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(54) Benævnelse: **ADAPTIV BATTERIOPLADNINGSFREMGANGSMÅDE OG SYSTEM**

(56) Fremdragne publikationer:

GB-A- 2 332 824
US-A1- 2006 061 332
US-A1- 2006 208 695
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DESCRIPTION

[0001] The disclosure relates to systems that use one battery to recharge another battery, and is particularly advantageous for charging a lithium ion battery from another battery.

[0002] Lithium ion batteries are typically charged using a constant current phase followed by a constant voltage phase. In the constant current phase, the voltage across the secondary battery is adjusted to maintain a constant maximum charging current I_{ch} until the voltage across the battery reaches a defined voltage limit V_{ch}, with I_{ch} and V_{ch} set by the properties of the battery. In the constant voltage phase the voltage across the battery is maintained at a fixed value V_{ch} until the current drops below a predetermined value I_{low}. For rapid charging it is desirable to maximise the length of the constant current phase.

[0003] As the second battery charges in the constant current phase, the charging voltage must increase to compensate for the increasing voltage of the second battery. The constant current phase accordingly requires a minimum charging voltage to be available from the charging battery.

[0004] In a battery to battery charging system, as the charging battery ages, its internal resistance increases and as a result the voltage that it can deliver is reduced. When it can no longer deliver the minimum voltage required for the fast charging operation it must be recharged or replaced.

[0005] US 2006/0208695 relates to a portable electrochemical power supply for handheld electronic devices. The power supply includes a housing with an electrical connector, a circuit board, and a removable electrochemical cell. The circuit board carries power supply circuitry which receives electrical energy from the electrochemical cell and provides a power supply output for powering an external device. The power supply can be used to charge a rechargeable battery in the external device, as long as the electrochemical cell voltage is above a threshold voltage.

[0006] It is an object of the invention to provide a battery to battery charging system that can provide for fast charging but which can support an increased number of charging cycles before the charging battery needs to be recharged or replaced, when compared with the systems currently available.

[0007] In a first aspect of the invention, there is provided a method of charging a second battery from a first battery, comprising the steps of:

comparing an output voltage of the first battery with a threshold voltage; and

when the output voltage from the first battery is equal to or greater than the threshold voltage, charging the second battery using a first current; and when the output voltage from the first battery is less than the threshold voltage, reducing the first current.

[0008] The first current may be reduced until the output voltage of the first battery is equal to or greater than a second threshold voltage. The second threshold voltage may be equal to the first threshold voltage or may be different to the first threshold voltage.

[0009] The step of comparing may be carried out iteratively during charging of the second battery. The step of reducing may comprise not applying a voltage pulse to a power converter connected between the first battery and the second battery following the outcome of the step of comparing.

[0010] The step of reducing the current may comprise reducing the frequency at which pulses of electrical current are applied to the second battery.

[0011] The method may comprise, when the output voltage from the first battery is equal to or greater than the threshold voltage, charging the second battery using a constant first current, and reducing the charging current when either the charging voltage applied to the second battery reaches a maximum permitted voltage or the output voltage from the first battery is less than the threshold voltage.

[0012] When the charging voltage applied to the second battery reaches a maximum permitted voltage or the output voltage from the first battery is less than the threshold voltage, the charging current may be reduced to maintain the charging voltage applied to the first battery at or close to the maximum permitted voltage.

[0013] The method may comprise stopping the charging of the second battery when the charging current is reduced to a current less than or equal to a minimum current threshold.

[0014] The second battery may be a lithium ion battery.

[0015] In a second aspect of the invention, there is provided a charging device comprising:

a first battery configured to charge a secondary battery connected to the device, and control circuitry configured to control charging of the secondary battery, wherein the control circuitry is configured to:

compare an output voltage of the first battery with a threshold voltage; and

if the output voltage from the first battery is equal to or greater than the threshold voltage, charge the second battery using a first current; and

if the output voltage from the first battery from the first battery is less than the threshold voltage, reduce the first current.

[0016] The control circuitry may be configured to reduce the first current until the output voltage of the first battery is equal to or greater than a second threshold voltage. The second threshold voltage may be equal to the first threshold voltage or may be different to the first threshold voltage.

[0017] The charging device may comprise a power converter connected between the first battery and the second battery, and the control circuitry may configured to reduce the first current by reducing the duty cycle of voltage pulses applied to the power converter from the first battery.

[0018] The control circuitry may be configured to compare the output voltage of the first battery with the threshold voltage periodically during charging of the second battery. The control circuitry may be configured to reduce the first current by not applying a pulse of voltage to a power converter connected between the first battery and the second battery following the outcome of the step of comparing.

[0019] The control circuitry may be configured, when the output voltage from the first battery is equal to or greater than the threshold voltage, to charge the second battery using a constant first current, and reduce the charging current when either the charging voltage applied to the second battery reaches a maximum permitted voltage or the output voltage from the first battery is less than the threshold voltage.

[0020] When the charging voltage applied to the second battery reaches a maximum permitted voltage or the output voltage from the first battery is less than the threshold voltage, the control circuitry may be configured to reduce the charging current to maintain the charging voltage applied to the first battery at or close to the maximum permitted voltage.

[0021] The control circuitry may be configured to stop the charging of the second battery when the charging current is reduced to a current less than or equal to a minimum current threshold.

[0022] The second battery may be a lithium ion battery. The first battery may be a lithium ion battery.

[0023] The method and charging device in accordance with the first and second aspects of the disclosure may be applied to electronic smoking systems. The charging device may be used to charge a secondary battery in an electronic smoking device. The electronic smoking device may include an electrically powered heater configured to heat an aerosol-forming substrate. The aerosol-forming substrate may be provided in the form of a cigarette having a mouthpiece portion on which an end user inhales. The secondary battery may advantageously provide sufficient power for a single smoking session, exhausting a single aerosol-forming substrate.

[0024] A short recharging time is crucial for the acceptance of electronic cigarettes. However, it is undesirable for a user to be unable to charge the smoking device simply because it cannot be achieved at the maximum possible speed. The method and charging device of the present invention allows for additional charging cycles of the electronic smoking device even as the battery of the charging device ages and deteriorates. The charging device may be a handheld charging device designed to be carried easily with a pocket or bag of a user.

[0025] In a third aspect of the invention, there is provided a computer program, that when executed on a processor in a charging device, the charging device having a first battery configured to charge a secondary battery connected to the device, and the processor being configured to control charging of the secondary battery, causes the processor to carry out the steps of the first aspect of the invention.

[0026] In a fourth aspect of the invention, there is provided a computer readable storage medium having stored thereon a computer program according to the third aspect.

[0027] It should be clear that features described in relation to one aspect of the disclosure may be applied to other aspects of the disclosure, alone or in combination with other described aspects and features of the disclosure.

[0028] Embodiments of the invention will now be described in detail, with reference to the accompanying drawings, in which:

Figure 1 is a schematic illustration of an handheld battery operated smoking device and an associated charging device including a charging battery;

Figure 2 is a circuit diagram illustrating a charging system in accordance with the disclosure;

Figure 3 illustrates a typical fast charging profile for a lithium ion battery;

Figure 4 illustrates a modified charging profile in accordance with the disclosure; and

Figure 5 is a flow diagram illustrating a control process for the charging profile of Figure 4.

[0029] Figure 1 shows a primary device 100 and a secondary device 102. The primary device 100 in this example is a charging unit for an electrically heated smoking system. The secondary device 102 in this example is an electrically heated aerosol-generating device adapted to receive a smoking article 104 comprising an aerosol-forming substrate. The secondary device includes a heater to heat the aerosol forming substrate in operation. The user inhales on a mouthpiece portion of the smoking article 104 to draw aerosol into the user's mouth. The secondary device 102 is configured to be received within a cavity 112 in the primary device 100 in order to recharge the power supply in the secondary device.

[0030] The primary device 100 comprises first battery 106, control electronics 108, and electrical contacts 110 configured to provide electrical power from the first battery 106 to a second battery in the secondary device when the secondary device is in connection with the electrical contacts 110. The electrical contacts 110 are provided adjacent the bottom of a cavity 112. The cavity is configured to receive the secondary device 102. The components of the primary device 100 are housed within the housing 116.

[0031] The secondary device 102 comprises a second battery 126, secondary control electronics 128 and electrical contacts 130. As described above, the second, rechargeable battery 126 of the secondary device 102 is configured to receive a supply of power from the first battery 106 when the electrical contacts 130 are in contact with the electrical contacts 110 of the primary device 100. The secondary device 102 further comprises a cavity 132 configured to receive the smoking article 104. A heater 134, in the form of, for example, a blade heater, is provided at the bottom of the cavity 132. In use, the user activates the secondary device 102, and power is provided from the battery 126 via the control electronics 128 to the heater 134. The heater is heated to a standard operational temperature that is sufficient to generate an aerosol from the aerosol-forming substrate of the aerosol-generating article 104. The components of the secondary device 102 are housed within the housing 136. A secondary device of this type is described more fully in EP2110033 for example.

[0032] The aerosol-forming substrate preferably comprises a tobacco-containing material containing volatile tobacco flavour compounds which are released from the substrate upon heating. Alternatively, the aerosol-forming substrate may comprise a non-tobacco material. Preferably, the aerosol-forming substrate further comprises an aerosol former. Examples of suitable aerosol formers are glycerine and propylene glycol.

[0033] The aerosol-forming substrate may be a solid substrate. The solid substrate may comprise, for example, one or more of: powder, granules, pellets, shreds, spaghettis, strips or sheets containing one or more of: herb leaf, tobacco leaf, fragments of tobacco ribs, reconstituted tobacco, homogenised tobacco, extruded tobacco and expanded tobacco. Alternatively, the aerosol-forming substrate may be a liquid substrate and the smoking article may comprise means for retaining the liquid substrate.

[0034] In this example, the secondary device 102 is an electrically heated smoking device. As such the secondary device 102 is small (conventional cigarette size) but must deliver high power over a period of just a few minutes, typically around 7 minutes for a single smoking session. The second battery may then need to be returned to the primary device 100 for recharging. Recharging is desirably completed, at least to a level sufficient to allow for another complete smoking experience, in a matter of a few minutes and preferably less than 6 minutes.

[0035] The first battery 106 in the primary device is configured to hold sufficient charge to recharge the second battery 126 several times before needing recharging itself. This provides the user with a portable system that allows for several smoking sessions before recharging from a mains outlet is required.

[0036] In order to satisfy the competing requirements for the second battery 126 of small size, sufficient capacity and safe, but fast, charge and discharge, as well as acceptable lifetime, a lithium iron phosphate (LiFePO4) battery chemistry may be used, as in this example. The second battery 126 in this example has a cylindrical shape, with a diameter of 10mm and a length of 37mm. This battery is able to undergo 8000 cycles of charge/discharge at more than 900J per cycle. The average charging rate may be up to 12C. A charging rate of 1C means that the battery is fully charged from zero charge to full charge in one hour and a charging rate of 2C means that the battery is fully charged from zero charge to full charge in half an hour. The battery capacity is in the region of 125mAh. The maximum charging current can range from 980mA to 1.5A. Discharging is performed using 1millisecond pulses of up to 2A. Discharge rate depends on the resistance of the heater, which is in turn dependent of the heater temperature. At ambient temperature the discharge rate may be as high as 28C but is reduced at higher temperatures as the resistance of the heater increases. At typical operating temperature the discharging rate is around 13C. As an alternative, a lithium titanate battery may be used for the second battery.

[0037] The first battery 106 in the primary unit 100 is a lithium cobalt oxide (LiCoO2) battery of the prismatic type. The first battery has a capacity of around 1350mAh, over ten times the capacity of the second battery. The second battery may be charged from the first battery at a rate between 2C and 16C. Discharging the first battery at a rate of 1C provides a charging rate of over 10C to the second battery. Charging of the first battery can be performed from a mains supply, at a rate between 0 and 1.5C, and typically at a rate of around 0.5C to maximise battery life.

[0038] A lithium cobalt oxide battery provides a higher battery voltage than lithium iron phosphate, allowing the charging of a lithium iron phosphate battery from a single lithium cobalt oxide battery.

[0039] Figure 2 is a schematic circuit diagram of the charging system. The first battery 106 has an associated internal resistance 107. Control electronics comprises a controller 200 and a switch mode power converter 205. The switch mode power converter 205 is connected between the first battery and the second battery. The controller 200 is configured to control the switching of a switch 206 within the switch mode power converter and thereby regulate the voltage and current applied to the second battery 126. The switch mode power converter 205 in this example is an integrated buck-boost converter.

[0040] Figure 3 shows a standard charging profile for charging the second battery. Figure 3 shows the charging voltage from the first battery 210, the charging current 220 from the charging device and the charging voltage 230 applied to the second battery being charged. The charging profile consists of an initial constant current phase 300. During the constant current phase 300 the charging voltage 230 is controlled so as to provide constant, maximum charging current I_{ch}. This is achieved by switching the switch mode power converter on to apply a voltage pulse from the first battery to the power converter at a maximum duty cycle. This provides for the maximum rate of charging. However, the constant charging current phase

300 comes to an end when the charging voltage from the first battery that is required to maintain the maximum charging current exceeds a maximum charging voltage V_{ch}. V_{ch} is set at a level that preserves the lifetime of the second battery. Once this stage is reached, indicated at time 303 on Figure 3, a constant voltage phase 302 begins. During the constant voltage phase the charging voltage 230 is held at the maximum V_{ch}. During the constant voltage phase, the charging current 220 drops as the difference between the charging voltage 230 and battery voltage of the second battery drops. The charging process is stopped when the charging current 220 reaches a low threshold I_{end}. The maximum charging current and the maximum charging voltage are set by the battery manufacturer.

[0041] The charging profile illustrated in Figure 3 can be used in a system as described with reference to Figure 1. However, in a battery to battery charging system, as the charging battery ages, its internal resistance 107 increases, and the voltage that it can deliver is therefore reduced. But for the fastest charging, in the constant current phase the charging voltage from the first battery must be able to reach the maximum charging voltage V_{ch}. Otherwise the fast charging process cannot be completed. Accordingly, in prior systems, when the first battery can no longer deliver the minimum voltage required for the fast charging process it has to be recharged or replaced.

[0042] Figure 4 illustrates a charging profile in accordance with an embodiment of the invention. In Figure 4, the battery voltage from the first battery is reduced as compared with Figure 3 because the first battery has aged and has a larger internal resistance. In Figure 4 it can be seen that the charging current 420 drops before the charging voltage 430 reaches its maximum V_{ch}, i.e. before the constant current phase would ordinarily end. The charging current 420 is reduced in order to maintain the charging voltage 430 at the required level. This is done by adjusting the current to keep the battery voltage 410 output from the first battery above a preset threshold level of 3.5 Volts. When the charging voltage 430 reaches V_{ch} the charging current is reduced further in order to maintain the charging voltage at or below V_{ch}. The process again ends when the charging current is reduced to I_{end}.

[0043] Figure 5 illustrates a control process used to regulate the current in accordance with the profile shown in Figure 3 or Figure 4. The process starts with step 500, in which a count of the number of cycles of the process is incremented by one. Then, in step 505 it is determined if the count has reached an odd number or an even number. If it is an even number the process continues to step 510, in which the processor switches off the switch in the switch mode power converter so that no energy is accumulated in the switch mode power converter from the first battery. The process then returns to step 500 in which the cycle count is incremented by one.

[0044] Then in step 505 it is determined that the count has reached an odd number and the process proceeds to step 515. In step 515 it is determined whether the charging voltage applied to the second battery has reached the maximum permitted voltage V_{ch}. If it has reached the target voltage then the switch in the power converter remains off as the charging current needs to be reduced to reduce the charging voltage. The process then proceeds to step 520, in which a voltage limit flag is set within the processor, so that an indication that the constant current phase has ended can be provided to a user.

[0045] If the charging voltage applied to the second battery is less than the maximum voltage then the process proceeds to step 525. In step 525, the current to the second battery is compared with a target current, I_{end}, below which the charging process should be stopped, as seen in the charging profiles of Figures 3 and 4. If the charging current is below the target current, the process proceeds to step 530, in which a current limit flag is set. The current limit flag is used to indicate to the end user that charging is complete.

[0046] If the charging current is greater than the target current then the process proceeds to step 535. In step 535 it is determined whether the voltage from the first battery is greater than the minimum required voltage for fast charging. If the battery voltage of the first battery is greater than the minimum required voltage, then, in step 545, the processor switches on the switch in the switched mode power converter so that electrical energy is drawn from the first battery and is accumulated in the power converter for application to the second battery. If the battery voltage of the first battery is not greater than the minimum required voltage, then, the switch in the switch mode power converter remains off and, in step 540, the processor sets a limit battery flag so that an indication that the first battery needs recharging or replacing can be provided to the end user.

[0047] After each of steps 520, 530, 540 and 545, the process proceeds to step 550. In step 550 new measurements of the voltage of the first battery and second battery are taken and a new measurement of the charging current is taken. These measurements are then converted into digital form ready for comparison with the corresponding target values in the next odd numbered cycle.

[0048] In the next even numbered cycle, in step 510, the switch in the switch mode power supply is switched off and energy accumulated in the switch mode power supply is applied as a charging current to the second battery. If during the preceding cycle the switch has been switched to an on state in step 545 the voltage output to the second battery will be at a higher level than if the switch has not been switched to an on state during the preceding cycle. A lower output voltage means that a lower current is drawn from the first battery. Drawing a lower current from the first battery has the effect of increasing the battery voltage from the first battery, as less voltage is dropped across the internal resistance of the first battery. As can be seen in the profile of Figure 4, when the minimum required target voltage is 3.5 Volts, this scheme has the effect of maintain the battery voltage of the first battery at around 3.5 Volts as the current drops. The process in Figure 5 also ensures than no charging current is applied to the second battery when it is fully charged.

[0049] This process allow the first battery to recharge the second battery for a few more times than it would otherwise be able to using a standard fast charge process of constant current followed by constant voltage. This comes at the cost of charge speed for those extra charge cycles, but in many cases the extra charging cycles are of great benefit to the user in terms of convenience. The process is energy efficient compared with methods that simply try to raise the first battery voltage using a power converter as it suffers from relatively lower losses.

[0050] The exemplary embodiments described above illustrate but are not limiting. In view of the above discussed exemplary embodiments, other embodiments consistent with the above exemplary embodiments will now be apparent to one of ordinary skill in the art.

REFERENCES CITED IN THE DESCRIPTION

Patent documents cited in the description

- US20060208695A **[0005]**
- EP2110033A **[0031]**

Patentkrav

1. Fremgangsmåde til opladning af et andet batteri (126) i en elektronisk rygeindretning (102) fra et første batteri (106) i en opladningsindretning (100), omfattende:

at sammenligne en udgangsspænding (410) af det første batteri (106) med en tærskelspænding; og

når udgangsspændingen (410) fra det første batteri (106) er lig med eller større end tærskelspændingen, at oplade det andet batteri (126) under anvendelse af en første strøm (420); og

når udgangsspændingen (410) fra det første batteri (106) er mindre end tærskelspændingen, at reducere den første strøm (420) indtil udgangsspændingen (410) af det første batteri (106) er lig med eller større end en anden tærskelspænding.

2. Fremgangsmåde ifølge krav 1, hvor den anden tærskelspænding er lig med den første tærskelspænding.

3. Fremgangsmåde ifølge krav 1 eller 2, hvor trinnet at reducere strømmen omfatter at reducere en driftscyklus af spændingsimpulser påført en strømomformer (205) forbundet mellem det første batteri (106) og det andet batteri (126).

4. Fremgangsmåde ifølge et hvilket som helst foregående krav, hvor sammenligningstrinnet udføres iterativt under opladning af det andet batteri (126), og hvor reduceringstrinnet omfatter ikke at påføre en spændingsimpuls på en strømomformer (205) forbundet mellem det første batteri (106) og det andet batteri (126) følgende udfaldet af sammenligningstrinnet.

5. Fremgangsmåde ifølge et hvilket som helst foregående krav, omfattende, når udgangsspændingen (410) fra det første batteri (106) er lig med eller større end tærskelspændingen, opladning af det andet batteri (126) under anvendelse af en konstant første strøm (420), og reducere opladningsstrømmen når enten opladningsspændingen (430) påført det andet batteri (126) når en maksimal tilladt spænding, eller udgangsspændingen (410) fra det første batteri (106) er mindre end tærskelspændingen.

6. Fremgangsmåde ifølge krav 6, hvor, når opladningsspændingen (430) påført det andet batteri (126) når en maksimal tilladt spænding, eller udgangsspændingen (410) fra det første batteri (106) er mindre end tærskelspændingen, at reducere opladningsstrømmen for at bevare opladningsspændingen påført det første batteri (106) ved eller tæt på den maksimale tilladte spænding

7. Opladningsindretning (100) omfattende:

et første batteri (106) konfigureret til at oplade et andet batteri (126) i en elektronisk rygeindretning (102) forbundet med opladningsindretningen (100), og styrekreds (128) konfigureret til at styre opladning af det andet batteri (126), hvor styrekredsen (128) er konfigureret til:

at sammenligne en udgangsspænding (410) af det første batteri (106) med en tærskelspænding; og

hvis udgangsspændingen (410) fra det første batteri (106) er lig med eller større end tærskelspændingen, at oplade det andet batteri (126) under anvendelse af en første strøm (420); og

hvis udgangsspændingen (410) fra det første batteri (106) er mindre end tærskelspændingen, at reducere den første strøm indtil udgangsspændingen (410) af det første batteri (106) er lig med eller større end en anden tærskelspænding.

8. Opladningsindretning (100) ifølge krav 7, hvor styrekredsen (128) er konfigureret, når udgangsspændingen (410) fra det første batteri (106) er lig med eller større end tærskelspændingen, til at oplade det andet batteri (126) under anvendelse af en konstant første strøm (420), og at reducere opladningsstrømmen, når enten opladningsspændingen (430) påført det andet batteri (126) når en maksimalt tilladt spænding, eller udgangsspændingen fra det første batteri (106) er mindre end tærskelspændingen.

9. Opladningsindretning (100) ifølge krav 8, hvor styrekredsen (128) er konfigureret til at reducere opladningsstrømmen for at bevare opladningsspændingen påført det første batteri (106) ved eller tæt på den maksimale tilladte spænding, når opladningsspændingen (430) påført det andet batteri (126) når en maksimal tilladt spænding, eller udgangsspændingen (410) fra det første batteri (106) er mindre end tærskelspændingen.

10. Opladningsindretning (100) ifølge krav 7, 8 eller 9, omfattende en strømomformer (205) forbundet mellem det første batteri (106) og det andet batteri (126), og hvor styrekredsen (128) er konfigureret til at reducere den første strøm (420) ved at reducere en driftscyklus af spændingsimpulser påført strømomformeren (205) fra det første batteri (106).

11. Opladningsindretning (100) ifølge et hvilket som helst af krav 7, 8, 9 eller 10, hvor styrekredsen (128) er konfigureret til at sammenligne udgangsspændingen (410) af det første batteri (106) med tærskelspændingen periodisk under opladning af det andet batteri (126).

12. Opladningsindretning (100) ifølge krav 11, hvor styrekredsen (128) er konfigureret til at reducere den første strøm (420) ved ikke at påføre en spænding impuls til en strømomformer (205) forbundet mellem det første batteri (106) og det andet batteri (126) følgende udfaldet af sammenligningstrinnet.

13. Computerprogramprodukt, der når det udføres i en processor i en opladningsindretning (100), hvor opladningsindretningen har et første batteri (106) konfigureret til at oplade et andet batteri (126) i en elektronisk rygeindretning (102) forbundet med opladningsindretningen (100), og hvor processoren er konfigureret til at styre opladning af det andet batteri (126), bevirker at processoren udfører fremgangsmåden ifølge et hvilket som helst af kravene 1 til 6.

14. Computerlæsbar lagringsmedie hvorpå der er lagret et computerprogramprodukt ifølge krav 13.

DRAWINGS

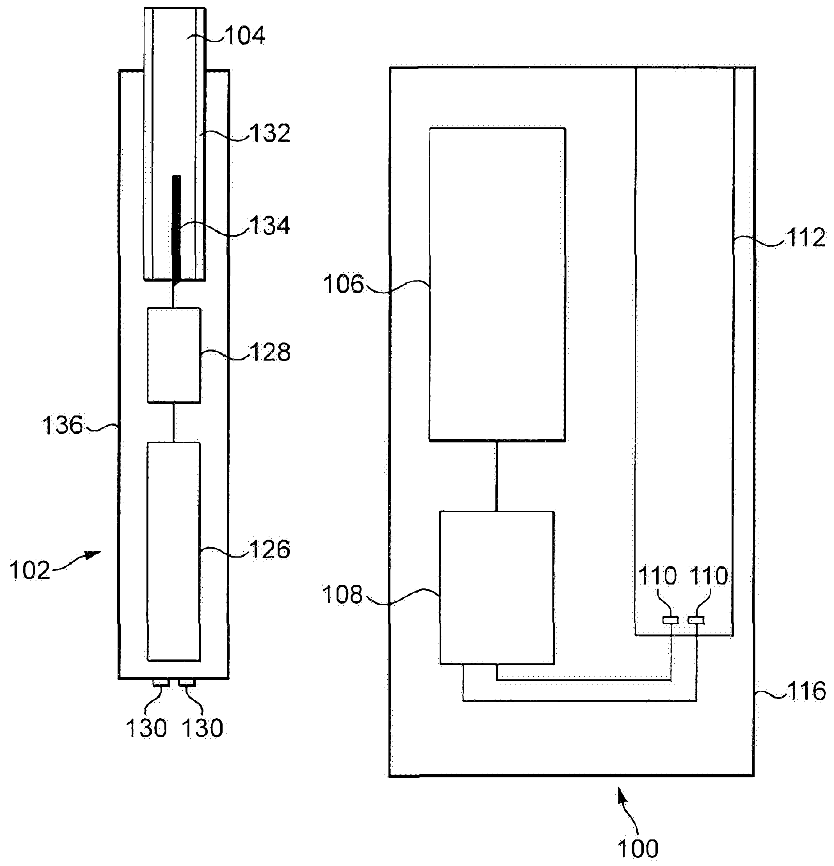


FIG. 1

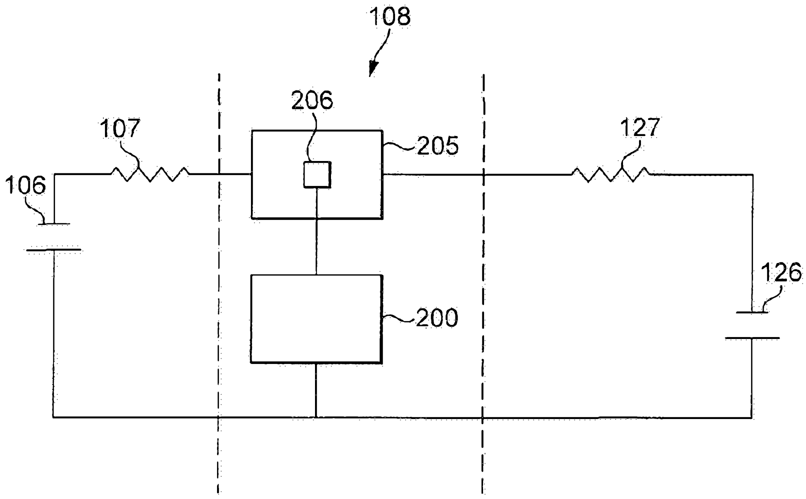
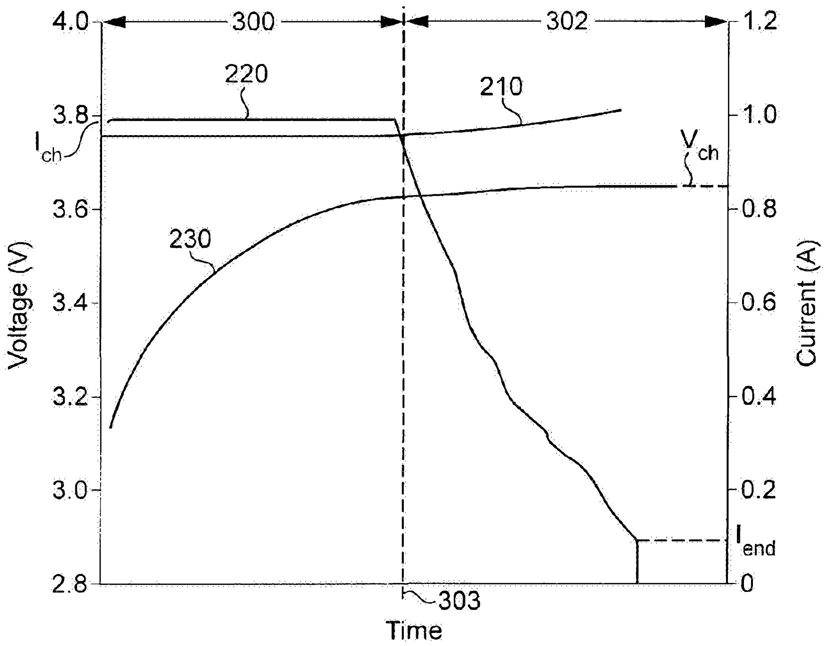
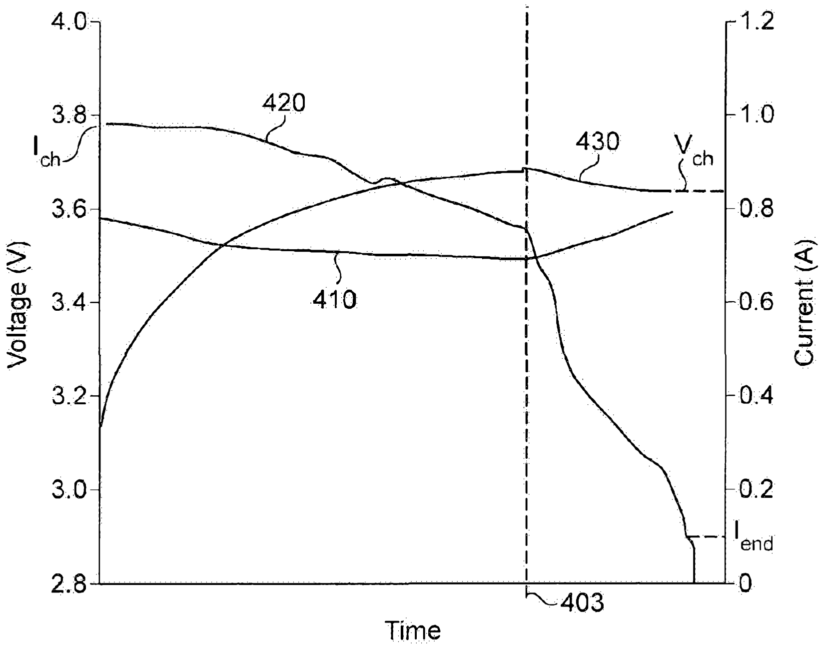


FIG. 2



300
302
220
210
4.0
3.8
3.6
3.4
3.2
3.0
2.8
1.2
1.0
0.8
0.6
0.4
0.2
0
I_{ch}
V_{ch}
230
I_{end}
303
Voltage (V)
Current (A)
Time

FIG. 3



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3.6
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0
420
430
I_{ch}
V_{ch}
410
I_{end}
403
Voltage (V)
Current (A)
Time

FIG. 4

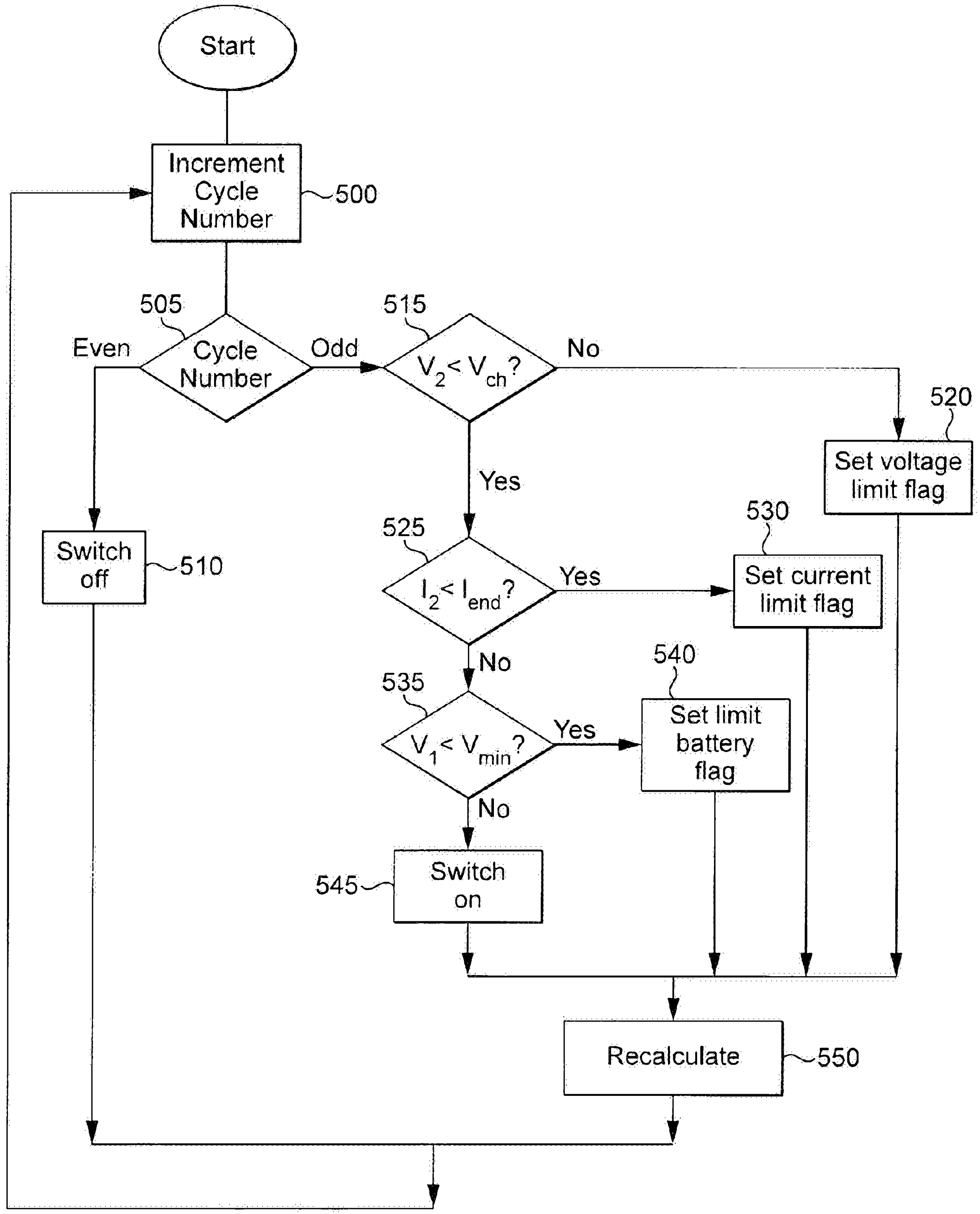
Start
Increment Cycle Number
500
505
Cycle Number
Even
Odd
515
$V_2 < V_{ch}$?
No
520
Set voltage limit flag
Yes
525
$I_2 < I_{end}$?
Yes
530
Set current limit flag
Switch off
510
No
535
$V_1 < V_{min}$?
Yes
540
Set limit battery flag
No
545
Switch on
Recalculate
550

FIG. 5