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(56) Related Art
US 5572110
US 5561361
US 5363030

ABSTACT

BATTERY CHARGING SYSTEM

A rechargeable battery pack (20 or 30) includes a rechargeable battery (20 or 30) having a predetermined charge voltage, and a circuit for generating a control voltage depending on a battery voltage of the rechargeable battery (20 or 30) so that the control voltage reaches a predetermined control voltage when the battery voltage reaches a predetermined charge voltage of the rechargeable battery (20 or 30). A battery charger (10) for the rechargeable battery (20 or 30) changes the charging control from constant-current to constant-voltage depending on whether the control voltage reaches the predetermined control voltage.

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COMPLETE SPECIFICATION

FOR A STANDARD PATENT

ORIGINAL

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Invention Title: Battery Charging System

The following statement is a full description of this invention, including the best method of performing it known to me/us:-

BATTERY CHARGING SYSTEM WITH BATTERY PACK OF DIFFERENT CHARGING VOLTAGES USING COMMON A BATTERY CHARGER

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention generally relates to a battery charging system, and in particular to a system for charging a rechargeable battery such as a lithium-ion battery and a rechargeable battery pack for use in the system.

2. Description of the Related Art

Recently, a rechargeable battery or a secondary battery has been widely used as a power supply for portable or hand-held electronic equipment in consideration of running costs. Such a rechargeable battery has predetermined charging conditions including charging current and time. Especially in the case of a rechargeable lithium-ion battery, the details about charging conditions have been defined.

In general, a constant-voltage and constant-current charging method is used to charge a rechargeable lithium-ion battery. More specifically, the rechargeable lithium-ion battery is charged with a constant current until the battery voltage has risen to a predetermined charge control voltage and thereafter with a constant voltage. Such a charging method has been disclosed in U.S. Pat. No. 5,237,259, for

example.

There has been commercially available rechargeable lithium-ion batteries having different prescribed voltages. Therefore, it is necessary for a single battery charger to provide a plurality of charge control voltages each corresponding to the prescribed voltage of a rechargeable lithium-ion battery. To cope with this, the battery charger may be provided with a plurality of constant-voltage circuits which are selectively used depending on the type of a rechargeable lithium-ion battery pack. The battery charger is further provided with a battery type identifying means. And the rechargeable lithium-ion battery pack is provided with a battery type indicating means. When the battery pack is electrically connected to the battery charger, the battery type identifying means of the battery charger identifies the type of the lithium-ion battery by checking the battery type indicating means of the battery pack. According to the battery type, the battery charger provides the corresponding constant voltage to the battery pack after the battery voltage has risen to the predetermined charge control voltage.

However, the rechargeable lithium-ion battery pack needs the battery type indicating means and the charger needs the battery type identifying means. Therefore, it is difficult to miniaturizing the size and weight of the batter charging system as well as the battery pack.

SUMMARY OF THE INVENTION

An object of the present invention is to provide a battery charging system which can cope with a plurality of battery types with reduced amount of hardware.

Another object of the present invention is to provide a rechargeable battery pack which can be charged without the need of changing a battery charger depending on its battery type.

According to the present invention, a battery charging system includes a battery charger and a plurality of rechargeable battery packs each having a different predetermined charge voltage. Each of the rechargeable battery packs includes a rechargeable battery having a predetermined charge voltage, and a circuit for generating a control voltage depending on a battery voltage of the rechargeable battery so that the control voltage reaches a predetermined control voltage when the battery voltage reaches a predetermined charge voltage of the rechargeable battery. The battery charger charges the rechargeable battery depending on the control voltage received from a rechargeable battery connected thereto.

Since the circuit of each rechargeable battery pack generates the control voltage such that the control voltage reaches the predetermined control voltage when the battery voltage reaches the predetermined charge voltage of the rechargeable battery, the battery charger can cope with the plurality of rechargeable battery packs each having a different predetermined

charge voltage. In other words, since the predetermined control voltage is set to a single common voltage among the rechargeable battery packs, the battery charger can charge any one of the different rechargeable battery packs.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a block diagram showing a battery charging system according to a first embodiment of the present invention;

Fig. 2A is a graph illustrating time-varying charging voltage and current in the case where a 4.1V Li-ion battery pack is connected to a battery charger of the battery charging system of Fig. 1;

Fig. 2B is a graph illustrating time-varying charging voltage and current in the case where a 4.2V Li-ion battery pack is connected to the battery charger of Fig. 1;

Fig. 3 is a block diagram showing a battery charging system according to a second embodiment of the present invention; and

Fig. 4 is a block diagram showing a battery charging system according to a third embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to Fig. 1, a battery charging system according to a first embodiment of the present invention is comprised of a battery charger 10 which is provided with a connection surface having power supply terminals T_+ and T_- and a control voltage detection terminal T_E. The battery charger 10 can be connected to one of a plurality of rechargeable battery packs including rechargeable lithium-ion batteries of different prescribed charge voltages, respectively. Each of rechargeable battery packs is provided with a connection surface having power receive terminals T_{B+} and T_{B-} and a control voltage supply terminal T_{BE} which correspond to the power supply terminals T_+ and T_- and the voltage detection terminal T_E, respectively.

BATTERY CHARGER

The battery charger 10 may use a widely-used lithium-ion battery charger which can provide a constant current until the control voltage reaches a predetermined voltage and thereafter keep the output voltage at a voltage appearing on the power supply terminal T_+ at that time.

For example, as shown in Fig. 1, the battery charger 10 includes a DC power source 101 which inputs a DC power applied on power input terminals as indicated by '++' and '-' and generates an output voltage V_{OUT} with limited current I_{OUT}. The output current I_{OUT} is detected by a current detector 102. The output voltage

V_{OUT} with limited current I_{OUT} is output to the power supply terminals T_+ and T_- through an on-off switch 103.

The control voltage detection terminal T_E is connected to a control voltage detector 104 which detects a control voltage V_{DEC} of a connected rechargeable battery pack. A charge controller 105 performs the charge control of the connected rechargeable battery pack using the detected output current I_{OUT}, the detected control voltage V_{DEC} and a reference voltage input from a reference voltage generator 106. As will be described later, the charge controller is set to a single predetermined control voltage V_{CV}, for example, V_{CV} = 4.1 V which may be the lowest prescribed battery voltage among the lithium-ion batteries.

More specifically, when a rechargeable battery pack is connected, the charge controller 105 performs constant-current charging control of the DC power source 101 based on the detected output current I_{OUT} until the detected control voltage V_{DEC} reaches the predetermined control voltage V_{CV}. When the detected control voltage V_{DEC} has reached the predetermined control voltage V_{CV}, the charge controller 105 changes the charging control of the DC power source 101 from constant-current to constant-voltage. When the constant-voltage charging control is started, the DC power source 101 keeps the current output voltage V_{OUT} constant.

In this manner, the battery charger 10 provide a constant current until the control voltage V_{DEC} reaches the predetermined control voltage V_{CV}, and thereafter performs the constant-voltage charging control with keeping the output voltage V_{OUT} constant and

with the output current I_{OUT} gradually decreasing.

It should be noted that the charge controller 105 changes the charging control from constant-current to constant-voltage by checking to see only whether the detected control voltage V_{DEC} reaches the predetermined control voltage V_{CV}.

RECHARGEABLE BATTERY PACKS

For simplicity, two rechargeable battery packs are shown in Fig. 1: 4.2V-rechargeable battery pack 20 and 4.1V-rechargeable battery pack 30.

The 4.2V-rechargeable battery pack 20 includes a rechargeable lithium-ion battery 201 of the prescribed charge voltage of 4.2 V. The rechargeable lithium-ion battery 201 is connected to the power receive terminals T_{B+} and T_{B-} through a protector 202.

Further, the power receive terminals T_{B+} and T_{B-} are electrically connected through a voltage divider comprising two resistors R1 and R2 connected in series. The control voltage supply terminal T_{BE} is electrically connected to a tap of the voltage divider. Therefore, the tap voltage is represented by $V_{BC} \times R2/(R1+R2)$, where V_{BC} is a voltage across the lithium-ion battery 201 during charging. In other words, the tap voltage is lower than the current battery voltage V_{BC} by a voltage drop of $V_{BC} \times R1/(R1+R2)$. Therefore, by setting the resistance ratio of the voltage divider to R1 : R2 = 1 : 41, a voltage of 4.1V appears on the control voltage supply terminal T_{BE} when the battery voltage V_{BC} across the rechargeable lithium-ion battery 201 reaches 4.2V.

Practically, in consideration of tolerance of a resistance, temperature and time-varying characteristics of the resistors R1 and R2, a chip-type thin-film resistor may be used for the resistors R1 and R2. Further, to reduce in the current flowing through the voltage divider, in this embodiment, the following resistors are selected: R1=16.5kΩ and R2=680kΩ.

The 4.1V-rechargeable battery pack 30 includes a rechargeable lithium-ion battery 301 of the prescribed charge voltage of 4.1 V. The rechargeable lithium-ion battery 301 is connected to the power receive terminals T_{B+} and T_{B-} through a protector 302.

Further, the control voltage supply terminal T_{BE} is electrically connected to the power receive terminal T_{B+} through a resistor R1 of 16.5kΩ in this embodiment. Since the battery voltage V_{BC} across the rechargeable lithium-ion battery 301 appears on the control voltage supply terminal T_{BE}, a voltage of 4.1V appears on the control voltage supply terminal T_{BE} when the battery voltage V_{BC} across the rechargeable lithium-ion battery 301 reaches 4.1V.

Therefore, as described above, in the case where the battery voltage V_{BC} across the rechargeable lithium-ion battery 201 reaches 4.2V and the battery voltage V_{BC} across the rechargeable lithium-ion battery 301 reaches 4.1V, the same voltage of 4.1V appears on the control voltage supply terminal T_{BE} of each rechargeable battery pack. As described before, in this embodiment, the charge controller 105 is set to the predetermined

control voltage V_{CV} = 4.1 V at which the charging control is changed from constant-current to constant-voltage. The charging control operation will be described hereinafter.

CHARGING CURRENT AND VOLTAGE

As shown in Fig. 2A, in the case where the 4.1V Li-ion battery pack 30 is connected to the battery charger 10, the charge controller 105 performs the constant-current charging control of the DC power source 101 by monitoring the detected output current I_{OUT}. The constant-current charging control causes the DC power source 101 to supply the constant current I_{OUT} to the 4.1V Li-ion battery 301 with gradually increasing in the output voltage V_{OUT} or the charging battery voltage V_{BC} across the rechargeable lithium-ion battery 301. Since the battery voltage V_{BC} appears on the control voltage supply terminal T_{BE}, the detected control voltage V_{DEC} is also equal to the output voltage V_{OUT}. Therefore, when the detected control voltage V_{DEC} reaches the predetermined control voltage V_{CV} = 4.1V, the charge controller 105 changes the charging control of the DC power source 101 from constant-current to constant-voltage. When the constant-voltage charging control is started, the DC power source 101 keeps the current output voltage V_{OUT} at the predetermined control voltage V_{CV} = 4.1V. In this charging state, the output current I_{OUT} gradually decreases as shown in Fig. 2A.

As shown in Fig. 2B, in the case where the 4.2V Li-ion battery pack 20 is connected to the battery charger 10, the charge controller 105 performs the constant-current charging control of

the DC power source 101 by monitoring the detected output current I_{OUT}. The constant-current charging control causes the DC power source 101 to supply the constant current I_{OUT} to the 4.2V Li-ion battery 301 with gradually increasing in the output voltage V_{OUT} or the charging battery voltage V_{BC} across the rechargeable lithium-ion battery 201.

Since the respective resistors R1 and R2 of the voltage divider are set to R1=16.5kΩ and R2=680kΩ and the resistance ratio R1/R2 is approximately 1/41, the detected control voltage V_{DEC} is lower than the output voltage V_{OUT} by a voltage drop of $V_{OUT} \times R1/(R1+R2)$ as shown in Fig. 2B. Therefore, when the output voltage V_{OUT} reaches 4.2V, the detected control voltage V_{DEC} reaches the predetermined control voltage V_{CV} = 4.1 V. In other words, when the output voltage V_{OUT} reaches 4.2V, the charge controller 105 changes the charging control of the DC power source 101 from constant-current to constant-voltage. When the constant-voltage charging control is started, the DC power source 101 keeps the current output voltage V_{OUT} at 4.2V and the output current I_{OUT} gradually decreases as shown in Fig. 2B.

As shown in Figs. 2A and 2B, in the case where the output voltage V_{OUT} of the 4.2V-rechargeable battery pack 20 reaches 4.2V and the output voltage V_{OUT} of the 4.1V-rechargeable battery pack 30 reaches 4.1V, the same voltage of 4.1V appears on the control voltage supply terminal T_{BE} of each rechargeable battery pack. When the detected control voltage V_{DEC} reaches the predetermined control voltage V_{CV} = 4.1 V, the charge controller 105 changes the

charging control from constant-current to constant-voltage. Therefore, the battery charger 10 can automatically provide one of the different constant voltages, 4.1V and 4.2V, without the need of a charge control voltage switch between 4.1V and 4.2V. In other words, the battery charger 10 can cope with a plurality of different types of rechargeable battery packs.

OTHER EMBODIMENTS

As described before, it is necessary to reduce in the current flowing through the resistors R1 and R2 of the voltage divider of the 4.2V-rechargeable battery pack 20. In the first embodiment of Fig. 1, the relatively high resistance (R1=16.5kΩ, R2=680kΩ) is employed to prevent the discharge of the Li-ion battery 201. Another means may be used as will be described hereinafter.

Referring to Fig. 3, the 4.2V-rechargeable battery pack 20 is further provided with a switch SW connected between the resistors R1 and R2. The switch SW is opened when the 4.2V-rechargeable battery pack 20 is removed from the battery charger 10 and is closed when it is connected to the battery charger 10. Therefore, when the 4.2V-rechargeable battery pack 20 is removed from the battery charger 10, the both electrodes of the 4.2V Li-ion battery 201 are perfectly opened.

Such a switch mechanism may be easily implemented. For example, the battery charger 10 is provided with a protrusion at a predetermined location of a connector surface having the terminals T_+, T_E and T_-. On the other hand, the 4.2V-rechargeable battery pack 20 is provided with a normally-open switch SW which

can be closed by the protrusion of the battery charger 10 when they are connected.

Referring to Fig. 4, a battery charger 11 has the power supply terminals T_+ and T_- and two control voltage detection terminals T_{E1} and T_{E2} which are connected to each other therein.

Each of rechargeable battery packs has power receive terminals T_{B+} and T_{B-} and two control voltage supply terminals T_{BE1} and T_{BE2} which correspond to the power supply terminals T_+ and T_- and the voltage detection terminals T_{E1} and T_{E2}, respectively. A 4.2V-rechargeable battery pack 21 includes a rechargeable lithium-ion battery 201 of the prescribed charge voltage of 4.2 V. The rechargeable lithium-ion battery 201 is connected to the power receive terminals T_{B+} and T_{B-} through a protector 202. Further, the power receive terminal T_{B+} is connected to the control voltage supply terminal T_{BE1} through a resistor R1 and the power receive terminal T_{B-} is electrically connected to the control voltage supply terminal T_{BE2} through a resistor R2. A 4.1V-rechargeable battery pack (not shown) is not provided with the resistor R2.

When the 4.2V-rechargeable battery pack 21 is removed from the battery charger 11, the terminals T_{BE1} and T_{BE2} of the resistors R1 and R2 are opened. When the 4.2V-rechargeable battery pack 21 is connected to the battery charger 11, the terminals T_{BE1} and T_{BE2} are closed to form the voltage divider as in the case of the 4.2V-rechargeable battery pack 20 of Fig. 1. Therefore, when the 4.2V-rechargeable battery pack 21 is removed from the battery

charger 10, the both electrodes of the 4.2V Li-ion battery 201 are perfectly opened.

The claims defining the invention are as follows:

1. A battery charging system comprising a battery charger and a plurality of rechargeable battery packs each having a different predetermined charge voltage,

each of the rechargeable battery packs comprising:

a rechargeable battery having a predetermined charge voltage; and

a circuit for generating a control voltage depending on a battery voltage of the rechargeable battery so that the control voltage reaches a predetermined control voltage when the battery voltage reaches a predetermined charge voltage of the rechargeable battery,

wherein the battery charger charges the rechargeable battery depending on the control voltage received from a rechargeable battery connected thereto.

2. The battery charging system according to claim 1, wherein the predetermined control voltage is set to a common voltage for each rechargeable battery.

3. The battery charging system according to claim 2, wherein the battery charger changes charging control from constant-current to constant-voltage depending on whether the control voltage reaches the predetermined control voltage.

4. The battery charging system according to claim 1, wherein the battery charger changes charging control from constant-current to constant-voltage depending on whether the control voltage reaches the predetermined control voltage.

5. The battery charging system according to claim 1, wherein the circuit is a voltage divider for dividing the battery voltage of the rechargeable battery by a predetermined resistance ratio to produce the control voltage.

6. The battery charging system according to claim 5, wherein each of the rechargeable battery packs further comprises:

an open/close switch for opening the circuit when the rechargeable battery pack is removed from the battery charger and closing the circuit when the rechargeable battery pack is connected to the battery charger.

7. The battery charging system according to claim 6, wherein the open/close switch is included in the voltage divider.

8. The battery charging system according to claim 6, wherein the open/close switch comprises two separate terminals which electrically divides the voltage divider into two parts, wherein the separate terminals are closed when the rechargeable battery pack is connected to the battery charger.

9. The battery charging system according to claim 1, wherein the circuit provides the battery voltage of the rechargeable battery as the control voltage.

10. A rechargeable battery pack comprising:

a rechargeable lithium-ion battery having a predetermined charge voltage; and

a circuit for generating a control voltage depending on a battery voltage of the rechargeable lithium-ion battery so that the control voltage reaches a predetermined control voltage when the battery voltage reaches a predetermined charge voltage of the rechargeable battery, wherein the predetermined control voltage is set to a common voltage for another rechargeable battery.

11. The rechargeable battery pack according to claim 10, wherein the circuit is a voltage divider for dividing the battery voltage of the rechargeable battery by a predetermined resistance ratio to produce the control voltage.

12. The rechargeable battery pack according to claim 11, wherein each of the rechargeable battery packs further comprises:

an open/close switch for opening the circuit when the rechargeable battery pack is removed from the battery charger and closing the circuit when the rechargeable battery pack is connected to the battery charger.

13. The rechargeable battery pack according to claim 12, wherein the open/close switch is included in the voltage divider.

14. The rechargeable battery pack according to claim 12, wherein the open/close switch comprises two separate terminals which electrically divides the voltage divider into two parts, wherein the separate terminals are closed when the rechargeable battery pack is connected to the battery charger.

15. The rechargeable battery pack according to claim 10, wherein the circuit provides the battery voltage of the rechargeable battery as the control voltage.

16. A battery charging method for a rechargeable battery pack, comprising the steps of:

a) generating a control voltage depending on a battery voltage of the rechargeable battery so that the control voltage reaches a predetermined control voltage when the battery voltage reaches a predetermined charge voltage of the rechargeable battery; and

b) charging the rechargeable battery depending on the control voltage.

17. The battery charging method according to claim 16, wherein the predetermined control voltage is set to a common voltage to another rechargeable battery.

18. The battery charging method according to claim 16, wherein the step b) comprises the step of changing charging control from constant-current to constant-voltage depending on whether the control voltage reaches the predetermined control voltage.

19. The battery charging method according to claim 16, wherein the step a) comprises the step of dividing the battery voltage of the rechargeable battery by a predetermined resistance ratio to produce the control voltage.

20. The battery charging method according to claim 16, wherein the step a) comprises the step of providing the battery voltage of the rechargeable battery as the control voltage.

Dated 9 March, 2000
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Patent Attorneys for the Applicant
SPRUSON & FERGUSON

FIG. 1

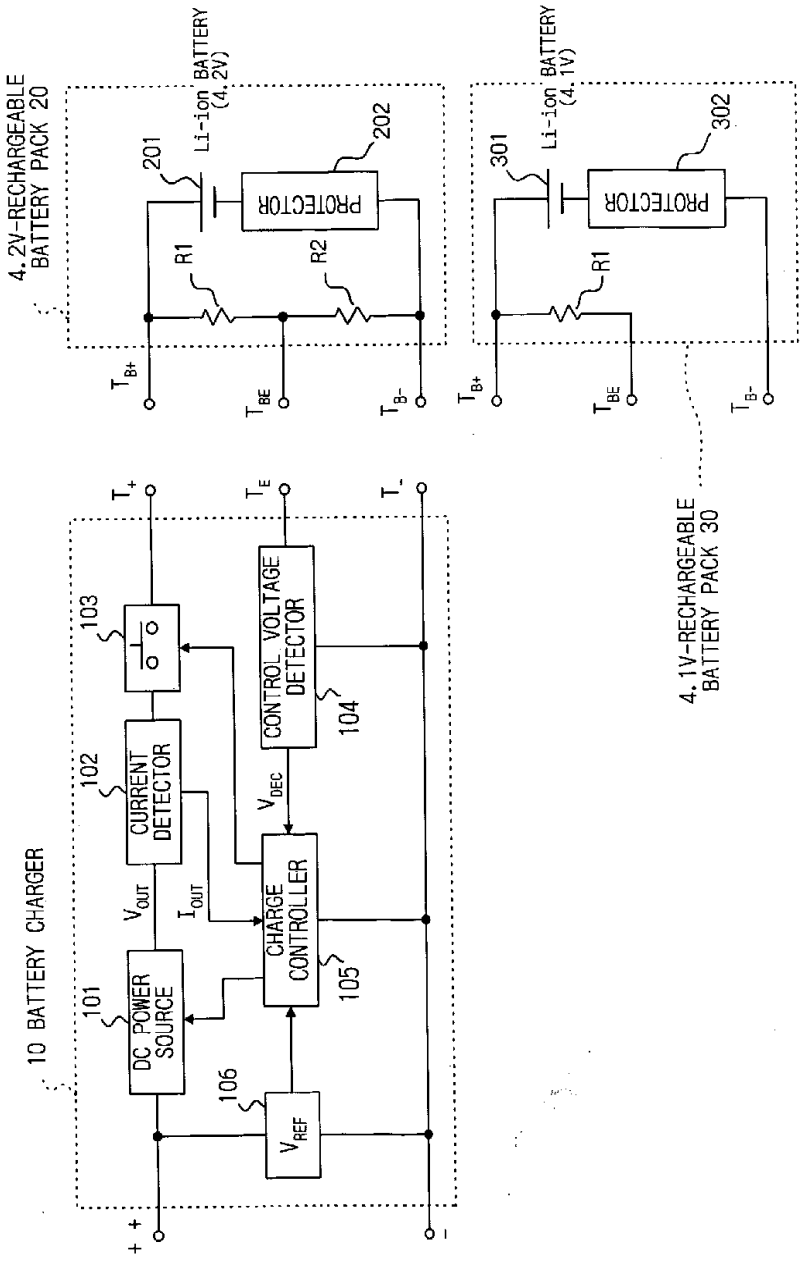

10 BATTERY CHARGER
DC POWER SOURCE
101
CURRENT DETECTOR
102
103
CONTROL VOLTAGE DETECTOR
104
CHARGE CONTROLLER
105
V_{REF}
106
V_{OUT}
I_{OUT}
V_{DEC}
T_+
T_E
T_-
+
-
4.2V-RECHARGEABLE BATTERY PACK 20
Li-ion BATTERY (4.2V)
201
PROTECTOR
202
R1
R2
T_{B+}
T_{BE}
T_{B-}
4.1V-RECHARGEABLE BATTERY PACK 30
Li-ion BATTERY (4.1V)
301
PROTECTOR
302
R1
T_{B+}
T_{BE}
T_{B-}

FIG. 2A

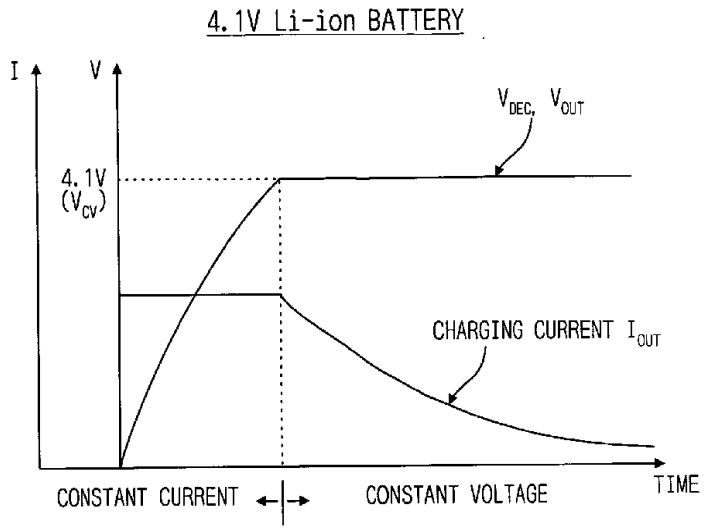

4.1V Li-ion BATTERY
I
V
V_{DEC}, V_{OUT}
4.1V
(V_{CV})
CHARGING CURRENT I_{OUT}
CONSTANT CURRENT
CONSTANT VOLTAGE
TIME

FIG. 2B

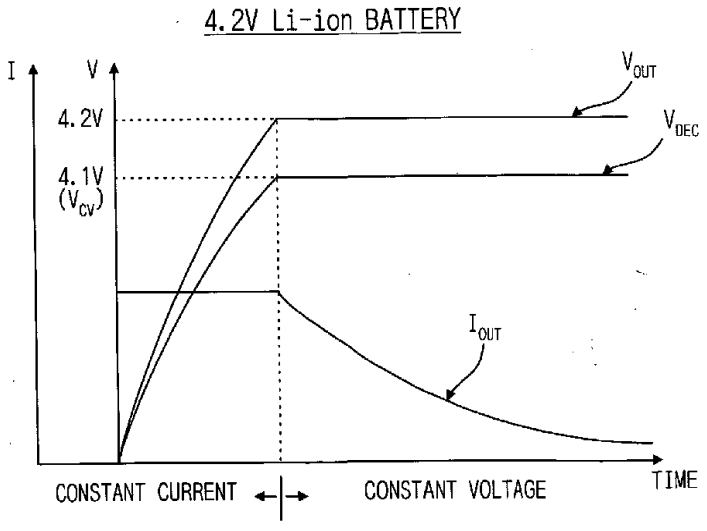

4.2V Li-ion BATTERY
I
V
V_{OUT}
V_{DEC}
4.2V
4.1V
(V_{CV})
I_{OUT}
CONSTANT CURRENT
CONSTANT VOLTAGE
TIME

FIG. 3

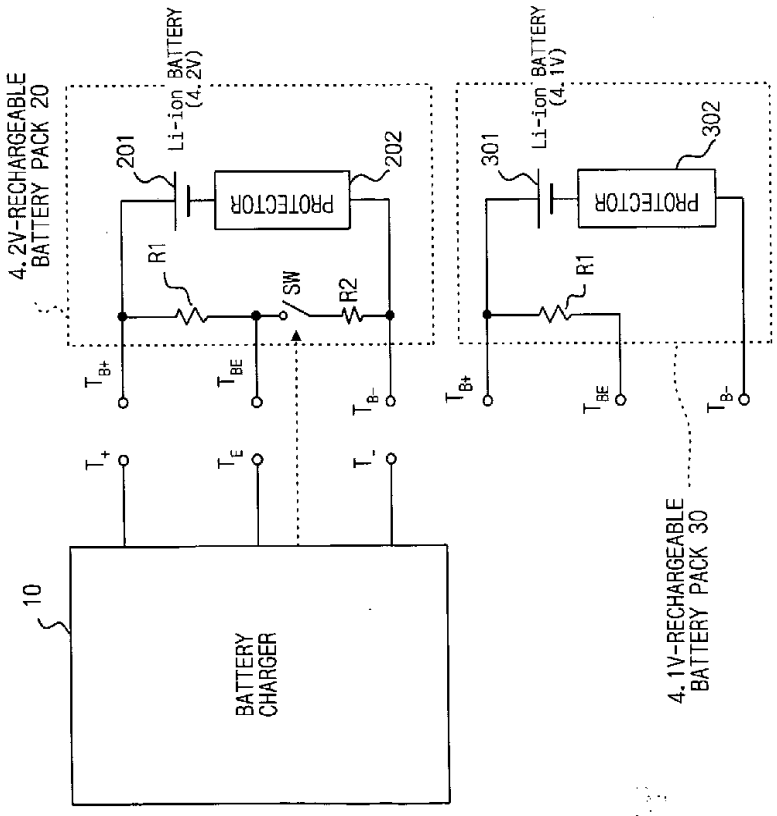
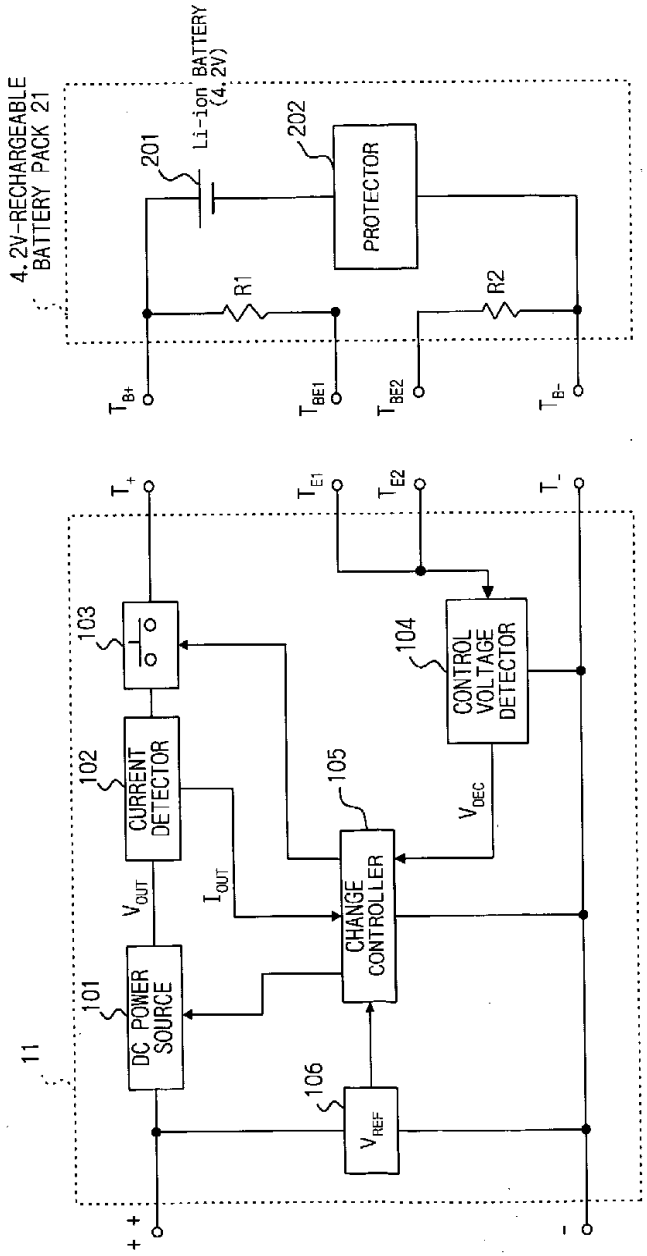

4.2V-RECHARGEABLE BATTERY PACK 20
Li-ion BATTERY (4.2V)
201
PROTECTOR
202
R1
SW
R2
T_{B+}
T_{BE}
T_{B-}
Li-ion BATTERY (4.1V)
301
PROTECTOR
302
R1
T_{B+}
T_{BE}
T_{B-}
4.1V-RECHARGEABLE BATTERY PACK 30
T_+
T_E
T_-
10
BATTERY CHARGER

FIG. 4


4.2V-RECHARGEABLE BATTERY PACK 21
Li-ion BATTERY (4.2V)
201
202
PROTECTOR
R1
R2
T_{B+}
T_{BE1}
T_{BE2}
T_{B-}
11
T_+
T_{E1}
T_{E2}
T_-
103
104
CONTROL VOLTAGE DETECTOR
102
CURRENT DETECTOR
105
V_{DEC}
V_{OUT}
I_{OUT}
CHANGE CONTROLLER
101
DC POWER SOURCE
106
V_{REF}
+
+
-