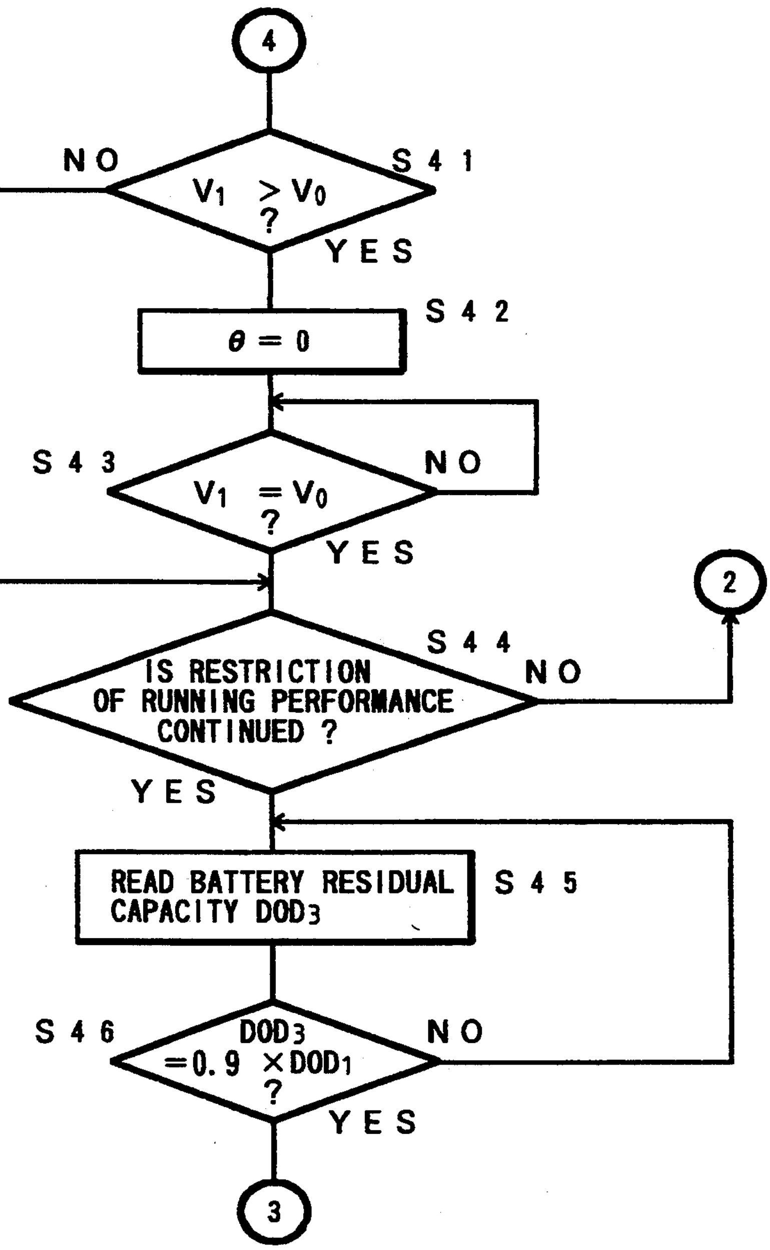

START CONTROL
2
S21
READ RESIDUAL CAPACITY DODs OF BATTERY
S22
COMPUTE RUNNING PERFORMANCE RESTRICTION LEVEL
S23
READ VEHICLE SPEED Vs AND ACCELERATION α_s
S24
DETERMINE CATEGORY OF RUNNING STATE
S25
READ SHIFT POSITION SP AND DEGREE-OF-OPENING-OF-ACCELERATOR θ
S26
DETERMINE CATEGORY OF OPERATING STATE
S27
DETERMINE CONTENTS OF RESTRICTION DATA OF RUNNING PERFORMANCE
1

FIG.3



1
2
S31
IS BATTERY RESIDUAL CAPACITY COINCIDENT WITH SET VALUE DOD1 ?
NO
YES
3
S32
RING ALARM BUZZER
S33
DISPLAY CONTENTS OF RESTRICTION DATA
S34
IS RUNNING PERFORMANCE RESTRICTED ?
NO
YES
S37
READ BATTERY RESIDUAL CAPACITY DOD2
S35
DE-ENERGIZE ALARM BUZZER
S38
DOD2 =0.9 ×DOD1 ?
NO
YES
S36
START RESTRICITON OF RUNNING PERFORMANCE
3
S39
IS MAXIMUN SPEED RESTRICTED ?
NO
YES
S39-1
IS ACCELERATION RESTRICTED ?
NO
YES
4
5
6

FIG.4



4
NO
S41
V1 > V0 ?
YES
S42
θ = 0
S43
V1 = V0 ?
NO
YES
2
S44
IS RESTRICTION OF RUNNING PERFORMANCE CONTINUED ?
NO
YES
READ BATTERY RESIDUAL CAPACITY DOD3
S45
S46
DOD3 =0.9 ×DOD1 ?
NO
YES
3

FIG.5

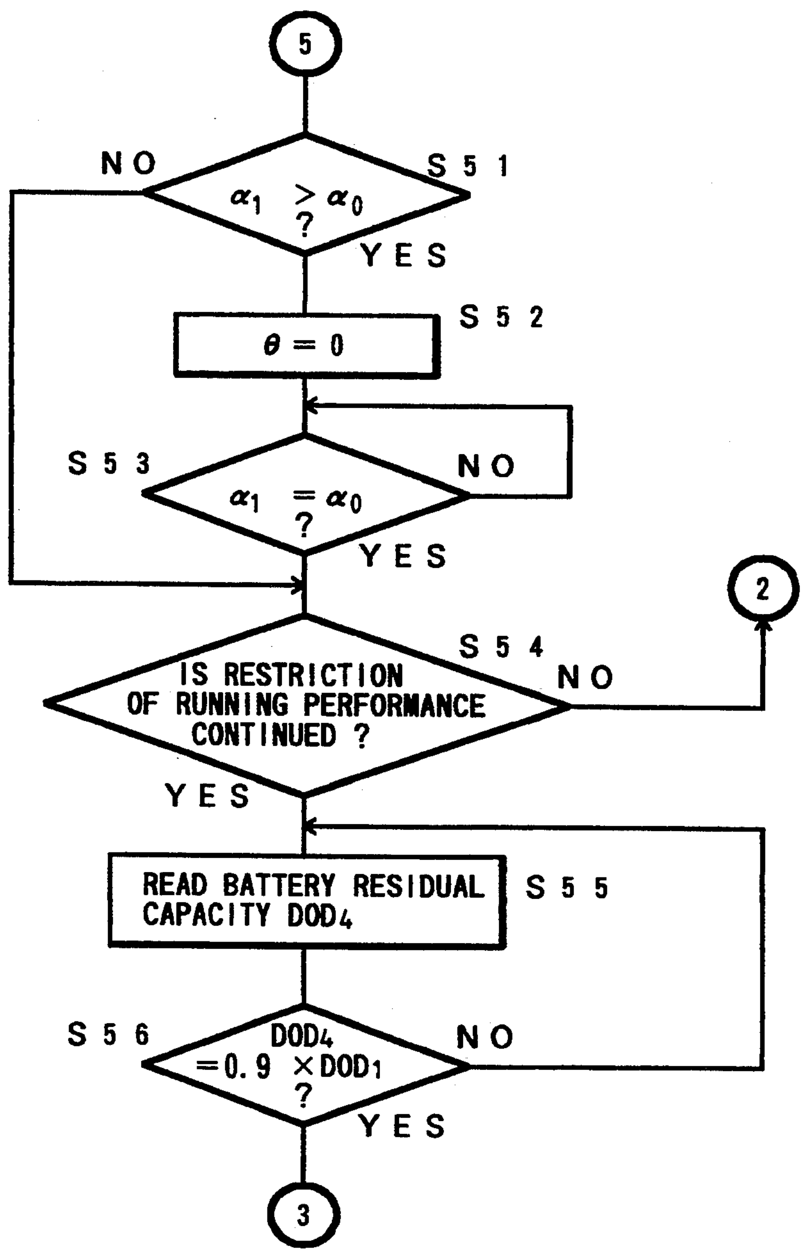
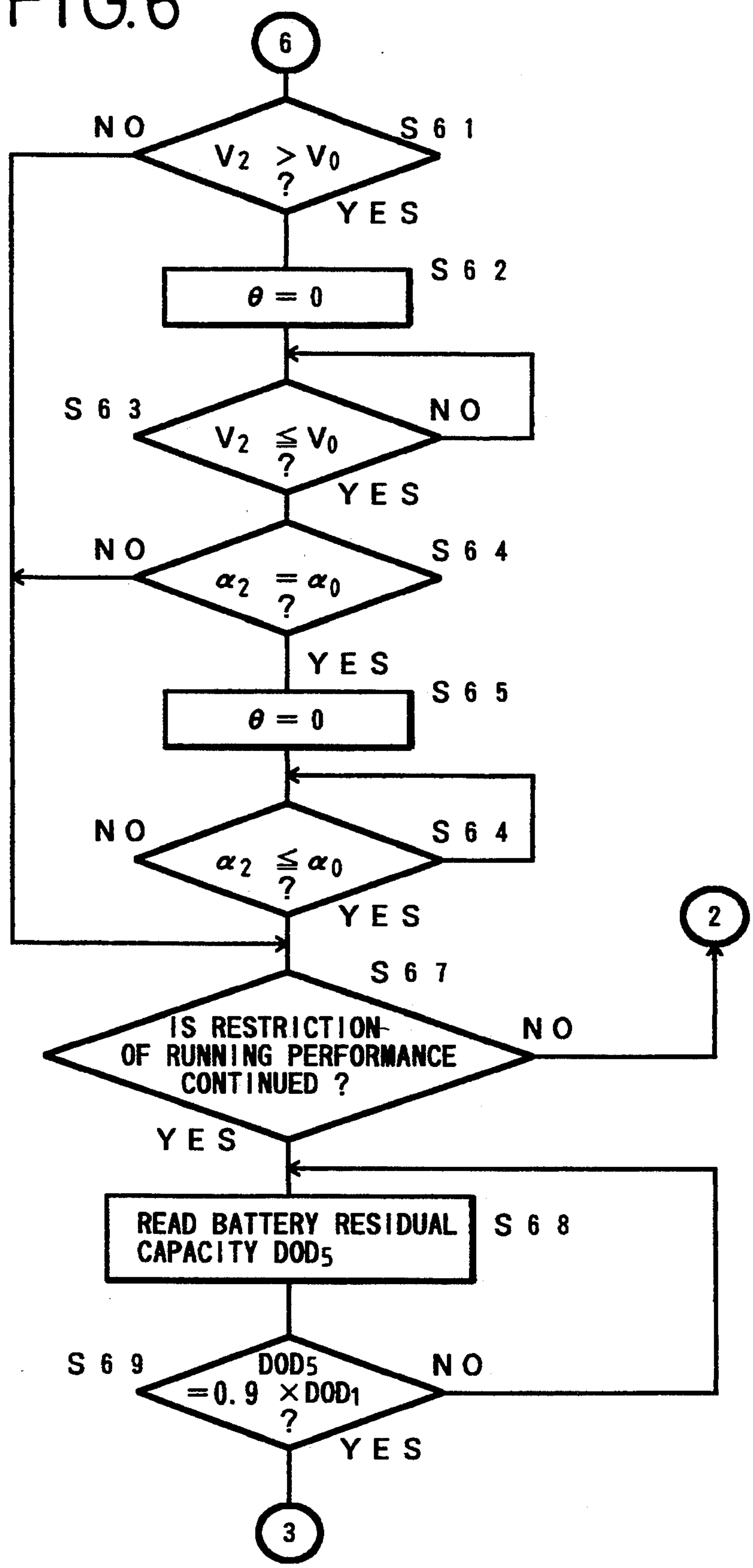

5
NO
S51
α1 > α0 ?
YES
S52
θ = 0
S53
NO
α1 = α0 ?
YES
2
S54
NO
IS RESTRICTION OF RUNNING PERFORMANCE CONTINUED ?
YES
READ BATTERY RESIDUAL CAPACITY DOD4
S55
S56
NO
DOD4 =0.9 ×DOD1 ?
YES
3

FIG.6



6
S 6 1
NO
V2 > V0 ?
YES
S 6 2
θ = 0
S 6 3
NO
V2 ≦ V0 ?
YES
S 6 4
NO
α2 = α0 ?
YES
S 6 5
θ = 0
S 6 4
NO
α2 ≦ α0 ?
YES
2
S 6 7
IS RESTRICTION OF RUNNING PERFORMANCE CONTINUED ?
NO
YES
READ BATTERY RESIDUAL CAPACITY DOD5
S 6 8
S 6 9
DOD5 =0.9 ×DOD1 ?
NO
YES
3

FIG. 7 (a)

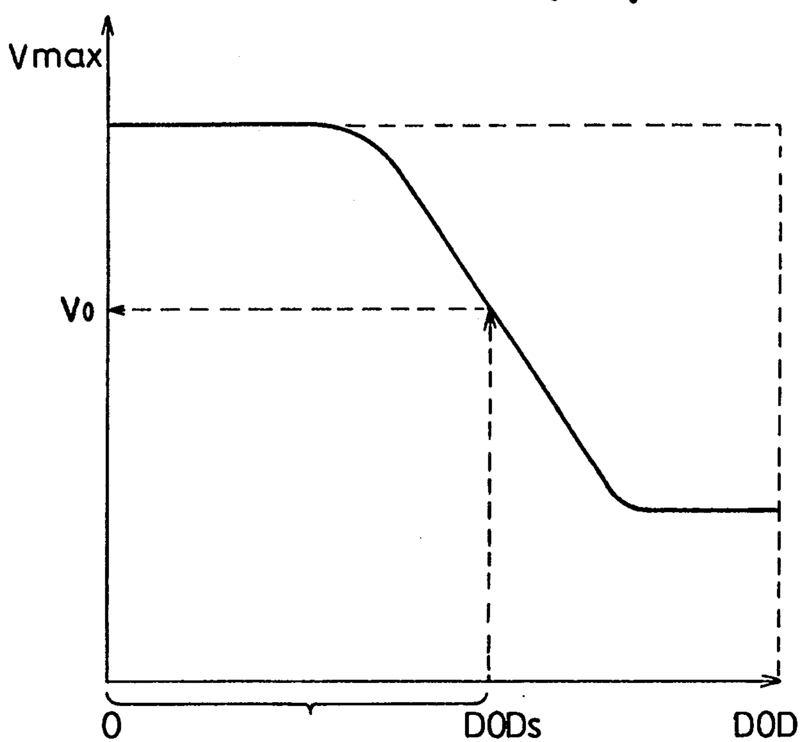


FIG. 7 (b)

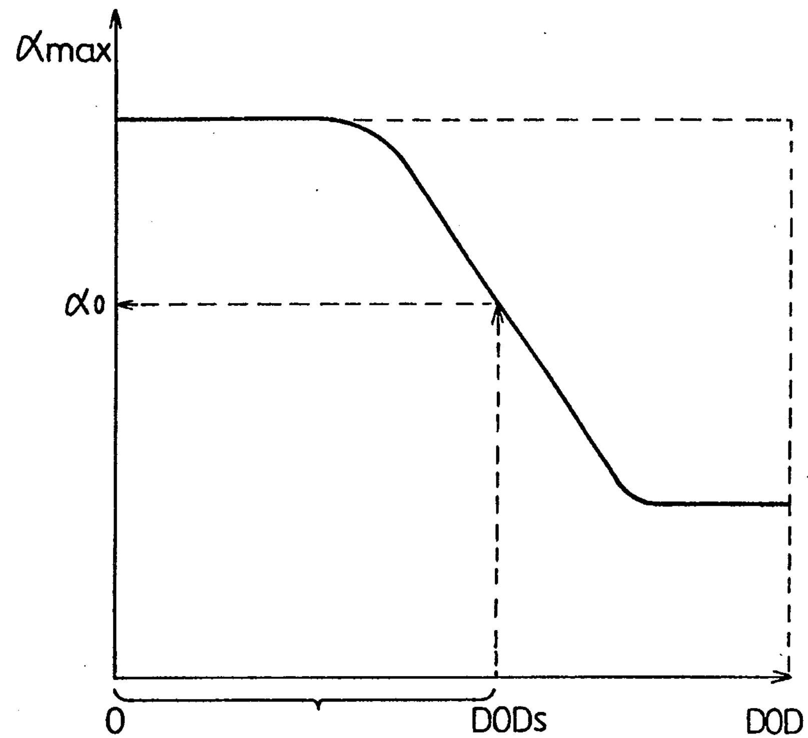
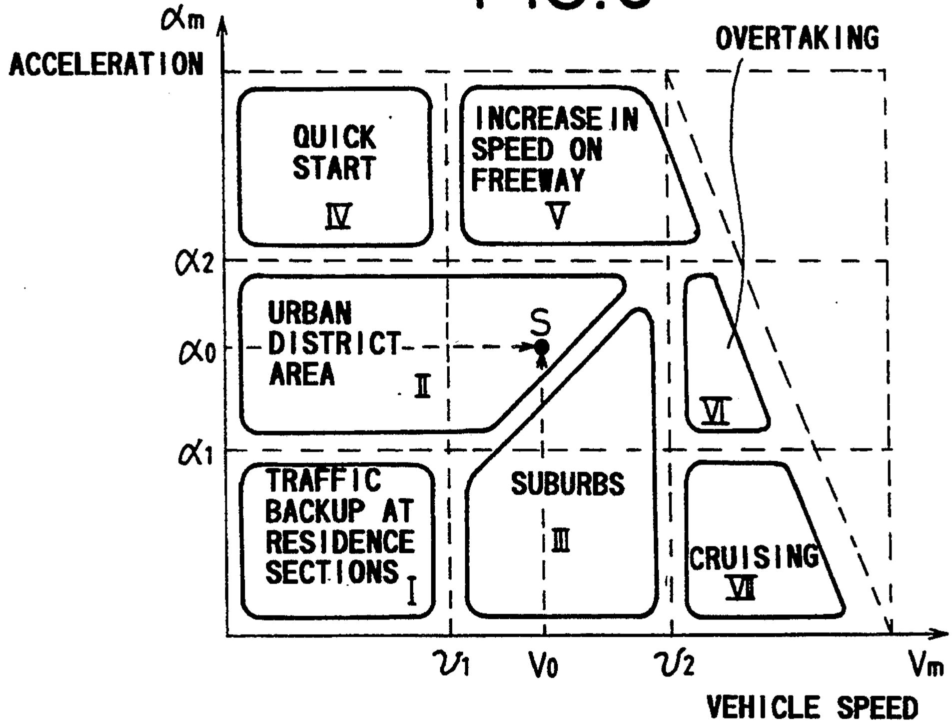
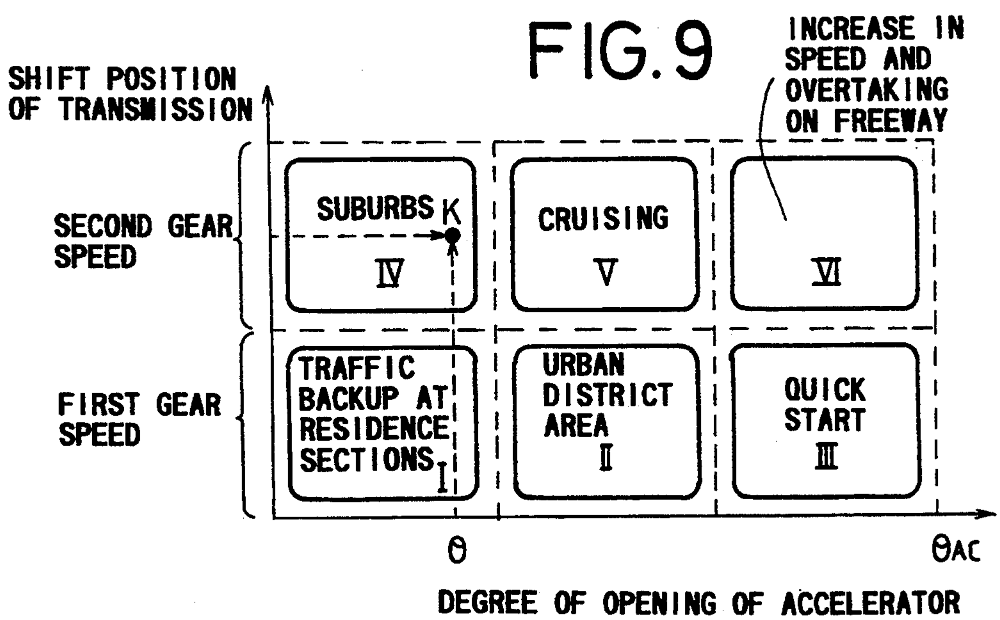


FIG.8



αm
ACCELERATION
OVERTAKING
QUICK START
IV
INCREASE IN SPEED ON FREEWAY
V
α2
URBAN DISTRICT AREA
II
S
α0
VI
α1
TRAFFIC BACKUP AT RESIDENCE SECTIONS
I
SUBURBS
III
CRUISING
VII
v1
V0
v2
Vm
VEHICLE SPEED

FIG.9



INCREASE IN SPEED AND OVERTAKING ON FREEWAY
SHIFT POSITION OF TRANSMISSION
SECOND GEAR SPEED
SUBURBS
K
IV
CRUISING
V
VI
FIRST GEAR SPEED
TRAFFIC BACKUP AT RESIDENCE SECTIONS
I
URBAN DISTRICT AREA
II
QUICK START
III
θ
θAC
DEGREE OF OPENING OF ACCELERATOR

FIG.10

		OPERATING STATE OF DRIVEN VEHICLE					
		I	II	III	IV	V	VI
RUNNING STATE	I	—	—	B	×	×	×
	II	—	—	B	A	×	×
	III	—	—	×	A	A	—
	IV	×	×	B	×	×	×
	V	×	×	B	—	—	—
	VI	×	×	×	—	—	—
	VII	×	×	×	—	—	C

A : RESTRICTION OF MAXIMUM SPEED

B : RESTRICTION OF MAXIMUM ACCELERATION

C : RESTRICTION OF BOTH MAXIMUM SPEED AND MAXIMUM ACCELERATION

× : IMPROBABLE ASPECTS

— : NON-RESTRICTION ASPECTS

RUNNING PERFORMANCE CONTROL APPARATUS AND METHOD FOR AN ELECTRIC VEHICLE

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a running performance control apparatus suitable for use in an electric vehicle, which is capable of determining, based on a driver's choice, whether the running performance of the vehicle while being driven should be restricted when the capacity of a battery used for the running of the electric vehicle is reduced to a predetermined value.

2. Description of the Related Art

It has recently been pointed out that the environment is deteriorating due to noise and exhaust gases produced by gasoline vehicles. Therefore, a strong demand is now arising for wide use of electric vehicles as a countermeasure for solving such environmental problems.

Since this type of electric vehicle is normally driven by electric energy stored in a battery, the vehicle is provided with a large battery. However, the continuous running distance over which tile electric vehicle can be driven by one charge level is shorter than that obtained by a gasoline vehicle. Therefore, a method of efficiently using the capacity of a battery is an important consideration.

When a battery develops trouble and electric power outputted from the faulty battery is reduced, for example, an electric vehicle is apt to abruptly stop running before it reaches a desired destination when the electric vehicle runs under the action of the electric power outputted from the battery which is at fault.

In order to solve such a problem, a technique for comparing a normal battery voltage with an actual battery voltage in view of improper variations in the battery voltage due to a failure in a valve, and for determining a torque command value for a motor based on the result of the comparison so as to reduce the torque outputted from the motor, thereby making it possible to increase a vehicle drivable distance under the action of the defective battery, has been disclosed in Japanese Patent Application Laid-Open Publication No. 63-77302, for example.

However, the method which is employed in the above prior art has the problem that the running state is not controlled to provide the running state corresponding to the running environment at all times because whether the running environment of a running vehicle falls into either an express highway or an urban district area has not been taken into consideration.

SUMMARY OF THE INVENTION

It is a general object of the present invention to provide a running performance control apparatus suitable for use in an electric vehicle, which is capable of restricting running performance to the optimum level based on a running state immediately preceding the present running state when the capacity of the battery is reduced to the preset residual capacity during running of the vehicle and the restriction of the running performance begins, and determining, based on a driver's choice, whether the restriction of the running performance should begin, thereby making it possible to restrict the running state to the most suitable level.

It is a principal object of the present invention to provide a running performance control apparatus suitable for use in an electric vehicle, the running performance control apparatus being used to restrict the running performance of the vehicle when the capacity of a battery employed in the vehicle is reduced to the preset residual capacity, the running performance control apparatus comprising detecting means for detecting that the battery capacity is reduced to the preset residual capacity, running state detecting means for detecting the vehicle running state including the speed of the running vehicle and the acceleration of the vehicle, operating state detecting means for detecting an operating state including shift positions of the transmission of the vehicle and the degree of opening of the vehicle accelerator, storing means for storing therein the contents of a plurality of restriction data each used to restrict the running performance of the vehicle, determining means for selectively determining whether the running state of the vehicle should be restricted when the battery capacity is reduced to the preset residual capacity, and running performance controlling means for reading information indicative of the contents of one restriction datum for restricting the running performance from the storing means based on information indicative of the running state detected by the running state detecting means and information indicative of the operating state detected by the operating state detecting means when the determining means determines that the running state of the vehicle should be restricted, thereby restricting the running performance of the vehicle.

It is another object of the present invention to provide a running performance control apparatus suitable for use in an electric vehicle, the running performance control apparatus being used to restrict the running performance of the vehicle when the capacity of a battery employed in the vehicle is reduced to the preset residual capacity, the running performance control apparatus comprising detecting means for detecting that the battery capacity is reduced to the preset residual capacity, running state detecting means for detecting the vehicle running state including the speed of a running vehicle and the acceleration of the vehicle, operating state detecting means for detecting an operating state including shift positions of the transmission of the vehicle and the degree of opening of the vehicle accelerator, storing means for storing therein the contents of a plurality of restriction data each used to restrict the running performance of the vehicle, and running performance controlling means for reading the contents of one restriction datum for restricting the running performance from the storing means based on information indicative of the running state detected by the running state detecting means add information indicative of the operating state detected by the operating state detecting means when the battery capacity detected by the detecting means is reduced to the preset residual capacity, thereby restricting the running performance of the vehicle.

It is a further object of the present invention to provide a running performance control apparatus of this type wherein the detecting means comprises a depth-of-discharge sensor for detecting the depth of discharge of the battery and a converter circuit for converting the output of the depth-of-discharge sensor into data on the residual capacity of the battery.

It is a still further object of the present invention to provide a running performance control apparatus of this type wherein the converter circuit can detect a plurality of residual capacities which differ from one another.

It is a still further object of the present invention to provide a running performance control apparatus of this type wherein the running state detecting means comprises a vehicle speed sensor for detecting the running speed of the vehicle and an acceleration sensor for detecting the acceleration of the running vehicle.

It is a still further object of the present invention to provide a running performance control apparatus of this type wherein the operating state detecting means comprises a shift position sensor for detecting each of the shift positions of the transmission and a degree-of-opening-of-accelerator sensor for detecting the degree of opening of the accelerator.

It is a still further object of the present invention to provide a running performance control apparatus of this type wherein each of the contents stored in the storing means represents any one of an aspect of the restriction of the maximum speed of the vehicle, an aspect of the restriction of the maximum acceleration of the vehicle, an aspect of the restriction of both the maximum speed and the maximum acceleration, and an aspect of the non-restriction of the maximum speed and the maximum acceleration.

It is a still further object of the present invention to provide a method of controlling a running performance of an electric vehicle having a battery and a transmission, when the capacity of the battery is reduced to a preset residual capacity, comprising the steps of detecting that the capacity of the battery is reduced to the preset residual capacity, detecting a vehicle running state including a speed of the vehicle while being driven and an acceleration of the vehicle, detecting an operating state including shift positions of a transmission of the vehicle and tile degree of opening of the vehicle accelerator, storing the contents of a plurality of restriction data each used to restrict the running performance of the vehicle, selectively determining whether the running state of the vehicle should be restricted when the battery capacity is reduced to the preset residual capacity, reading information indicative of the stored contents of one restriction datum for restricting the running performance based on information indicative of the running state and reading information indicative of the operating state when it has been selectively determined that the running state of the vehicle should be restricted, and restricting the running performance of the vehicle in response to the read information.

It is a still further object of the present invention to provide a method of controlling the running performance of an electric vehicle having a battery and transmission, wherein the detecting of the capacity of the battery includes detecting the depth of discharge of the battery and converting the detected depth-of-discharge into data on the residual capacity of the battery.

It is a still further object of the present invention to provide a method of controlling the running performance of an electric vehicle having a battery and transmission, wherein the converting step converts a plurality of residual capacities of the battery which differ from one another.

It is a still further object of the present invention to provide a method of controlling the running performance of an electric vehicle having a battery and transmission, wherein each of the contents stored in the storing step represents any one of an aspect of the restriction of the maximum speed of the vehicle, an aspect

of the restriction of the maximum acceleration of the vehicle, an aspect of the restriction of both the maximum speed and the maximum acceleration, and an aspect of the non-restriction of the maximum speed and the maximum acceleration.

It is a still further object of the present invention to provide a running performance control apparatus suitable for use in an electric vehicle, the running performance control apparatus being used to restrict the running performance of the vehicle when the capacity of a battery employed in the vehicle is reduced to a preset residual capacity, the running performance control apparatus comprising means for determining that the battery is reduced to the preset residual capacity, means for determining a vehicle running state including a speed of the vehicle and an acceleration of the vehicle, means for storing restriction data used to restrict the running performance of the vehicle, and control means for reading one of the restriction data from the storing means based on information indicative of the running state determined by the running state determining means when the battery capacity determined by the battery capacity determining means is reduced to the preset residual capacity, and for restricting the running performance of the vehicle in response to the one restriction data.

It is a still further object of the present invention to provide a running performance control apparatus, wherein operating state determining means are provided for determining each of the shift positions of a transmission and a degree of opening of an accelerator of the vehicle, and the control means reading is also based on information determined by the operating state determining means.

It is a still further object of the present invention to provide a running performance control apparatus, wherein means are provided for a driver of the vehicle to selectively prevent the restriction on the running performance of the vehicle.

It is a still further object of the present invention to provide a running performance control apparatus, wherein the restriction data stored in the storing means represents any one of an aspect of the restriction of the maximum speed of the vehicle, an aspect of the restriction of the maximum acceleration of the vehicle, an aspect of the restriction of both the maximum speed and the maximum acceleration, and an aspect of the non-restriction of the maximum speed and the maximum acceleration.

It is a still further object of the present invention to provide a running performance control apparatus, wherein means are provided for indicating to a driver of the vehicle which aspect of the restriction on the running of the vehicle has been imposed by the control means.

It is a still further object of the present invention to provide a running performance control apparatus, wherein means are provided for the driver to selectively prevent the restriction on the running performance of the vehicle.

The above and other objects, features and advantages of the present invention will become apparent from the following description and the appended claims, taken in conjunction with the accompanying drawings in which a preferred embodiment of the present invention is shown by way of illustrative example.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a block diagram showing the structure of a running performance control apparatus according to one embodiment of the present invention;

FIG. 2 is a flowchart for describing a procedure for restricting running performance of an electric vehicle while being driven, by the running performance control apparatus shown in FIG. 1;

FIG. 3 is a flowchart for describing another procedure for restricting the running performance of the vehicle by the running performance control apparatus;

FIG. 4 is a flowchart for describing a further procedure for restricting the running performance of the vehicle by the running performance control apparatus;

FIG. 5 is a flowchart for describing a still further procedure for restricting the running performance of the vehicle by the running performance control apparatus;

FIG. 6 is a flowchart for describing a still further procedure for restricting the running performance of the vehicle by the running performance control apparatus;

FIGS. 7(*a*) and 7(*b*) are graphs for describing a look-up table (LUT) used to read or determine the maximum limit speed and the maximum limit acceleration from data indicative of the remaining capacity of the battery of the running vehicle by the running performance control apparatus;

FIG, 8 is a diagram for describing a LUT used to determine a running state of the vehicle from data indicative of both the speed and the acceleration of the vehicle by the running performance control apparatus;

FIG. 9 is a diagram for describing a LUT used to determine an operating state of the running vehicle from data indicative of the degree of opening of the accelerator and the shift positions of the transmission by the running performance control apparatus; and

FIG. 10 is a diagram for describing a LUT used to read data for restricting the running performance from data indicative of the vehicle's running state determined in FIG. 8 and data indicative of the vehicle's operating state determined in FIG. 9.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIG. 1 is a block diagram showing the structure of a running performance control apparatus according to one embodiment of the present invention.

In FIG. 1, reference numeral **10** indicates a running performance control apparatus for an electric vehicle (not shown). The running performance control apparatus **10** comprises a running state detecting circuit **16** for reading or detecting signals output from a vehicle speed sensor **12** and an acceleration sensor **14**, an operating state detecting circuit **22** for detecting signals output from a shift position sensor **18** and a degree-of-opening-of-accelerator sensor **20**, a residual-capacity-of-battery detecting and converting circuit **26** for detecting a signal output from a depth-of-discharge (hereinafter called "DOD") sensor **24** used to detect a discharged state of the main vehicle battery (not shown) and for converting the detected signal into data on the remaining capacity of the battery, an input circuit **28** for receiving a signal output from a running-performance restriction canceling switch **27** used to input information about a selective determination to be made by the driver of the vehicle as to whether the running performance of the electric vehicle should be restricted, and an input port **30** used for these circuits.

Further, the running performance control apparatus **10** comprises a control circuit **32** for restricting the running performance of the vehicle, a ROM **34** for storing therein a program used to restrict the running performance of the vehicle, and a plurality of look-up tables (hereinafter called "LUTs"), a RAM **36** for temporarily storing therein data under the control of the control circuit **32**, an output port **38** used for the control circuit **32**, a buzzer **40** serving as a warning sound producing means, which is electrically connected to the output port **38**, a liquid crystal display (LCD) **42** serving as a display device, and a motor drive circuit **44** for energizing an unillustrated motor used to run or drive the vehicle.

Operations and effects for restricting the running performance of the vehicle by the running performance control apparatus **10** constructed as described above will be described in detail with reference to FIGS. **1** through **10**.

When the vehicle starts running, the control circuit **32** reads the remaining capacity DODs (DOD at start) of a battery from the residual-capacity-of-battery detecting and converting circuit **26** via the input port **30** (Step **S21**, see FIG. **2**), and determines a running performance restriction level from the remaining capacity DODs.

More specifically, the maximum limit speed V_0corresponding to the residual capacity DODs of the battery is read from a LUT (see FIG. 7(*a*)) representing a relationship between the residual capacity DOD of the battery and the maximum speed Vmax previously stored in the ROM **34**. The maximum limit speed V_0 thus read is then stored in the RAM **36**. In addition, the maximum limit acceleration α_0 corresponding to the residual capacity DODs is read from a LUT (see FIG. 7(*b*)) showing a relationship between the remaining capacity DOD of the battery and the maximum acceleration α_{max}. The maximum limit acceleration a_0 thus read is then stored in the RAM **36** (Step **S22**).

Next, the control circuit **32** reads a vehicle speed Vs of a running vehicle detected by the vehicle speed sensor **12** and an acceleration α_s of the running vehicle detected by the acceleration sensor **14** via the running state detecting circuit **16** and the input port **30** (Step **S23**). Thereafter, one desired LUT previously stored in the ROM **34** is read based on the vehicle speed Vs and the acceleration α_s, thereby determining that, for example, the vehicle is running in an urban district area (see a point S in FIG. **8**) indicated by the number II (Step **S24**).

Further, the control circuit **32** reads a shift position SP of a lever for shifting the transmission (not shown), e.g., a second gear speed, and the degree of opening of an accelerator θ from the operating state detecting circuit **22** via the input port **30** (Step **S25**). Then, the control circuit **32** reads a desired LUT based on both the shift position SP and the degree of the opening of the accelerator θ and determines that, for example, the operating state of the running vehicle falls under the category of a suburb (see a point K in FIG. **9**) indicated by the number IV (Step **S26**).

Next, the control circuit **32** determines or calculates restriction data A for restricting the running performance of the vehicle from the LUT stored in the ROM **34** based on the number II as data indicative of the running state of the vehicle, which has been read in Step

S24 and the number IV as data indicative of the operating state, which has been read in Step S26 (see FIG. 10). The restriction data A is used to restrict only the maximum speed of the vehicle without restricting the maximum acceleration of the vehicle. That is, the maximum speed of the vehicle is restricted to the maximum limit speed V_0 determined in Step S22 (Step S27).

Thus, the restriction data A for restricting the running performance of the vehicle has been obtained. However, the calculation of the restriction data A is carried out repeatedly until the remaining capacity DODs of the battery, which has been determined from the depth-of-discharge sensor **24** by the residual-capacity-of-battery detecting and converting circuit **26**, is reduced to a set value DOD_1 which has been previously set in the ROM **34**. The restriction data A is brought up to date for each calculation and stored in the RAM **36**.

When the remaining capacity DODs detected by the residual-capacity-of-battery detecting and converting circuit **26** is reduced to the set value DOD_1 (Step S31, see FIG. 3), the control circuit **32** is activated to energize the buzzer **40** via the output port **38**, thereby producing a warning sound (Step S32). The contents of the latest restriction data read from the LUT shown in FIG. **10** and stored in the RAM **36** are displayed and blinked on the LCD **42** (Step S33).

Next, the control circuit **32** determines whether the running-performance restriction canceling switch **27** has been operated by the driver (Step S34). When the running-performance restriction canceling switch **27** is operated during a predetermined period, the control circuit **32** stops the buzzer **40** from ringing (Step S35) and starts restricting the running performance (Step S36).

If the answer is determined to be No in Step S34, then the control circuit **32** is activated to cause the residual-capacity-of-battery detecting and converting circuit **26** to read the present remaining capacity DOD_2 from the depth-of-discharge sensor **24** (Step S37). When the read remaining capacity DOD_2 is reduced to a value corresponding to 90% of the remaining capacity DOD_1 read in Step S31 (Step S38), the procedure is returned to Step S32 where the buzzer **40** is energized to ring.

On the other hand, the control circuit **32** determines whether the contents of the latest restriction data determined in Step S27 represent information indicative of the restriction of the maximum speed (Step S39). If the answer is determined to be Yes (see "A" in FIG. 10), then the control circuit **32** reads the present vehicle speed V_1 from the running state detecting circuit **16** and determines whether the present vehicle speed V_1 is faster than the maximum limit speed V_0 (Step S41, see FIG. 4). If the answer is determined to be Yes (i.e., $V_1>V_0$), then the degree of opening of the accelerator θ is set to "0" to restrain the speed of the vehicle (Step S42). The running speed of the vehicle is restrained until the present vehicle speed V_1 coincides with the maximum limit speed V_0 (i.e., $V_1=V_0$) (Step S43).

When the running speed V_1 of the vehicle is restricted to the maximum limit speed V_0, the control circuit **32** is activated to cause the input circuit **28** to read the state of the running-performance restriction canceling switch **27** again (Step S44). If the state of the running-performance restriction canceling switch **27** represents that the restriction of the running performance continues, then the control circuit **32** reads the present remaining capacity DOD_3 of the battery (Step S45) and determines whether the present remaining capacity DOD_3 is of the value corresponding to 90% of the remaining capacity DOD_1 read in Step S31 (Step S46). If the answer is determined to be Yes in Step S46, then the routine procedure is returned to Step S32 where the buzzer **40** is energized to buzz.

If the answer is determined to be No in Step S41, then the control circuit **32** determines in Step S44 whether the restriction of the running performance should be carried out continuously. If the state of the running-performance restriction canceling switch **27**, which has been read by the control circuit **32** in Step S44, represents that the restriction of the running performance be discontinued, then the routine procedure is returned to Step S21 as the initial control step.

If, on the other hand, the result of the determination in Step S27 does not represent the restriction of the maximum speed, it is then determined whether the latest restriction data of the running performance, which has been determined in Step S27, represents data used to restrict an acceleration α (Step S39-1). If the answer is determined to be Yes (see "B" in FIG. 10), then tile control circuit **32** reads the present acceleration α_1 from the running state detecting circuit **16** and determines whether the present acceleration α_1 is greater than the maximum limit acceleration α_0 (Step S51, see FIG. 5). If the answer is determined to be Yes (i.e., $\alpha_1>\alpha_0$), then the degree of opening of the accelerator θ is set to "0" to restrain the speed of the vehicle (Step S52). The running speed of the vehicle is restrained until the present acceleration α_1 coincides with the maximum limit acceleration α_0 (i.e., $\alpha_1=\alpha_0$) (Step S53).

When the acceleration α_1 of the vehicle is restricted to the maximum limit acceleration α_0, the control circuit **32** is activated to cause the input circuit **28** to read the state of the running-performance restriction canceling switch **27** again (Step S54). If the state of the running-performance restriction canceling switch **27** represents that the restriction of the running performance continues, then the control circuit **32** reads the present remaining capacity DOD_4 of the battery (Step S55) and determines whether the read remaining capacity DOD_4 is of the value corresponding to 90% of the remaining capacity DOD_1 read in Step S31 (Step S56). If tile answer is determined to be Yes in Step S56, then the routine procedure is returned to Step S32 where the buzzer **40** is energized to ring.

If the answer is determined to be No in Step S51, then the control circuit **32** determines in Step S54 whether the restriction of the running performance should be carried out continuously. If the state of the running-performance restriction canceling switch **27**, which has been read by the control circuit **32** in Step S54, represents that the restriction of the running performance be discontinued, then the routine procedure is returned to Step S21 as the initial control step.

If the result of the determination in Step S39-1 does not represent the restriction of the acceleration α, it is then determined that the latest restriction data of the running performance, which has been determined in Step S27, represents data used to restrict the maximum speed and the maximum acceleration (see "C" in FIG. 10).

The present vehicle speed V_2 is reduced to the maximum limit speed V_0 in a manner similar to the process executed in each of Steps S41 through S43 (Steps S61 through S63, see FIG. 6). Next, the present acceleration α_2 of the vehicle is brought into agreement with the maximum limit acceleration α_0 in a manner similar to the process executed in each of Steps S51 through S53 (Steps S64 through S66). It is then determined, based on a driver's choice, whether these restrictions should be carried out continuously (Step S67). If the answer is determined to be Yes in Step S67, then the present remaining capacity DOD_5 of the battery is read (Step S68). When the read remaining capacity DOD_5 coincides with the value corresponding to 90% of the remaining capacity DOD_1 read in Step S31 (Step S69), the routine procedure is returned to Step S32 where the buzzer 40 is energized to produce a buzzing sound.

According to the present embodiment, as described above, when the remaining capacity DODs of the battery of the vehicle while being driven is reduced to the preset remaining capacity DOD_1 (Step S31), the buzzer 40 is activated to ring (Step S32) and the contents of the restriction data are displayed on the LCD 42 (Step S33). Then, the driver is urged to make a decision as to whether the restriction of the running performance should be carried out (Step S34). If the answer is determined to be Yes in Step S34, then the restriction of the running performance is made.

Further, when the running performance of the vehicle is limited to a target restriction state, it is determined, based on a driver's choice, whether the restriction of the running performance should be carried out continuously. Thus, the driver's circumstantial judgments made depending on running environments can be adopted for control without automatically and uniformly restricting the running state according to the residual capacity of the battery, thereby making it possible to provide the restriction of the running performance most suitable for the running state.

In the running performance control apparatus according to the present invention, which is used in the electric vehicle, the running performance of the vehicle while being driven is restricted based on the contents of the restriction data of the running performance, which are obtained from information indicative of the running state of the vehicle and information indicative of the operating state. It is therefore possible to provide the restriction of the most suitable running performance based on the running state just before the present running state.

Further, when the running performance of the vehicle is restricted, information can be read indicative of a decision to be made as to whether the running performance, input via the inputting means by the driver, should be restricted, and a selective decision can be made in accordance with the read information as to whether the restriction of the running performance should be carried out. Therefore, the restriction of the optimum running performance can be made, to which a consideration as to the running environments has been given.

Having now fully described the invention., it will be apparent to those skilled in the art that many changes and modifications can be made without departing from the spirit or scope of the invention as set forth herein.

What is claimed is:

1. A running performance control apparatus for use in an electric vehicle, wherein said running performance control apparatus restricts the running performance of the vehicle when a capacity of a battery employed in the vehicle is reduced to a preset residual capacity, said running performance control apparatus comprising:

battery capacity detecting means for detecting that said battery capacity is reduced to said preset residual capacity;

speed detecting means for detecting a speed of the vehicle while being driven;

acceleration detecting means for detecting an acceleration of the vehicle;

running state determining means for determining a vehicle running state based on detected values from said speed detecting means and said acceleration detecting means;

shift position detecting means for detecting a shift position of a transmission of the vehicle;

accelerator opening detecting means for detecting a degree of opening of an accelerator of the vehicle;

operating state determining means for determining an operating state based on detected values from said shift position detecting means and said accelerator opening detecting means;

storing means for storing therein a plurality of restriction data each used to restrict the running performance of the vehicle;

restriction determining means for selectively determining whether the running state of the vehicle should be restricted when said battery capacity is reduced to said preset residual capacity; and

running performance controlling means for reading information indicative of at least one restriction datum for restricting the running performance from said storing means based on information indicative of the running state determined by said running state determining means and on information indicative of the operating state determined by said operating state determining means when said restriction determining means determines that the running state of the vehicle should be restricted, and for restricting the running performance of the vehicle in response to said read information.

2. A running performance control apparatus according to claim 1, wherein said battery capacity detecting means comprises a depth-of-discharge sensor for detecting the depth of discharge of said battery and a converter circuit for converting the output of said depth-of-discharge sensor into data on the residual capacity of the battery.

3. A running performance control apparatus according to claim 2, wherein said converter circuit can detect a plurality of residual capacities of said battery which differ from one another.

4. A running performance control apparatus according to claim 1, 2, or 3, wherein said running state determining means comprises said speed detecting means and said acceleration detecting means.

5. A running performance control apparatus according to claim 1, 2, or 3, wherein said operating state determining means comprises said shift position detecting means and said accelerator opening detecting means.

6. A running performance control apparatus according to claim 1, 2, or 3, wherein each of said plurality of restriction data stored in said storing means represents any one of an aspect of the restriction of the maximum speed of the vehicle, an aspect of the restriction of the maximum acceleration of the vehicle, an aspect of the restriction of both the maximum speed and the maximum acceleration, and an aspect of the non-restriction of the maximum speed and the maximum acceleration.

7. A running performance control apparatus for use in an electric vehicle, wherein said running performance control apparatus restricts the running performance of the vehicle when capacity of a battery employed in the vehicle is reduced to preset residual capacity, said running performance control apparatus comprising:

battery capacity detecting means for detecting that said battery capacity is reduced to said preset residual capacity;

speed detecting means for detecting a speed of the vehicle while being driven;

acceleration detecting means for detecting an acceleration of the vehicle;

running state determining means for determining a vehicle running state based on the detected values from said speed detecting means and said acceleration detecting means;

shift position detecting means for detecting a shift position of a transmission of the vehicle;

accelerator opening detecting means for detecting a degree of opening of an accelerator of the vehicle;

operating state determining means for determining an operating state based on the detected values from said shift position detecting means and said accelerator opening detecting means;

storing means for storing therein a plurality of restriction data each used to restrict the running performance of the vehicle; and

running performance controlling means for reading at least one restriction datum for restricting the running performance from said storing means based on information indicative of the running state determined by said running state determining means and on information indicative of the operating state determined by said operating state determining means when said battery capacity detected by said battery capacity detecting means is reduced to said preset residual capacity, and for restricting the running performance of the vehicle in response to said at least one restriction datum.

8. A running performance control apparatus according to claim 7, wherein said battery capacity detecting means comprises a depth-of-discharge sensor for detecting the depth of discharge of the battery and a converter circuit for converting the output of said depth-of-discharge sensor into data on the residual capacity of the battery.

9. A running performance control apparatus according to claim 8, wherein said converter circuit can detect a plurality of residual capacities of said battery which differ from one another.

10. A running performance control apparatus according to claim 7, 8, or 9, wherein said running state determining means comprises said speed detecting means and said acceleration detecting means.

11. A running performance control apparatus according to claim 7, 8, or 9, wherein said operating state determining means comprises said shift position detecting means and said accelerator opening detecting means.

12. A running performance control apparatus according to claim 7, 8, or 9, wherein each of said plurality of restriction data stored in said storing means represents any one of an aspect of the restriction of the maximum speed of the vehicle, an aspect of the restriction of the maximum acceleration of the vehicle, an aspect of the restriction of both the maximum speed and the maximum acceleration, and an aspect of the non-restriction of the maximum speed and the maximum acceleration.

13. A method of controlling the running performance of an electric vehicle having a battery and a transmission, when the capacity of the battery is reduced to a preset residual capacity, comprising the steps of:

detecting that the capacity of said battery is reduced to said preset residual capacity;

detecting a speed of the vehicle while being driven;

detecting an acceleration of the vehicle;

determining a vehicle running state based on the detected speed of the vehicle while being driven and the detected acceleration of the vehicle;

detecting a shift position of a transmission of the vehicle;

detecting a degree of opening of an accelerator of the vehicle;

determining an operating state of the vehicle based on the detected shift position and the detected degree of accelerator;

storing a plurality of restriction data each used to restrict the running performance of the vehicle;

selectively determining whether the running state of the vehicle should be restricted when said battery capacity is reduced to said preset residual capacity;

reading information indicative of said stored restriction data for restricting the running performance based on information indicative of the running state and on information indicative of the operating state when it has been selectively determined that the running state of the vehicle should be restricted; and

restricting the running performance of the vehicle in response to the read information.

14. A method according to claim 13, wherein said detecting of the capacity of the battery includes detecting the depth of discharge of said battery and converting said detected depth-of-discharge into data on the residual capacity of the battery.

15. A method according to claim 14, wherein said converting step converts a plurality of residual capacities of said battery which differ from one another.

16. A method according to claim 13, 14, or 15, wherein each of said plurality of restriction data stored in said storing step represents any one of an aspect of the restriction of the maximum speed of the vehicle, an aspect of the restriction of the maximum acceleration of the vehicle, an aspect of the restriction of both the maximum speed and the maximum acceleration, and an aspect of the non-restriction of the maximum speed and the maximum acceleration.

17. A running performance control apparatus for use in an electric vehicle, wherein said running performance control apparatus restricts the running performance of the vehicle when capacity of a battery employed in the vehicle is reduced to a preset residual capacity, said running performance control apparatus comprising:

means for determining that said battery is reduced to said preset residual capacity;

means for detecting a speed of the vehicle while being driven;

means for detecting an acceleration of the vehicle;

running state determining means for determining a vehicle running state based on the detected speed of the vehicle and the detected acceleration of the vehicle;

means for detecting a shift position of a transmission of the vehicles;

means for detecting a degree of opening of an accelerator of the vehicle;

operating state determining means for determining an operating state of the vehicle based on the detected shift position and the detected degree of opening of the accelerator;

means for storing restriction data used to restrict the running performance of the vehicle; and

control means for reading said restriction data from said storing means based on information indicative of the running state determined by said running state determining means and information indicative of the operating state determined by said operating state determining means when said battery capacity determined by said battery capacity determining means is reduced to said preset residual capacity, and for restricting the running performance of the vehicle in response to said restriction data.

18. A running performance control apparatus according to claim **17**, wherein means are provided for a driver of the vehicle to selectively prevent the restriction on the running performance of the vehicle.

19. A running performance control apparatus according to claim **17** wherein said restriction data stored in said storing means represents any one of an aspect of the restriction of the maximum speed of the vehicle, an aspect of the restriction of the maximum acceleration of the vehicle, an aspect of the restriction of both the maximum speed and the maximum acceleration, and an aspect of the non-restriction of the maximum speed and the maximum acceleration.

20. A running performance control apparatus according to claim **19**, wherein means are provided for indicating to a driver of the vehicle which said aspect of the restriction on the running of the vehicle has been imposed by said control means.

21. A running performance control apparatus according to claim **20**, wherein means are provided for the driver to selectively prevent the restriction on the running performance of the vehicle.

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