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(54) Title: EXTENDED LIFE BATTERY

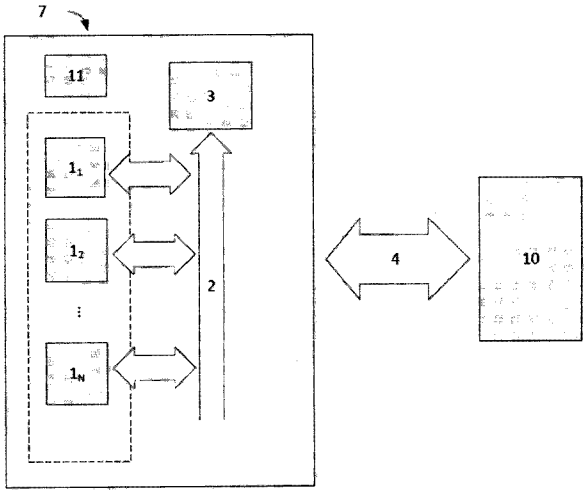


FIG 1A.

(57) Abstract: Methods and apparatuses are described for use in preserving and / or recovering the lifetime and charge storage capacity of batteries. The methods include pulse charging, energy juggling, energy leveling, all resulting in extended battery life. Methods of storing batteries for maintaining their capacity at their nominal level for extended periods of time are also presented.

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Extended Life Battery

Related applications

001. This patent application claims priority from US provisional patent application 61/615,282, filed March 25, 2012, entitled "Controlled Multi-Core Battery System"; US provisional patent application 61/662,882, filed June 21, 2012, entitled "Multicore Rechargeable Battery with extended calendar life"; and US provisional patent application 61/683691 filed August 15, 2012, entitled "Multi-core Rechargeable Battery with extended calendar life", all of which are incorporated herein by reference.

Field of invention.

002. The present invention relates to battery technology and methods of extending and recovering battery lifetime and charge storage capacity.

Background information

003. Advances in battery technology have not kept up with market demands. Effective solutions to extend or preserve battery lifetime and charge storage capacity are needed.

004. Batteries are electrochemical energy storage systems. The useful lifetime of a battery is limited by the battery aging process. A battery ages (loses its energy storage capacity) with use, and with time, even if not used. After the energy storage capacity of a battery has decreased below a threshold value it is said to have reached its end of life. Aging from use is called "life cycle aging", while aging with time, is known as "calendar aging." These two processes occur together, and their magnitudes depend on an individual battery's application and usage pattern. As such, one process may dominant the other.

005. A battery's operating conditions affect the aging process. Temperature and high charging voltages are some of the most operating factors in aging. Exposing a battery to high temperatures and storing the battery in a full state-of-charge for an extended period may age a battery faster than charge-discharge cycling with use. Different battery types have different life cycle aging and calendar aging characteristics.

006. Lithium ion batteries are widely used in laptops, cell phones and other portable applications. Lithium-ion batteries age significantly when exposed to elevated temperatures and when stored in a fully charged (high voltage) state. A temperature above 30°C (86°F) is considered an elevated temperature for Lithium ion batteries. For most Lithium-ion (Li-ion) batteries, a cell voltage above 4.10 V is considered a high voltage.

007. A lithium ion laptop battery is usually exposed to an elevated temperature when operating. In normal use, a laptop battery is also usually fully charged and may rarely be disconnected from the charger. Some cell phone batteries experience similar operating conditions. It is common for a cell phone battery to lose much of its capacity during the first one or two years of its calendar life

008. A short description of how batteries operate is provided for convenience. Batteries contain chemically active materials and deliver energy through an electrochemical reaction. When current is discharged from the battery, two concurrent phenomena occur:

i) the concentration of the active materials around the electrode drops forming a depletion region and generating a concentration gradient. This is known as the polarization effect. This concentration gradient acts as an internal resistance and reduces the efficiency of the battery;

ii) at the same time, the active materials move toward the depletion region due to a diffusion process resulting in a decreased gradient concentration and decreasing the polarization effect.

009. Depletion typically occurs faster than diffusion. Both phenomena act concurrently to redistribute the active materials. In the ideal case depletion takes place at a similar rate to diffusion and the concentration of active material is at an ideal equilibrium point whereby the battery has maximum efficiency. In reality however, the equilibrium point usually settles at a different level. If diffusion constantly exceeds depletion, the battery delivers less energy than expected. Conversely, if the polarization effect overcomes the diffusion process, the battery will be discharged before the active materials are actually exhausted.

0010. US patent application No. 2010/0164430 (Lu) teaches that during discharging of a Lithium-ion battery cell, lithium ions accumulate on the cathode. Conversely, during charging, the lithium ions accumulate on the cell anode. The accumulation of ions during discharging generates a concentration gradient which compensates for the movement of ions during discharging. A gradient is also produced during the battery charging process. In an equivalent circuit model, the concentration gradients can be modelled as internal resistances that decrease battery efficiency during charging and discharging. If a battery has a large internal resistance then a portion of its stored energy is dissipated internally by the internal resistance when it is discharging and is not delivered to the load. Similarly the internal resistance will dissipate energy during charging making charging less efficient. A battery's storage capacity is therefore diminished by internal resistance.

0011. It is known that battery capacity and lifetime can be improved by using a pulsed discharge current instead of a constant discharge current. A charge recovery process occurs in the battery during the time between discharge pulses (the "rest time") when the discharge current is not flowing.

0012. It is also known that the battery lifetime and capacity can be significantly increases by pulse charging a battery. Some studies also suggest that reversing the current for a short time during charging or discharging in a technique known as the 'mode reversal', positively affects battery capacity and lifetime. For example when a short discharge pulse is applied prior to each charging pulse, this improves the charging process of the battery. When a short charging pulse is applied prior to each discharging pulse, this improves the battery recovery between discharging pulses and increases the battery storage capacity.

0013. A battery's state of charge is directly related to the discharge current and decreased by it. If the discharge current is interrupted, however, the battery's state of charge may recover and improve during the interruption. The recovery process is dependent on the duration of the interruption, the capacity of the battery, and the present state of charge of the battery. The recovery effect progressively decreases as the battery's state of charge decreases, until all the active materials are exhausted and the battery is depleted.

0014. In one simple known battery model that describes battery behavior during the discharge process the recovery mechanism depends only on the rest time. Other battery models take into account the degradation of the recovery mechanism as the battery state-of-charge decreases.

0015. Typically Lithium-ion batteries used in mobile applications last between one and four years during which interval they constantly lose the capacity to hold a charge for long periods of time. These batteries are typically used in cell phones, cameras, tablets, battery packs, portable power tools and laptops due to their high energy density. The capacity loss is mainly due to increased internal resistance. Processes causing an increased internal resistance are more damaging when the battery charge state is close to full for longer periods. The internal cell resistance increases to a point where the battery pack can no longer deliver the stored energy irrespective of the fact that the battery indicates it is fully charged. In other words, a new battery, when fully charged delivers its nominal charge. An aged battery delivers less than its nominal charge.

0016. Internal resistance typically increases for lithium-ion and lithium-polymer batteries with time and with each charge /discharge cycle. The aging speed is dependent on the working temperature and the battery state-of-charge. In most mobile devices the battery is in a fully-charged state while the device is plugged into a power adapter. The constant fully-charged state of the battery and elevated working temperatures contribute to a reduction of the battery life.

Summary of the invention

0017. There is a need to extend and preserve the lifetime of batteries to obtain important savings to the battery users.

0018. Furthermore, there is a need to reduce the impact of end of life batteries on the environment; by extending battery lifetime, the impact on the environment can be significantly reduced, along with disposal expenses.

0019. A method comprising performing a capacity enhancing operation on a cell within an electrochemical energy storage system whereby said capacity enhancing operation is performed internally to the electrochemical energy storage system is disclosed.

0020. In an embodiment the capacity enhancing operation is a charge and discharge operation.

0021. The charge operation could be performed from at least a first cell to a second cell.

0022. The charge operation could also be performed from at least a first passive energy storage element to a first cell.

0023. The charge operation could also be performed from a series combination of at least a first cell and a first passive energy storage element to a second cell.

0024. The passive energy storage element could be a capacitor or an inductor.

0025. The charging operation could also use a DC to DC converter.

0026. The durations of the charge and discharge operations could be based on operational parameters of the electrochemical energy storage system. The operational parameters could include: a temperature, a cell charging current, a cell discharging current, a cell voltage, an internal impedance, an internal battery pressure, a number of system charge / discharge cycles.

0027. The capacity enhancing operation could be performed repetitively until a cell capacity threshold is met.

0028. According to another aspect of the disclosure an electrochemical energy storage system includes at least one storage cell and circuitry for performing a capacity enhancing operation on the cell whereby the capacity enhancing operation is performed internally to the electrochemical storage system.

0029. In an embodiment the capacity enhancing operation comprises a charge and a discharge operation.

0030. The charge operation could be performed from at least a first cell to a second cell.

0031. In another embodiment the system contains a passive energy storage device and the charge operation is performed from a series combination of at least a first cell and a first passive energy storage element to a second cell. The passive energy storage device could be a capacitor or an inductor.

0032. The electrochemical energy storage system could contain a DC to DC converter and the charge operation could be performed using the DC to DC converter.

0033. The system could contain a controller for determining the timing of the capacity enhancing operation from the operational parameters of the electrochemical energy storage system. The system could contain circuitry for sensing the operational parameters of the system including: an internal battery pressure, a charging current, a discharging current, a cell voltage, an internal impedance, a number of charge/discharge cycles.

0034. The capacity enhancing operation could be performed repetitively until a cell capacity threshold is met.

0035. Numerous scientific papers and publications teach that Li-ion battery capacity deterioration after a calendar life of more than 5 years is not recoverable and the battery capacity fading is irreversible. Our experiments demonstrate that the lifetime of a battery may be extended significantly by maintain and/or restoring the capacity using pulsed charging/discharging, and/or energy juggling methods.

Description of the drawings

Figure 1A is a block diagram of an exemplary Multi-Core Battery of the present invention;

Figure 1B is a block diagram of an MCB connected to a smart charger;

Figure 1C is a block diagram of an example battery core.

Figure 2 is an exemplary discharge timing diagram;

Figure 3 is an exemplary timing diagram for charging and discharging of a core;

Figure 4 is a schematic diagram of an exemplary switching network for a four-core battery;

Figure 5 is a schematic diagram of an exemplary energy juggling circuit;

Figure 6A is a schematic diagram of an exemplary energy juggling circuit configuration;

Figure 6B is a simplified circuit diagram of Figure 6A;

Figure 7A is a schematic diagram of another exemplary energy juggling circuit configuration;

Figure 7B is a simplified circuit diagram of Figure 7B;

Figure 8 is a schematic diagram of another exemplary energy juggling circuit connection;

Figure 9 illustrates an energy juggling circuit for a four-core battery using an external power supply;

Figure 10 illustrates an exemplary energy juggling circuit for a four core MCB that uses a capacitor;

Figure 11 is a schematic diagram of a variable voltage MCB;

Figure 12 is a flow diagram of an exemplary pulse charging sequence of the MCB of figure 9;

Figure 13 is a flow diagram of an example pulse charging process of the four cell battery used in the circuit of Figure 10;

Figure 14 is a schematic diagram of a battery using a DC to DC converter to generate a charging voltage.

Description of the preferred embodiments

0036. The methods and systems described herein are applicable to a variety of Multi-Cell Batteries (MCB) and single cell batteries currently used for electric and hybrid cars, scooters, portable computers and tablets, portable power tools, uninterruptible power supplies, portable light sources, bi/uni-cycles, or other various portable electronic devices. The methods and systems described here are not limited to the above battery types, but they are applicable to any multiple cell battery, or single cell battery, also referred to here as multiple core or single core batteries. Preferably, the battery types may include, but not limited to, nickel cadmium batteries, nickel metal hydride batteries, lithium ion batteries, lithium ion polymer batteries or lead-acid batteries.

0037. In this specification, the term 'static parameters' refers to, but is not limited to, the nominal battery voltage, nominal internal battery impedance, the nominal output current of an individual battery core into a standard load R . Furthermore, in this specification the term 'operational parameters' describes actual operating values of the battery and includes the charging and discharging current, the charging and discharging voltage, state of charge of the battery, state of charge of individual cores, internal battery pressure, the age of the battery (calendar age and the remaining life), number of charge

and discharge cycles, the ambient temperature. Other operational parameters may also be considered in the methods and apparatus described here.

0038. The calendar life of a battery, may be extended significantly if the battery is charged and discharged using pulses rather than a continuous current. The calendar lifetime of a battery may be also be extended significantly if the duration of the charging and discharging pulses and/or the rest times between pulses are selected based on the battery's static and operational parameters.

0039. In this invention a procedure referred to as 'energy juggling' is used to extend or recover a battery's capacity and lifetime. In energy juggling a battery is pulse charged and pulse discharged. In one embodiment, energy juggling is performed while the battery is idle and not supplying a load. In another embodiment energy juggling is performed while the battery is being charged or discharged. In one embodiment of energy juggling, individual cells in an MCB are pulse charged and pulse discharged from/to other cells of the MCB. In another embodiment of energy juggling individual cells in an MCB, are pulse-charged and pulse discharged from/to a combination of other cells and an internal passive energy storage device. In yet another embodiment of energy juggling individual cells in an MCB, are pulse charged and pulse discharged from/to an internal passive energy storage device. In yet another embodiment of energy juggling the cell of a single cell battery is pulse-charged and pulse discharged from/to an internal passive energy storage device. The types of passive energy storage devices used may include but are not limited to a capacitor or an inductor.

0040. Energy juggling has a number of advantages. For example, it allows a battery to be stored at full charge without suffering the normal lifetime reduction associated with storage at full charge. Energy juggling during storage prevents normal calendar aging and recovers lost battery lifetime and capacity. Energy juggling also allows the lifetime and capacity of a degraded battery or cells to be restored if, for example, the battery has been subjected to high temperatures or arduous cycling or other operations that degrade its capacity and lifetime.

0041. The duration, shape and periodicity of the charge/discharge pulses used in energy juggling may be determined based on the operational parameters of the battery.

0042. In a further embodiment of energy juggling, during the rest time between pulses, each cell is subjected to 'mode reversal'. For example, after a discharge pulse, the cell is briefly pulse charged for a prescribed, short period with a predetermined current. Similarly, after a charge pulse the cell is briefly pulse discharged. In different embodiments the mode reversal operation is performed for portions of the rest period such as the beginning or end of the rest period, or it may be performed at an intermediate point in the rest period.

Pulse charge/discharge

0043. Figure 1A is a block diagram of an exemplary Multi-Cell Battery (MCB). MCB **7** contains multiple battery cores,$\mathbf{1_1,1_2,..1_N}$. Each battery core $\mathbf{1_1,1_2,..1_N}$ contains at least one battery cell (not shown). Battery cores $\mathbf{1_1,1_2,..1_N}$ may be connected in series or in parallel or in a series -parallel combination to provide the required output voltage, depending on the application. Battery cores $\mathbf{1_1,1_2,..1_N}$ may consist of a single cell or may be self-sufficient batteries with the ability to function independently, or in combination with other cores in the MCB **7**.

0044. Figure 1C is a block diagram of an example battery core. Battery core **101** contains battery cells $\mathbf{102_1}$ and $\mathbf{102_2}$ for energy storage. Core controller **103** controls the operation of cells $\mathbf{102_1}$ and $\mathbf{102_2}$. Battery core **101** optionally contains DC to DC converter **104** for the conversion of the voltage of cells $\mathbf{102_1}$ and $\mathbf{102_2}$ to a DC level.

0045. Battery cores $\mathbf{1_1,1_2,..1_N}$ in figure 1A connect to MCB controller **3** via power control bus (PCB) **2**. PCB bus **2** may carry switch control signals, core and output voltage sense signals, current sense signals, temperature sense signals, internal pressure sense signals or other sense and control signals. Controller **3** monitors the status of battery cores $\mathbf{1_1,1_2,..1_N}$ and controls the operation of MCB **7**. In one embodiment controller **3** includes a Central Processing Unit for processing instructions and data, on-board memory for storing instructions and data, a digital to analog converter for voltage measurement and drive circuitry for the control of switches. In one embodiment controller **3** is a single chip microcontroller. MCB **7** can connect to external load **10** or a battery charger (not shown) through battery interface **4**. MCB **7** optionally contains

passive energy storage element **11** for the temporary storage of energy. In one embodiment passive energy storage element **11** is a capacitor, in another embodiment it is an inductor. MCB **7** also contains a switching network (not shown in figure 1A for clarity) which allows for the battery cores $\mathbf{1_1,1_2,..1_N}$ to be configured in multiple ways to facilitate energy juggling.

0046. In some embodiments, the energy juggling operation of each battery core is controlled and monitored by controller **3**. Controller **3** may monitor one or more of the following parameters: the charging/discharging current, cell voltages, battery temperature, internal battery pressure, battery and cell voltages, mechanical stress, and state of charge. Other relevant parameters of the battery core may also be monitored if desired. Monitoring circuitry may include temperature and pressure sensors, safety circuits, voltmeters, ammeters and other sensors (not shown), as needed.

0047. In another embodiment, an MCB may have more than one controller whereby each controller monitors and operates one or more cores in the MCB. In still another embodiment, controller **3** may be implemented externally to MCB **7**. Other variants of distributed control are also possible.

0048. Figure 1B is a block diagram of an MCB connected to a smart charger. In this embodiment controller **3** communicates with smart charger **5** over battery interface **4**. In some embodiments control of the MCB **7** may be shared between the MCB controller **3** and the smart charger (SC) **5**. Operational measurements may be provided to smart charger **5** over battery interface (IF) **4**.

0049. In other embodiments, the control of the cores may be implemented entirely in the SC **5**, In this case SC **5** also monitors and operates the MCB. Hybrid configurations are also possible, where some cores have their own controller **3** and the SC **5** controls the functionality of the reminder of the battery cores which are not controlled by controller **3**.

0050. In one embodiment MCB controller **3** detects the usage pattern of MCB **7** including its charge and discharge pattern and determines when to charge the MCB **7** to a 'vacation level' charge. The vacation level is defined here as the level of charge at

which the battery may be safely stored for a long period without significant use without major capacity degradation. Once charged to the vacation level, the MCB controller **3** will then decide, based on the detected usage pattern, the best time to charge the stored battery to full capacity. This delay of full charging until required may substantially improve battery lifetime. This similar optimization of charge levels is not restricted to MCBs and can also be used with single core batteries.

0051. In another embodiment, the MCB **7** is not rechargeable and each core is a disposable battery and no energy juggling is performed inside the MCB **7**. The discharging cycle may be performed in a continuous mode, when all cores are discharged in parallel, or in a pulse mode, when discharging of each core is done during an assigned time slot. The time slots are assigned by the MCB controller **3**. Discharging time slot durations are dependent on the energy demand of the external load and current condition of each non-rechargeable battery core. The pulse discharge mode reduces the polarization effect, while individual adjustments of discharge timing compensate for variations in depletion/diffusion processes attributable to the manufacturing process. When a core becomes unusable, the MCB controller **3** may indicate which core has to be replaced or serviced.

0052. When charged from an external power source, each battery core, or group of cores, may be pulse charged by individually connecting to the external power source for short periods of time . Duration and periodicity of the charging pulses is optimized according to: the design parameters of the battery core, individual history of each battery core or group of cores, individual state of charge of each battery core or group of cores, operational factors, and estimated internal impedance of the battery core. Other parameters may also be taken into consideration. One parameters might be the charging current value measured during different parts of a charging pulse. It is beneficial to measure the charging current value during the first portion of charging pulse and later during the second portion of charging pulse. Multiple charging current measurements (more than two) performed during the charging pulse would allow even better accuracy of accessing the current state of charge of each individual battery core, or group of battery cores.

0053. In still another embodiment, multiple MCBs communicate with each other, and use a central controller (not shown).

0054. Battery cores that are affected by aging, capacity deterioration and physical degradation, can be withdrawn from use in various ways. For example when all available battery output current is required, the cores are connected in parallel. However, in some routine energy delivery modes, the weak cores may be left aside to recover. The weak cores still participate in the energy juggling process to recover their charge storage capacity. Finally, when a core becomes unstable and dangerous to be actively used, the MCB controller **3** might permanently remove the core from the MCB activity.

0055. In another embodiment, the MCB **7** uses a variable number of battery cores during the charging and discharging processes. For example, when a small amount of energy needs to be stored in the battery, MCB controller **3** can decide to only use some of its battery cores. The unused cores can be kept at a low "vacation" charge level and continuously maintained through the energy juggling mechanism. A smart charger **5** communicates with the MCB controller **3** to negotiate the timing and the duration for the charging pulses. Such usage model might be beneficial in cases where energy costs are high and usage of all battery cores would require purchasing of more energy than necessary. The unused battery cores benefit from low charge levels, significantly lower compared to current industry recommended storage charge levels. Currently recommended "vacation" levels for Li-ion batteries are cell voltages of 3.6 V to 3.8 V. An MCB using energy juggling however, might allow unused cells to be kept at voltages of between 3.1V to 3.4V without affecting the cell or battery lifetime.

0056. A similar approach could be used when only a small amount of energy (compared to the overall energy already stored in the Multi-Core battery) is requested by the load. In such case, only a limited number of battery cores (perhaps as few as one) participate in the discharge process.

0057. Energy juggling involves the charge and discharge of individual battery cores in an MCB or the charge and discharge of the single battery core of a single core battery. Figure 2 is an exemplary discharge timing diagram. It shows the discharge timing for the

N cores $\mathbf{1_1}$-$\mathbf{1_N}$ of MCB **7**. During a first period **201**, the battery core $\mathbf{1_1}$ is discharged while all, or some, other cores $\mathbf{1_2}$-$\mathbf{1_N}$ are resting. During a second period **202**, the battery core $\mathbf{1_2}$ is discharging while all, or some, other cores are resting, and so on. During time period **203** battery core $\mathbf{1_i}$ is discharged while all or some cores are resting. Finally, during time period **204** battery core $\mathbf{1_N}$ is discharged while all or some cores are resting. For the general case when the MCB **7** has N cores, the total discharge period is defined as 'TD' and the discharge time for core **i** is denoted as 'TDi', where $i \in [1\text{-}N]$. The term 'discharging-to-rest time ratio' (DTR) is used for the ratio between the discharge and rest times for a core and is given by the formula

0058. $DTR = TDi/(TD-TDi)$.

0059. A similar approach may be used for charging the cores of the multi-core battery (MCB) **7**. The total charging time for all battery cores in MCB **7** is denoted as 'TC'. The charging time for core **i** is denoted as 'TCi', , where $i \in [1\text{-}n]$. The term 'charging-to-rest time ratio' CTR is used for the ratio between the charging and rest time of a core and is given by the formula

0060. $CTR = TCi/(TC-TCi)$.

0061. While Figure 2 shows equal discharge times for all cores, the charging and discharging durations for individual cores can be different in some embodiments. Pulses of varying duration may be used for the same core.

0062. Figure 3 is an exemplary timing diagram for charging and discharging of a single core. There is a first charge period **210** with pulse duration T1, followed by a first discharge period **212** with a pulse duration T2, followed by a second charge period **213** of duration T3, and finally a second discharge period **214** of duration T4. Using charge and discharge pulse durations of differing values is advantageous for the battery health in some applications.

0063. In one embodiment, the durations of TDi and TCi are adjusted according to the state of charge of the i-th core. For example when core **i** has a low state of charge the duration TCi is increased.

0064. In general, the DTR ratio and/or CTR ratio for each core is adjusted depending on the battery's static parameters and operational parameters.

0065. Referring to figure 1B, the smart charger **5**, or the MCB controller **3** may determine the individual adjustments for each battery core. The smart charger **5** can also devise individual adjustments for groups of battery cores.

0066. The charging energy for energy juggling may be supplied from smart charger **5.**

0067. Alternatively, the charging energy may be obtained from another core in MCB **7.**

0068. In another embodiment, the charging energy for a first core is supplied from a second core, stored temporarily in an intermediary energy storage device and supplied to the first core via a DC to DC converter. In another embodiment, depending on the source used for charging the cores, (i.e. one of the battery cores, or an external source), MCB **7** may be equipped with an ultra-capacitor, as to absorb a portion of the charging energy provided by the charging source. This portion of charging energy is then delivered to a load during the rest time.

0069. By varying the duration, periodicity and shape of the charging pulses, various charging patterns may be selected to optimize the charging time for a specified core, or to optimize the battery calendar life, or to optimize the battery capacity.

Energy juggling

0070. As indicated above, energy juggling can reduce the energy losses and improve battery lifetime and capacity. The duration, shape and periodicity of the charge/discharge pulses may be adjusted depending on the actual state of charge of each battery core. In one embodiment, after a battery has been charged to a pre-established state of charge during a charging cycle, the charging cycle is stopped and energy juggling begins.

0071. In another cases, the energy juggling process may be started from the beginning of the MCB charging process.

0072. In one embodiment of energy juggling, energy is pumped from one battery core to another battery core inside the MCB, such that the energy remains within the MCB. Energy juggling can occur not only when the battery is idle (not discharging into a load) or also when it is discharging into a load.

0073. For example, in an MCB when a first core is discharging into the load, two other cores discharge a short current pulse into a fourth core. Thereafter, the most recent charged fourth core discharges into the load. During this discharging period the first discharged core is charged by a short high voltage pulse supplied from a newly configured group of two or more battery cores. The process is repeated so that each battery core gets periodically pulse charged and pulse discharged for a short period of time.

0074. During energy juggling, a selected battery core can be charged with short pulses from one or more other cores of the MCB. A selected core can also be discharged into another core. A battery core can be connected in parallel with other cores, or in series with other cores. In some embodiments current pulses are delivered from one battery core to another via an intermediate energy storage device, such as a capacitor. In another embodiment, a DC to DC converter is used to generate the charging voltage.

0075. Figure 14 is a schematic diagram of a battery using a DC to DC converter to generate a charging voltage. Battery **1401** contains cell **1410**, capacitor **1420**, switches **1431**, **1432** and **1433** and DC to DC converter **1460**. Energy juggling proceeds as follows. With switch **1431** closed and all other switches open, capacitor **1420** is charged from cell **1410**. Switch **1431** then opens and switch **1432** closes. DC to DC converter **1460** supplies a charging current to cell **1410** at a voltage higher than voltage of cell **1410**. DC to DC converter **1460** converter allows independent control of the timing and amplitude of the charging pulse. DC to DC converter **1460** is controlled by MCB controller **3** in one embodiment. DC to DC converter **1460** may use a variety of known architectures. In one embodiment DC to DC converter **1460** is a boost type converter.

0076. In one embodiment a pulse duration of 0.5 sec and pulse amplitude of 2-3 Amperes is used. It should be understood that pulse duration, periodicity, amplitude and shape could be different for each type of battery cell or group of battery cells. The duration periodicity, amplitude and shape of periodic pulses can be determined based on operational parameters of the battery.

0077. Energy juggling involves charging/discharging the cores in a MCB in a certain order. Different numbers of battery cores may be used during the charging and discharging cycles. It is also possible to combine the battery cores into groups and to charge/discharge more than one battery core at a time. For example, during some energy juggling periods a group of 2 cores may charge a third core; then, a group of 3 cores may charge a group of two cores ; thereafter, a group of 5 cores may charge a group of 3 cores, and so on. The battery cores may participate in different groups and as such, are exposed to different charging/discharging currents which further improves battery lifetime.

0078. Figure 4 is a schematic diagram of an exemplary switching network for a four-core battery. MCB **420** contains four Li-ion battery cores **431, 432, 433, 434** and has a nominal charge storage capacity C. MCB **420** connects to external load **410** through output terminals **451** and **452**. A plurality of switches **S1...S15** are used to configure the battery into multiple charging/discharging configurations. Other components of the MCB such as the controller and buses are not shown for clarity.

0079. The configuration shown in Figure 4 can be used to implement one embodiment of the method for extending the calendar lifetime of the batteries using pulse charging and discharging technique, called "energy juggling".

0080. Table 1 shows the state of the switches **S1...S15** corresponding to three controlled pulse charge/discharge modes.

0081. Table 1.

Switch #															Battery Mode
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
1	1	0	0	1	1	0	0	1	1	0	0	1	1	0	1) Battery delivers 3.7 V with current up to 4x2C= 8 C (C has a numerical value for a core capacity) when discharging. All cores charging in parallel when charging
1	0	0	1	0	0	0	1	0	0	0	1	0	1	0	2) Battery delivers 15.1 V with current up to 2C. Charging is running with all cores in series. Voltage levelling required.
0	0	1	1	0	1	0	0	0	1	0	0	1	1	0	3) Core 434 is connected to outside and can be charged from a charger or discharged into a load. Output voltage is 3.7 V. Cores 431, 432 are connected in series and provide 7.4 V discharge into core 433. Cores 431, 432, 4333, are all disconnected from outside.

0082.

0083. By changing the configuration for switches **S1... S15** the battery can be configured to additional multiple modes similar to Mode 3, but with other pairs of battery cores discharging to a third core while another core is connected to an outside load **10**. To avoid providing repetitive information we are not describing such modes. Preferably, each mode configuration is maintained for a very short period of time. We have tested time periods between 50 msec to 2 sec, but these periods can be longer depending on the state-of-charge of both the charging and discharging cores.

0084. Different types of switches **S1-S15** may be used for the high side (coupling to output terminal **451** and the low side (coupling to output terminal **452**) switching to

minimize losses during storage. If same type of switches are used, the voltage level V1 to which a first battery core **431** is charged by a second partner battery core **432**, and the voltage level V2 to which the first battery core is then discharged to a third partner battery core **433**, may be optimized to minimize overall energy losses.

0085. Other arrangements may be used taking into account various factors relevant to charging/discharging requirements and core status. Timing, duration, and pulse shape for charging a battery core by its partner battery cores can vary depending on the state-of-charge, the health status of each core and other operational parameters. Discharging of battery cores into external load **410** can be done according to a pre-established rotation. In such a case, current is constantly provided to an external load **410**.

0086. As an example, for a Multi-Core Battery with 230 battery cores forming a 120V battery, the output voltage may be adjusted in increments of one cell voltage, or 3.7 V. As mentioned above, for the highest output current and lowest output voltage, all battery cores are connected in parallel.

0087. Due to the fact that the battery cores are practically never connected in parallel for long periods of time, there is no need to pre-match their internal resistances, as usually done when battery cores are assembled in an MCB. As the internal resistance of cores change in time, the cores become quite different from each other. The monitored differences in battery cores may be compensated by a variable number of battery cores grouped for charging and discharging during the energy juggling process. Similar timing and group adjustments are done during pulse charging and pulse discharging as described in connection with Figure 3.

0088. Each core of an MCB may be equipped with an individual controller and a safety switch to deal with external factors like temperature, overload, pressure, etc. The individual core controllers communicate through a bus such as PCB bus **2** in figure 1A to control switches **S1-S15** of figure 4. The cores may have voltage and current sensors which may be controlled by a MCB controller **3** in Figure 1A, or from outside the MCB, by charger **6** in Figure 1B. Switch and battery core control may be also done through a wireless channel such as Bluetooth, WiFi, specialized UHF communications, conventional RF communications or NFC communication.

0089. It has also been observed that with periodic energy juggling, a Li-ion battery maintains almost a constant capacity even when operating at elevated temperatures of +55°C for 3 months. The results showed full restoration of the battery's nominal capacity by energy juggling.

0090. Figures 5-8 illustrate various circuits that may be used to implement energy juggling between two battery cores using a capacitor.

0091. Figure 5 is a schematic diagram of an exemplary energy juggling circuit. Circuit **501** contains battery cells **511** and **512**, capacitor **521** and switches **531**, **532** ... **537**. Capacitor **521** is sequentially connected to battery cells **511** and **512** for controlled periods of time using switches **531** to **537** to perform charging and discharging of battery cells **511** and **512**.

0092. Capacitor **531** may be a ceramic or electrolytic capacitor; other types of capacitors, or combinations thereof may also be used. The use of a super-capacitor (ultra-capacitor) is also possible. Furthermore, groups of capacitors could be used instead of one capacitor. Charge could be transferred to an individual capacitor or group of capacitors dedicated to each battery cell or each group of battery cells or batteries involved into the energy juggling process.

0093. A rechargeable battery may be used for performing the temporary energy storage function of the capacitor. Such a battery may be used as a temporary energy storage, subsequently transferring energy between battery cells, or groups of battery cells, or batteries. The combination of a capacitor and a battery is also possible for such temporary energy storage purposes. An inductor may also be used as a temporary energy storage device and perform a similar energy transfer function.

0094. When connected in parallel to battery cell **511**, for a first controlled period of time, capacitor **521** is first charged to a voltage level Vcap, while **511** is discharged by a controlled amount of energy. The amount of energy is controlled by adjusting the first period of time during which **521** is connected parallel to cell **511**. Thereafter, **521** is connected in series with cell **512** having a voltage Vcell2 and the voltage across the

combination of capacitor **521 and cell 512** reaches a combined value (Vcell2 + Vcap) sufficient to support the charging of **511**. This charging of cell **511** is performed for a second controlled period of time. During this second period of time, a portion of the charge previously supplied to capacitor **521** and a portion of charge from battery cell **512** are transferred to battery cell **511**. The second period of time may be adjusted whenever the transferred amount of energy needs to be adjusted.

0095. Instead of a single current pulse as described above, multiple current pulses could be used. In one embodiment, each energy transfer consists out of multiple current pulses each of which has an adjustable duration, amplitude and shape. In some cases, it is beneficial to perform the energy transfer with current pulses of varying duration, shape and amplitude.

0096. Similarly, the energy juggling process may be performed starting with battery cell **512** initially discharged onto capacitor **521** and then charged back from capacitor **521** coupled in series with battery cell **511**.

0097. A number of possible energy juggling circuits may be configured through switches **531** to **537** as further shown in Figures 6, 7 and 8. Figure 6A is a schematic diagram of an exemplary energy juggling circuit connection. Switches **531**, **533** and **535** are closed, capacitor **521** is connected in series with cell **512** for charging cell **511**. Figure 6B is a simplified circuit diagram of Figure 6A. Figure 7A is a schematic diagram of another exemplary energy juggling circuit connection. Switches **532** and **535** are closed, capacitor **521** is connected parallel to cell **512** and is charged by cell **512**. Figure 7B is a simplified circuit diagram of Figure 7B. Figure 8 is a schematic diagram of another exemplary energy juggling circuit connection. Switches **531** and **532** are closed and capacitor **521** is charged by cell **512**.

0098. Figure 9 is a schematic diagram of an exemplary energy juggling circuit for a four cells MCB. Cells **911** to **914** in MCB 901 are charged from external power supply **915** via switches **931** to **938** controlled by microcontroller **940**. Voltages and currents for cells **911** to **914** are measured and communicated to microcontroller **940**. Monitoring of only voltages may be sufficient in some cases. Based on the recorded history of measurement results and/or the most recently measured values, microcontroller **940**

decides the timing, shape and amplitude for the charging pulses for each battery cell. Each cell is charged for a period of time (Tcharge) followed by a time rest (Tpause). During (Tpause1) corresponding to the rest time of battery cell **931**, the other batteries **932**, **933**, **934** are charged. For battery **931**,

0099. Tpause1 = Tcharge2 +Tcharge3+Tcharge4+Tadd

00100. Tadd is an optional additional time if the battery, or a group of cells, needs extra time to relax after absorbing the energy delivered by the charging pulse. Microcontroller 940 may change as required the values of Tcharge1 to Tcharge4 and Tadd according to the actual state-of-charge and health status of each battery, as well as its history of charging/discharging cycles

00101. Figure 10 illustrates an exemplary energy juggling circuit for a four core MCB that uses a capacitor. MCB **1039** includes capacitor **1021**, switch array **1030**, controller **1040** and battery cells **1011** to **1014**. Capacitor **1021** is charged from selected battery cells **1011** to **1014** through switching array **1030** and discharged to selected battery cells **1011** to **1014** through switching array **1030**. Switching array **1030** consists of switches **1031** to **1038**. When discharging capacitor **1031**, in some embodiments, capacitor **1021** is connected in series with at least one of cells **1011** to **1014** by switching array **1030**, such that the combined voltage of the series combination is higher than the voltage of the cell selected for charging. The configuration of switching array **1030** is controlled by controller **1040**. Controller **1040** receives as inputs measurements of the cell voltages (shown as V1,V2, V3 and V4 in Figure 10). Although capacitor **1021** is shown as internal to MCB **1039** in other embodiments capacitor **1039** is an external capacitor.

00102. In another embodiment, a DC/DC converter is used to develop the charging voltage. In this embodiment, there is no need for a storage device such as capacitor **1021** to connect in series with another battery cell to create the charging voltage. When the DC/DC converter is used, one battery cell may be connected to another battery cell via the DC/DC converter without using an intermediary energy storage device. The DC/DC converter can be controlled to provide the necessary higher charging voltage.

00103. Figure 11 is a schematic diagram of a variable voltage MCB. MCB **1101** includes battery cells **1111** to **1114**, switches **1131** to **1142** and controller **1140** and output terminals **1151** and **1152**. Controller **1140** includes a smart load communication bus **1161**, a temperature input **1162** and voltage inputs **1064** to **1068**. In this embodiment battery cells **1111 to 1114** exchange current pulses between each other. Switches **1131** to **1143** allow individual battery cells **1111** to **1114** to be connected in series or in parallel, or to form groups of battery cells. For example, when switches **1131**, **1134**, **1138**, **1141** and **1143** are ON and all other switches are OFF, battery cells **1111 to 1114** are connected in series. In the situation that battery cells **1111** to **1114** are Lithium ion battery cells equally charged to a voltage of 4.2V, the battery can deliver a voltage of 16.8V between output terminals **1151** and **1152**. By switching switches **1131**, **1134** and **1136** ON and keeping all other switches OFF, the battery cells **1111** and **1112** are connected in series. This provides 8.4V voltage between the output connectors **1151** and **1152**.

00104. Variable voltage MCB **1101** may communicate with a smart load (not shown) equipped with an MCB controller via smart load communication bus **1161**. When the smart load controller requests a particular voltage or current, the MCB will dynamically self-reconfigure to satisfy the request. Such a variable voltage MCB has the advantage of eliminating a DC-DC voltage converter when a load requires a variable output voltage.

Figure 12 is a flow diagram of an exemplary pulse charging sequence of the MCB of figure 9. Pulse charging of the four cell MCB **901** uses external power supply **915**. At step **33** it is determined whether external power supply **915** is coupled to MCB **901**. If it is not coupled, then pulse charging is not possible, shown by branch 'Yes' of decision block **33**. If an external power supply is coupled, the process moves to step **35.** At step **35** voltages V1 to V4 are measured and voltage differences V2-V1, V3-V2, V4-V1 are determined and compared with historical cell voltage measurements. At step **37**, the charging time periods for cells **911**, **912**, **913** and **914** (TC1, TC2, TC3, TC4 respectively) are calculated. At step **39**, switches **931** and **932** are closed for a period TC1 and then opened after TC1 finishes. All other switches remain open. Next, at step **41**, switches **933** and **934** are closed for a period TC2. At the end of TC2, **933** and **934** are immediately open. All other switches remain open. At step **43**, switches **935** and **936** are closed for a period TC3, and then open at the end of TC3. All other switches

remain open. Thereafter, at step **45**, switches **937** and **938** are closed for a period TC4 At the end of TC4 switches **937** and **938** are opened. All other switches remain open. Voltages V1 to V5 are measured continuously in the meantime, as shown at **47**. At step **49**, it is determined if the charging should continue. If it is determined that charging should not continue the process stops, at step **53.** If it is determined that the charging should continue, the periods TC1, TC2, TC3 and TC4 are adjusted based on the current measurements in step **51** and the process returns to step **39**

00105. Figure 13 is a flow diagram of an example energy juggling process of the four cell battery used in the circuit of Figure 10. At step **30** it is determined whether an external charger is coupled to MCB **1039**. If a charger is coupled, no energy juggling takes place and the process ends at **52**. If an external power supply not is coupled to MCB **1039**, voltages V1 to V4 are measured and voltage differences V2-V1, V3-V2, V4-V1 are determined and compared with the historical values at step **32**. Charge pulse durations for TC1, TC2, TC3, TC4 and discharge pulse durations TD1, TD2, TD3 and TD4 respectively for energy juggling are computed at step **34**. A capacitor charging mode is also chosen from the possible capacitor charging modes M1...M7 shown in Table 2 below. Capacitor **1021** is charged according to the selected capacitor charging mode M, at step **36**, during TC1. The capacitor charging mode and duration determines the voltage that capacitor **1021** is charged to.

00106. At step **38**, switches **1031** and **1032** are closed for a period TD1, charging cell **1011** from capacitor **1021**. Switches **1031** and **1032** are immediately opened at the end of TD1. At step **40**, capacitor **1021** is charged according to the selected capacitor charging mode for period TC2. Next, at step **42**, switches **1033** and **1034** are closed for a period TD2 charging cell **1012** and then immediately opened at the end of TD2.

00107. Capacitor **1021** is now charged according to the selected mode at step **44**, during TC3. At step **46**, switches **1035** and **1036** are closed for a period TD3 charging cell 1033 and immediately opened at the end of TD3. Capacitor **1021** is again charged, this time according to the selected mode at step **48**, during TC4. At step **50**, switches **1037** and **1038** are closed for a period TD4 charging cell **1034** and then immediately opened at the end of TD4. At step **54** if energy juggling should continue. If yes, the process returns to step **32** . If no further energy juggling is needed, the process stops at step

52. This decision to halt juggling may be based on reaching a certain battery capacity threshold, a cell or battery voltage threshold, a discharge current or other operational parameters. Juggling may also cease if the operating mode of the battery changes. For example, juggling might cease if the battery is required to deliver full power.

00108. Table 2 shows the position of the switches for various modes M1-7, where '1' means that the respective switch is closed, '0' means that the switch is open.

Table 2

	1031	1032	1033	1034	1035	1036	1037	1038
M7	1	0	1	0	0	0	0	0
M6	1	0	0	0	1	0	0	0
M5	1	0	0	0	0	0	1	0
M4	1	0	0	0	0	0	0	1
M3	0	0	1	0	0	0	0	1
M2	0	0	0	0	1	0	0	1
M1	0	0	0	0	0	0	1	1

00109. The number of battery cells is variable and is not limited to the examples described above. In large battery groups, individual battery cells may perform charging while other groups, or individual battery cells, are relaxing, and the remaining groups, or individual battery cells, are performing energy juggling.

00110. In some cases energy juggling might be combined with battery charging. When combined, energy juggling may be performed for battery cells, or groups of battery cells, or batteries, not currently involved in the battery charging process. The energy juggling process may be performed while some battery cells of battery are in a relaxing period.

00111. A similar approach may be used when the MCB delivers energy to an external load. In such a case, some individual battery cell, or group of cells, or batteries, may be connected to the load, while other battery cells, or groups, or batteries, are relaxing, and the remaining battery cells, or groups of cells, or batteries, are performing energy juggling. Relaxation time may be adjusted or even eliminated.

00112. Energy juggling is applicable also to embodiments where the MCB contains battery cores of different shapes and sizes that are to be assembled in a desired overall shape having pre-designed dimensions. The physical differences of the cores leading

to differences in their performance characteristics are compensated by controlled variable charging/discharging pulses, including pulse periods, the number of cores placed in the receiving groups and the delivery groups, during the energy juggling process.

00113. Another embodiment of the MCB uses different batteries, or groups of batteries, placed at different locations within the electrical system. The energy juggling mechanism is now adjusted according to the specifics of each battery corresponding to its actual location. Same approach applies during the charging/discharging cycles.

00114. Practical applications

00115. The methods described next are also applicable to batteries that must permanently be in a full state-of-charge for optimal operation.

00116. It has been determined by experimentation that Li-ion batteries have an optimal charge level called 'vacation level'. When a Li-ion battery is stored at this charge level, minimum losses relative to its capacity are noted for long periods of time. For example, it is not recommended to store a Lithium-ion battery at a charge level below 15% from its nominal capacity for a long time. Conversely, if stored fully charged, the Li-ion battery quickly loses its charge storage capacity. Energy juggling can prevent unnecessary energy losses and significantly improves the lifetime of a Lithium-ion battery even when it is stored fully charged.

00117. In some circumstances it may be important to keep a battery at full capacity for an extended period of time. For example, a battery used as a power back-up is required to deliver the full capacity at any moment of time. Therefore, for greatest portion of its working life this type of battery is fully charged. In this case, energy juggling may be performed using a short cycle pulse charging /discharging using a load and a charger. The load may be a 10 W, 1 Ω resistor. The battery is discharged by several millivolts (mV) only in this embodiment of energy juggling. The voltage of the battery should be preferably monitored and the timing for pulse discharging/charging adjusted according to the measured voltage after each charging/discharging cycle, the voltage under load and the dynamics of voltage dropping under load. Charging may be performed through an USB power supply, via computer controlled solid state relay. The power supply voltage

could be different from regular USB Vbus value, for example any value from 4.3V to 8 V. Other types of relays could be used, not limited to solid state relays. A reed relay would be beneficial because of high endurance and low voltage drop values. Regular signal or power relays may also be used.

00118. Energy juggling may be done periodically or randomly. During the energy juggling process the energy may be transferred between all battery cells of a battery and in some cases the transfer may be performed from a battery cell with lower energy to a battery cell with higher stored energy level. The duration and periodicity of such energy loss prevention operations depends on the overall state-of-charge of the MCB , the state-of-charge of each battery core, battery temperature, battery age, optimal battery efficiency, desired battery self-discharge rate, etc.

00119. Energy juggling also allows the MCB to be recharged to a range of different charge levels without affecting the battery's calendar lifetime and overall health status.

00120. Energy juggling should e distinguished from cell leveling. Cell leveling is performed to maintain all cells in an MCB at an equal state of charge . Energy is always transferred from battery cells with higher amounts of stored energy to battery cells with lower amounts of stored energy. This transfer is usually done during battery charging and in some cases during battery discharging.

00121. The energy juggling mechanism transfers energy between cells of an MCB periodically, during battery storage, or battery charging, or battery discharging. Unlike cell leveling, energy juggling intentional creates time varying differences between the state of charge of cells in an MCB. In the case of a single cell battery energy is moved back and forth between the cell and a temporary energy storage device.

00122. In some embodiments energy juggling is combined with the cell leveling. However there are some situations where cell leveling is not desirable. For example, some battery cells in an MCB may be kept as reserve cells and purposely kept at long term vacation levels, different from the charge levels of working cells.

Capacity restoration based on pulse charge/discharge

00123. Battery capacity is equal to the total time a battery can deliver energy to a known load, (within prescribed current value limits) multiplied by the current. As such, the battery capacity is expressed in ampere hour (Ah) and is usually tested by connecting the battery to the load and measuring the time from start until the battery voltage reaches the low voltage threshold.

00124. Testing the capacity restoration (recovery) of rechargeable battery is now described. A Sony Ericsson BST-33 battery with serial number 766135SWKFLT was used for the test. The previously number of cycles undergone for this battery was unknown. Estimated calendar age of the battery was around 5 years. During first capacity measurement test the battery has shown capacity of 150 mAh instead of the rated value of 900 mAh.

Experiment #1 - Lifetime Recovery

00125. One of the experiments used for recharging a battery comprises two phases. During a first phase, a constant current of 0.5A was applied to the battery until it reached a 4.2V level. For Li-ion batteries 3.7V is considered the standard voltage, while 4.2V the maximum recommended voltage. During a second phase of charging a constant voltage of 4.2 V was maintained until the charging current decreased to 0.01A. At this point the battery was disconnected from charger for a 10 minutes resting period, followed by a discharge at constant current of 0.5A until the battery reached 3.0V level, which is the lowest voltage reached by the tested batteries. The battery was kept in idle state for a second resting period of 10 minutes. The above steps were repeated three times, and the maximum capacity of 900 mAh was recorded.

Experiment #2

00126. In another experiment, a battery was connected to an external USB power supply via a solid state relay controlled by a computer. Computer based software performed a series of charging pulse cycles. The relay was kept in ON state for 3 sec and OFF state for 12 sec. The solid state relay with ON resistance of 250 mΩ was used. The battery voltage was measured after each 12 sec OFF period. The ON/OFF cycles where repeated until the battery voltage reached 4.2V at the end of 12s OFF period. After this the battery was kept in idle state for 10 minutes of resting period. Its voltage was measured at the end of the resting period. If measured voltage was below 4.2V, another

series of above described charge pulse cycles was performed until reaching the next resting period. Reaching of 5 resting periods was allowed. The battery pulse–discharging mode was initiated after a maximum of 5 resting periods.

00127. Battery pulse-discharging was started after a 10 min resting period. Discharging current was kept at 1A level. Discharge ON time was 2 seconds, and discharge OFF time was 6 seconds. Pulse discharging was stopped after battery wattage reached 3V level. Battery was kept in idle state for 10 min before performing any other testing step. The total elapsed discharge ON time was considered to be the measured battery capacity value.

00128. After performing of four such charge/discharge cycles, the battery delivered 850 mAh. A number of 100 pulse charge/discharge cycles have been performed with battery under test. The measured capacity was between 850 and 950 milli-Ah without showing any degradation.

Experiment #3.

00129. It has been determined experimentally that the capacity of an aged Li-ion battery, i.e. a battery with substantially reduced capacity and reduced performance characteristics may be restored if the battery which was containing a charge to a voltage Vinitial between 3V and 4.2V periodically performs following steps:

(a) the battery is pulse discharged to a voltage lower than the Vinitial by several millivolts (mV) and the total discharged energy is recorded, and thereafter,

(b) the battery is pulse charged with approximately same energy amount back.

00130. The recorded energy amount discharged from and charged back to the battery is maintained at the same level and as such, the battery is maintained at approximately the same voltage level Vinitial after each pulse charging /discharging cycle.

00131. Same treatment may be applied to new batteries. In this case, the battery capacity and performance do not deteriorate for a long period even when the battery is charged to the nominal voltage and exposed to a high temperature, i.e. +55°C. The period during which the battery was fully charged and exposed to high temperatures was 5 month, equivalent of 5 to 6 years of calendar life. The battery capacity was not fading during the entire period of testing.

Experiment #4

00132. This testing was done with a battery charged from a USB power supply, 3 sec ON and 12 sec Off. The battery was discharged through a solid state relay to a 3 Ohm load, 2 sec ON and 6 sec OFF. The solid state relay has 250 mΩ in ON state.

00133. This test shows that when an aged battery with faded capacity is pulse charged and pulse discharged multiple times, its capacity is restored and the battery remains stable for a large number of subsequent pulse charge/discharge cycles. Such a large number of subsequent charge/discharge cycles is not expected, since the battery had exceeded both its calendar lifetime and its cycle life.

Experiment #5

00134. The methods described herein may be used for controlled variable voltage MCB. Variable voltage MCB can use different reconfiguration/charging strategies depending on the available battery charger. An intelligent MCB will reconfigure itself according to an optimal mode, matching the available charger voltage/current.

00135. For example, an electric power tool is equipped with a controller and a controlled voltage MCB . The tool controller communicates with the MCB controller to request the presently needed voltage and current as well as the voltage/current needed in the nearest future. The variable voltage MCB can supply power as requested. The result is a high efficiency for the power tool providing a longer working time compared to a regular power tool.

00136. Another way in which the controlled variable voltage MCB may be used is for electric vehicles. Use of the methods of recharging provided here, allows the vehicle to

achieve a higher efficiency and a longer driving range for the same amount of energy stored in the battery. Such controlled variable voltage MCB has an extended calendar life, without significant degradation of its capacity.

What is claimed is:

1. A method comprising performing a capacity enhancing operation on a cell within an electrochemical energy storage system whereby said capacity enhancing operation is performed internally to the electrochemical energy storage system.
2. The method of claim 1 wherein the capacity enhancing operation comprises a charging and a discharging operation
3. The method of claim 2 wherein said charge operation is performed from at least a first cell to at a second cell.
4. The method of claim 2 wherein said charge operation is performed from at least a first passive energy storage element to a first cell.
5. The method of claim 2 wherein said charge operation is performed from a series combination of at least a first cell and a first passive energy storage element to a second cell.
6. The method of claims 4 and 5 wherein said first passive energy storage element is a capacitor or an inductor.
7. The method of claim 2 wherein said charging operation uses a DC to DC converter.
8. The method of claim 2 wherein the timing of said charge and discharge operations are based on operational parameters of the electrochemical energy storage system.
9. The method of claim 8 wherein said operational parameters include: a temperature, a cell charging current, a cell discharging current, a cell voltage, an internal impedance, a internal battery pressure, a number of system charge / discharge cycles.
10. The method of claim 1 wherein said capacity enhancing operation is performed repetitively until a cell capacity threshold is met.
11. An electrochemical energy storage system containing a cell and circuitry for performing a capacity enhancing operation on the cell whereby the capacity enhancing operation is performed internally to the electrochemical storage system.
12. The electrochemical energy storage system of claim 11 wherein said capacity enhancing operation comprises a charge and a discharge operation.
13. The electrochemical energy storage system of claim 12 wherein said charge operation is performed from at least a first cell to a second cell.
14. The electrochemical energy storage system wherein said charge operation is performed from at least a first passive energy storage element to a first cell.

15. The electrochemical energy storage system of claim 12 wherein the electrochemical energy storage system contains a passive energy storage device and the charge operation is performed from a series combination of at least a first cell and a first passive energy storage element to a second cell,
16. The electrochemical energy storage system of claims 14 and 15 wherein said passive energy storage element is an inductor or a capacitor.
17. The electrochemical energy storage system of claim 12 wherein said system contains a DC to DC converter and said charge operation is performed using the DC to DC converter.
18. The electrochemical energy storage system of claim 11, said system containing a controller for determining the timing of said charge and discharge operations from the operational parameters of the electrochemical energy storage system.
19. The electrochemical energy storage system of claim 11, said system containing circuitry for sensing operational parameters of the system including: an internal battery pressure, a charging current, a discharging current, a cell voltage, an internal impedance, a number of system charge/discharge cycles.
20. The electrochemical energy storage system of claim 11 whereby said capacity enhancing operation is performed repetitively until a cell capacity threshold is met.

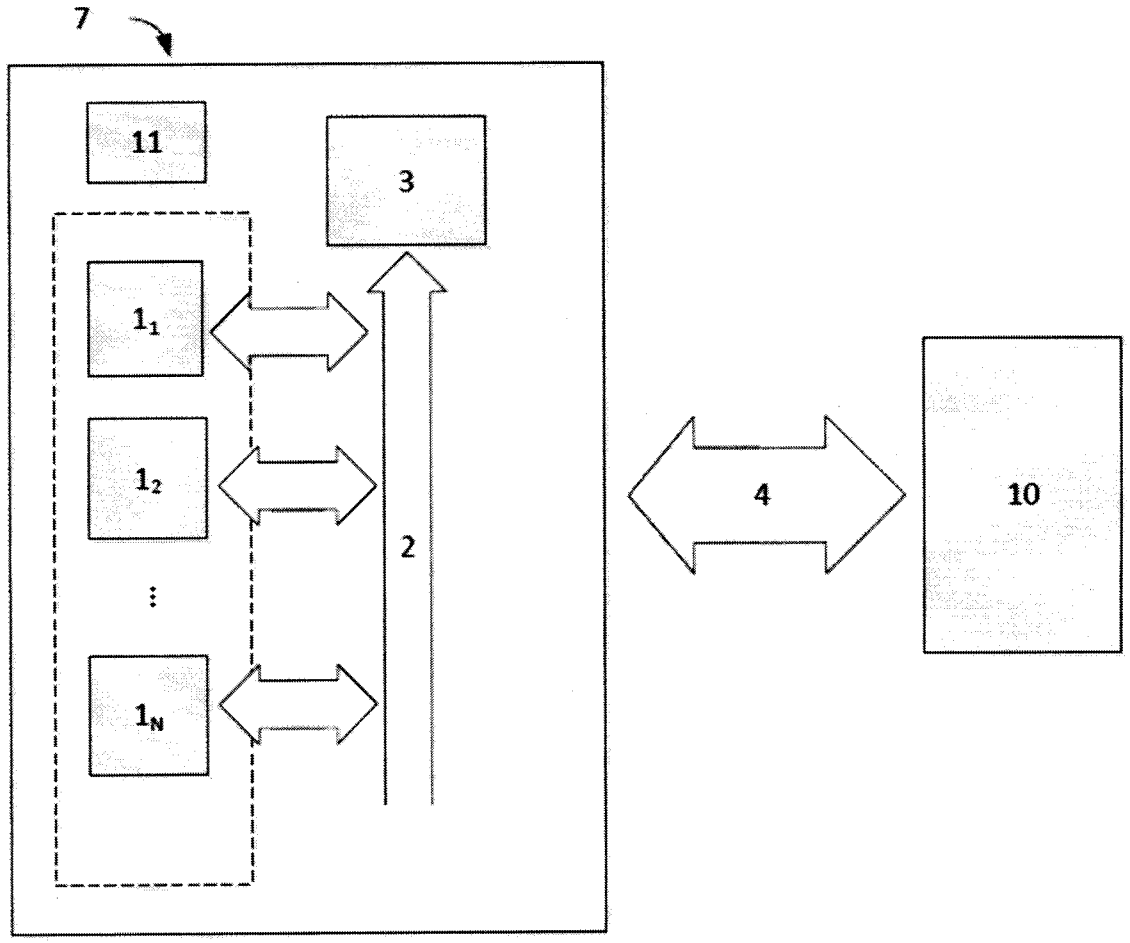


FIG 1A.

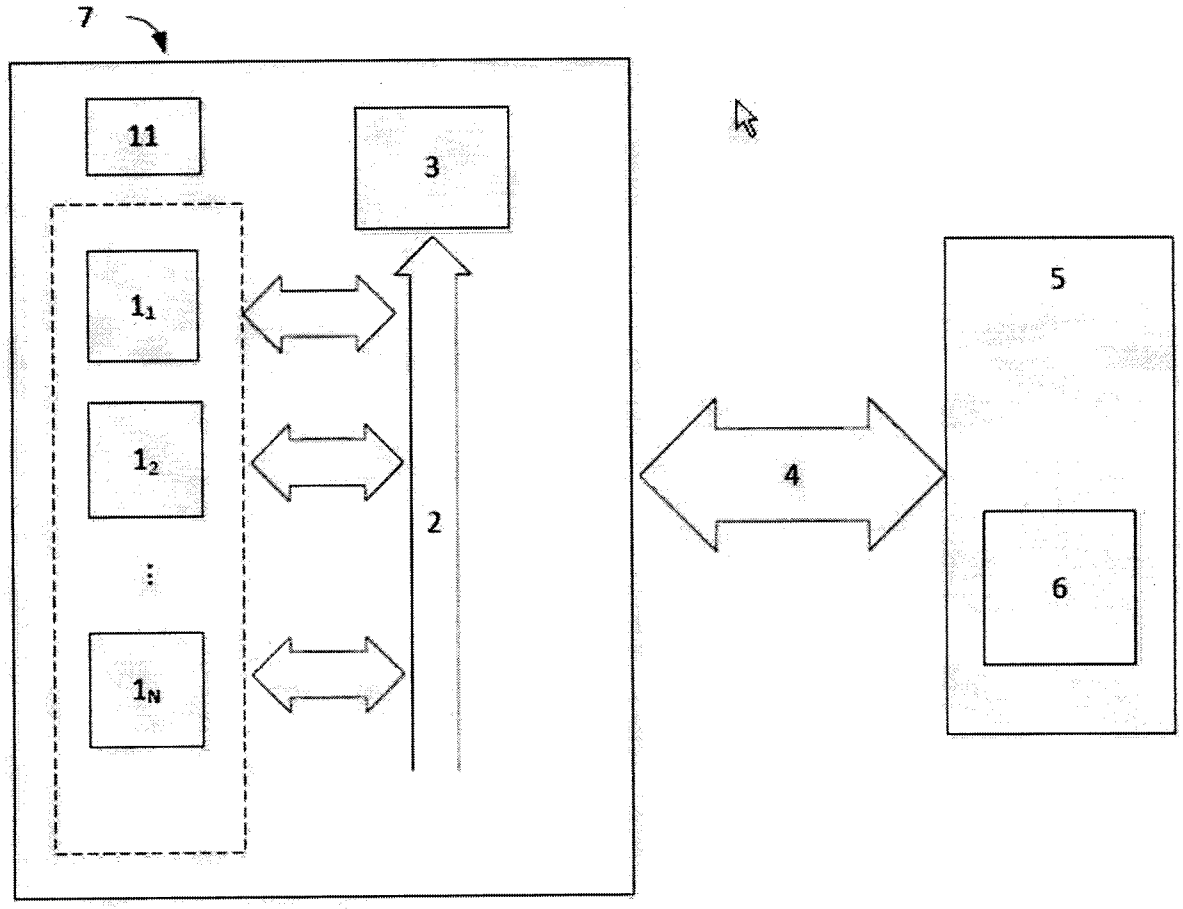


Fig 1B

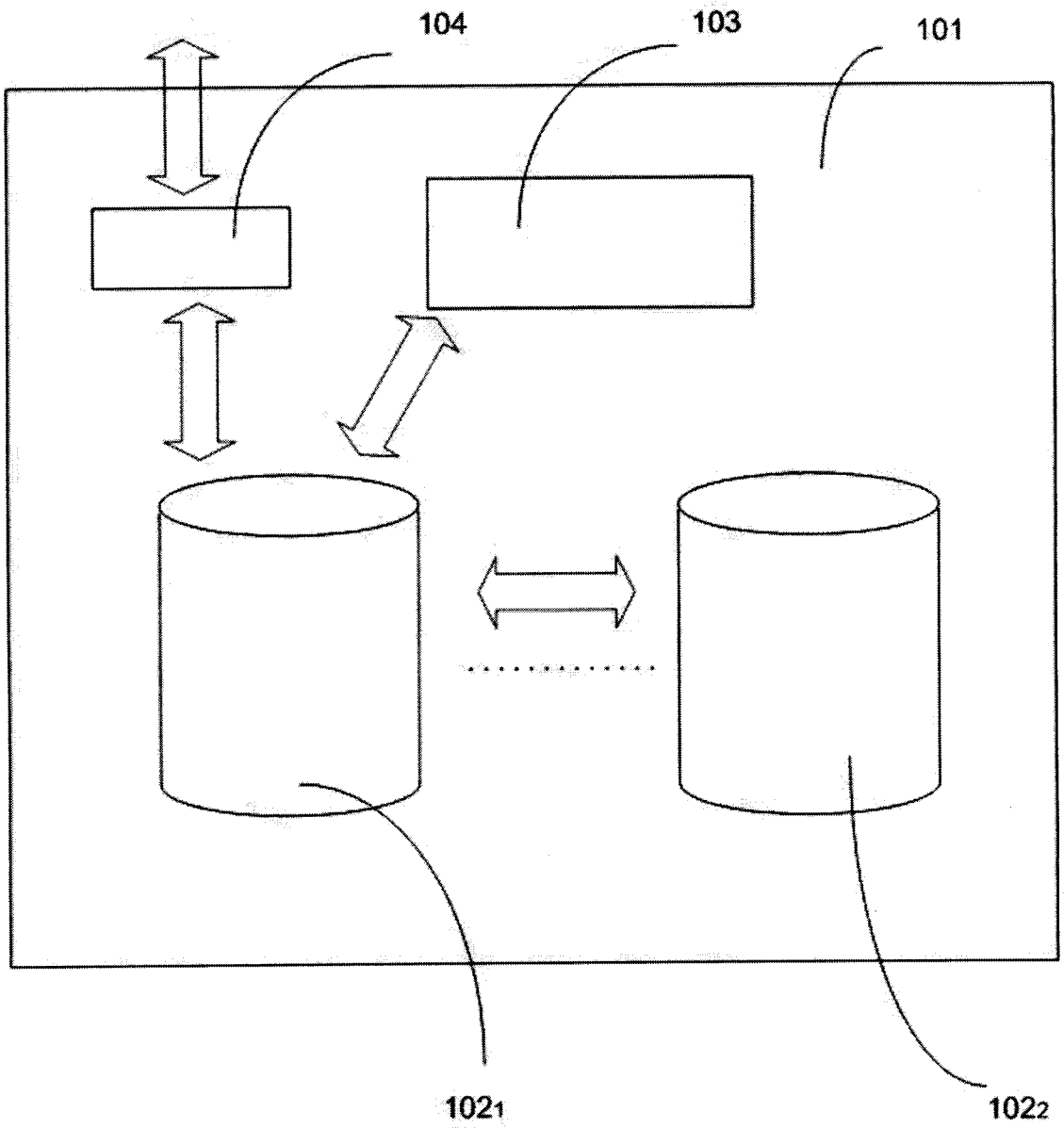


Fig 1C

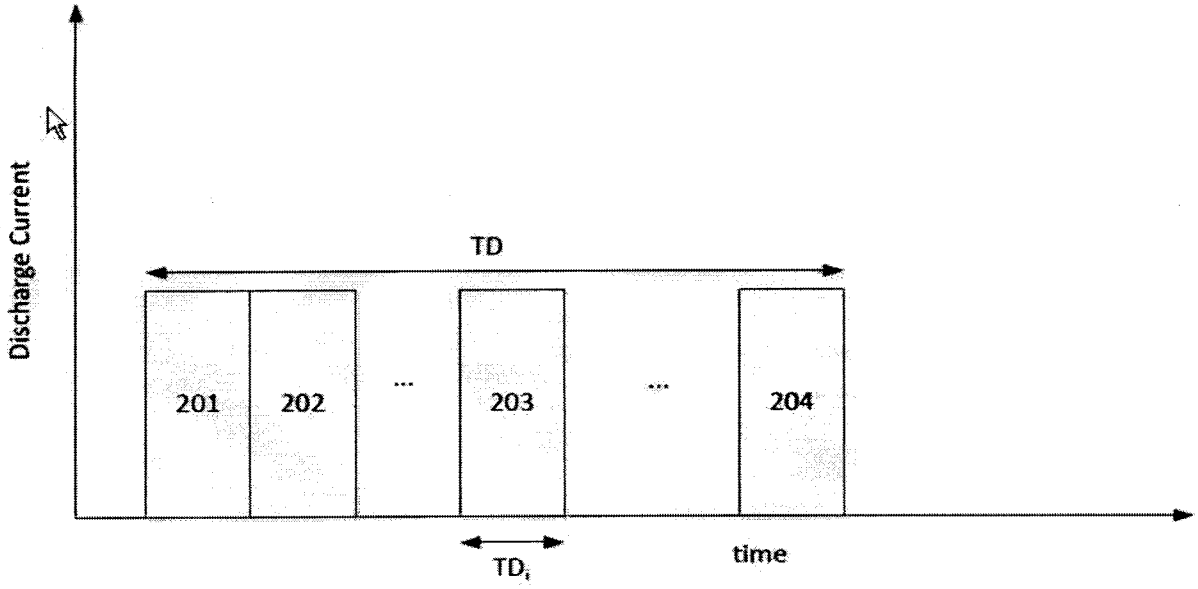


Fig 2

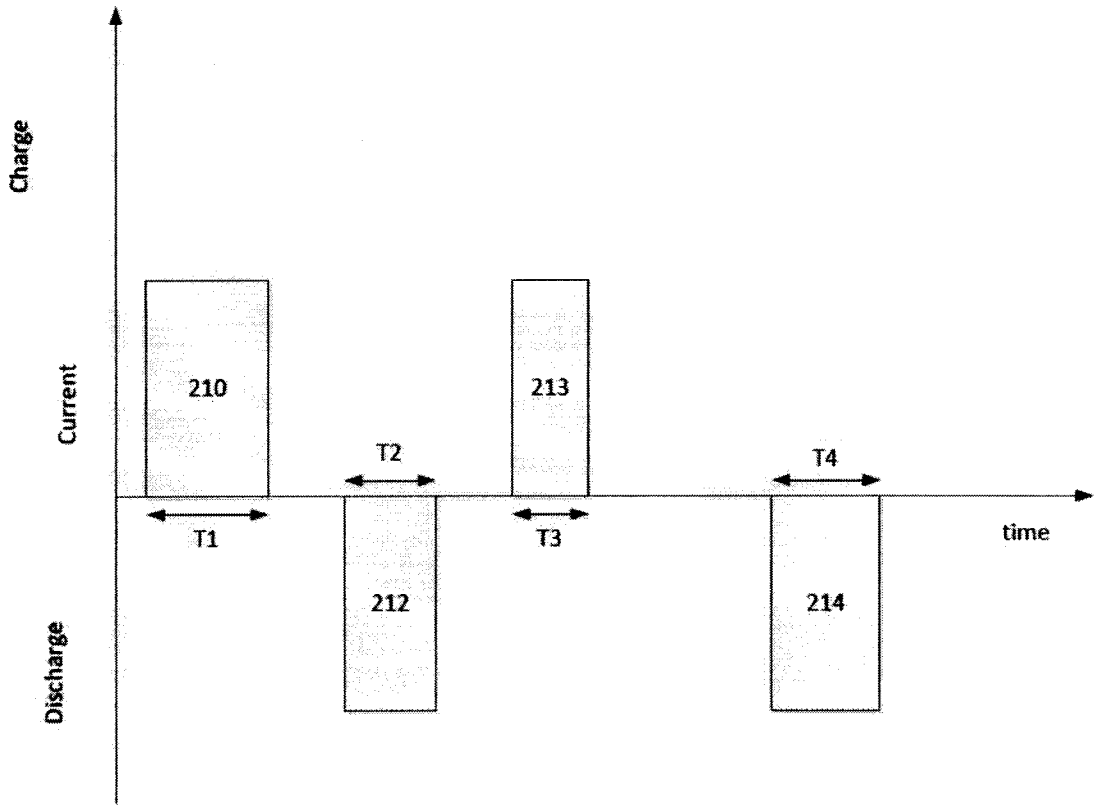


FIG 3.

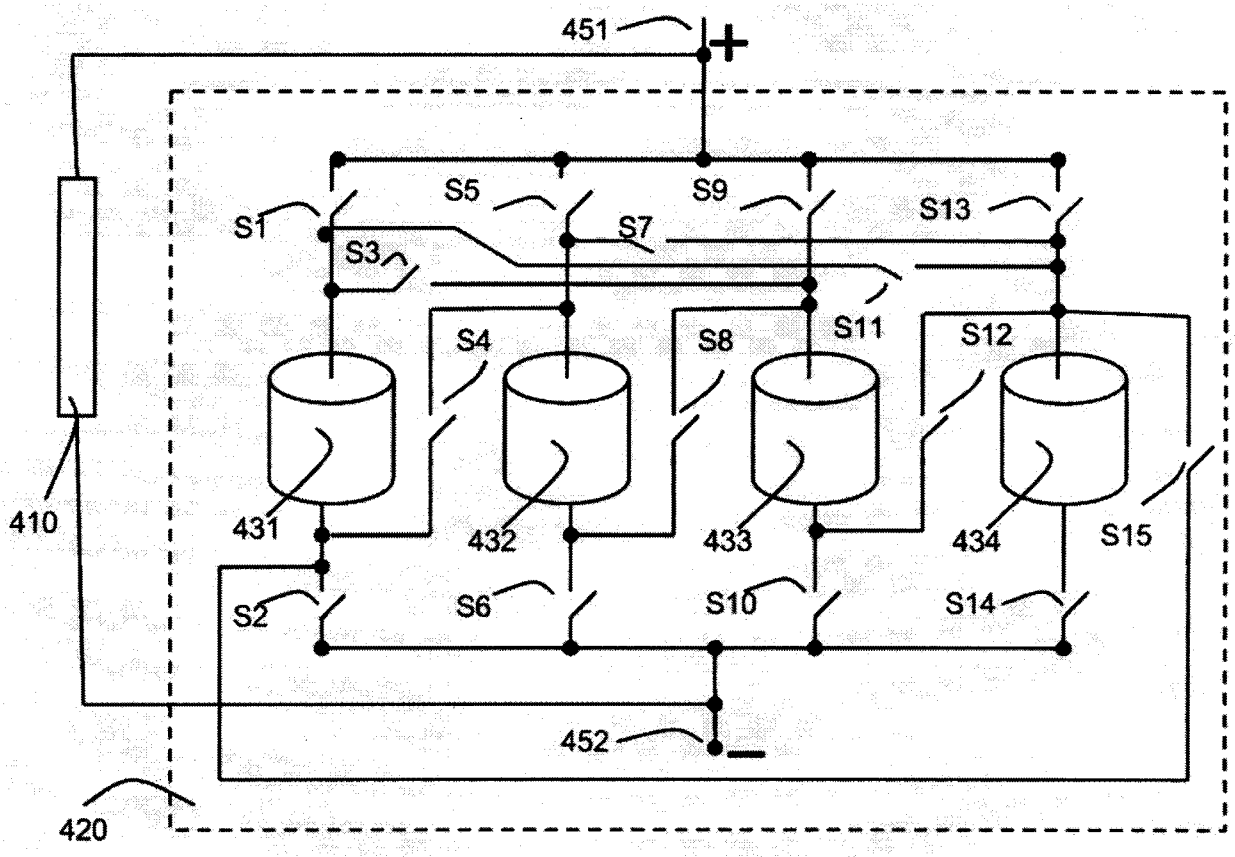

451
+
S1
S5
S9
S13
S7
S3
S11
S4
S8
S12
410
431
432
433
434
S15
S2
S6
S10
S14
452
−
420

Fig 4

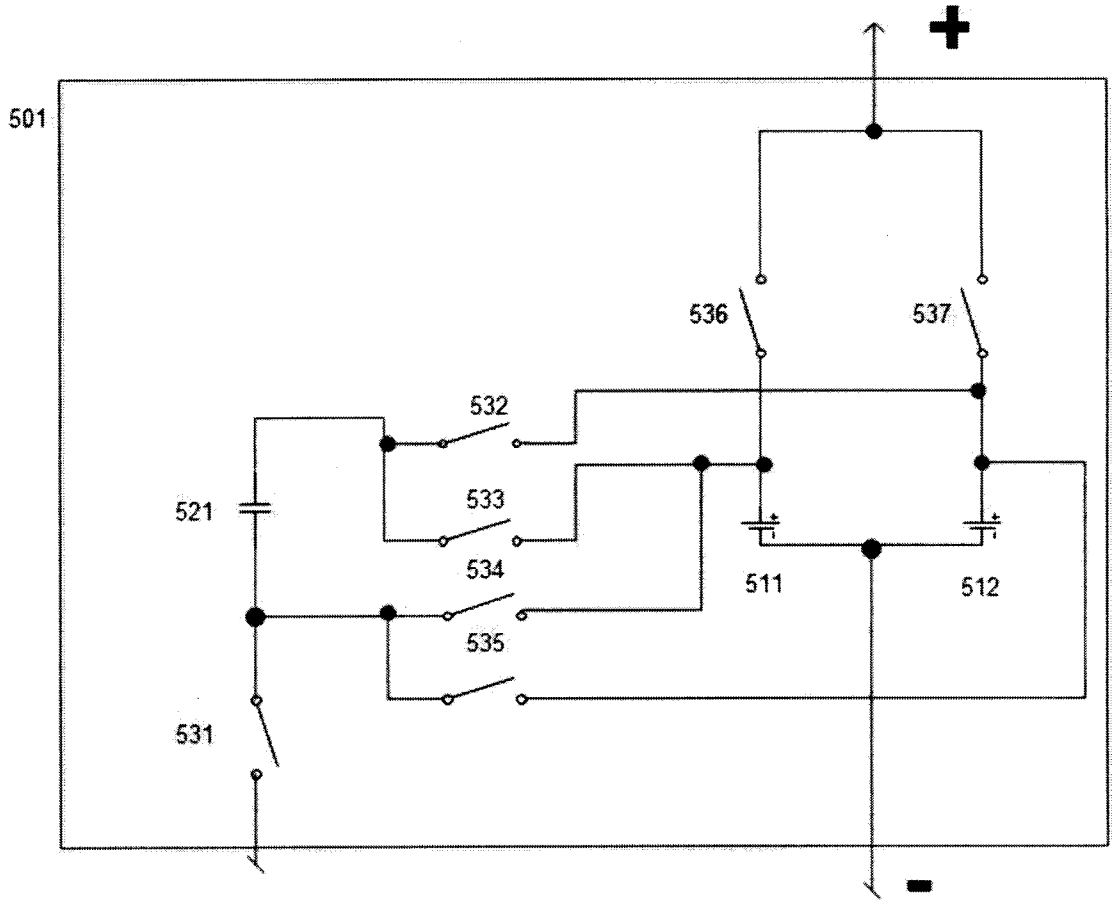


Fig 5

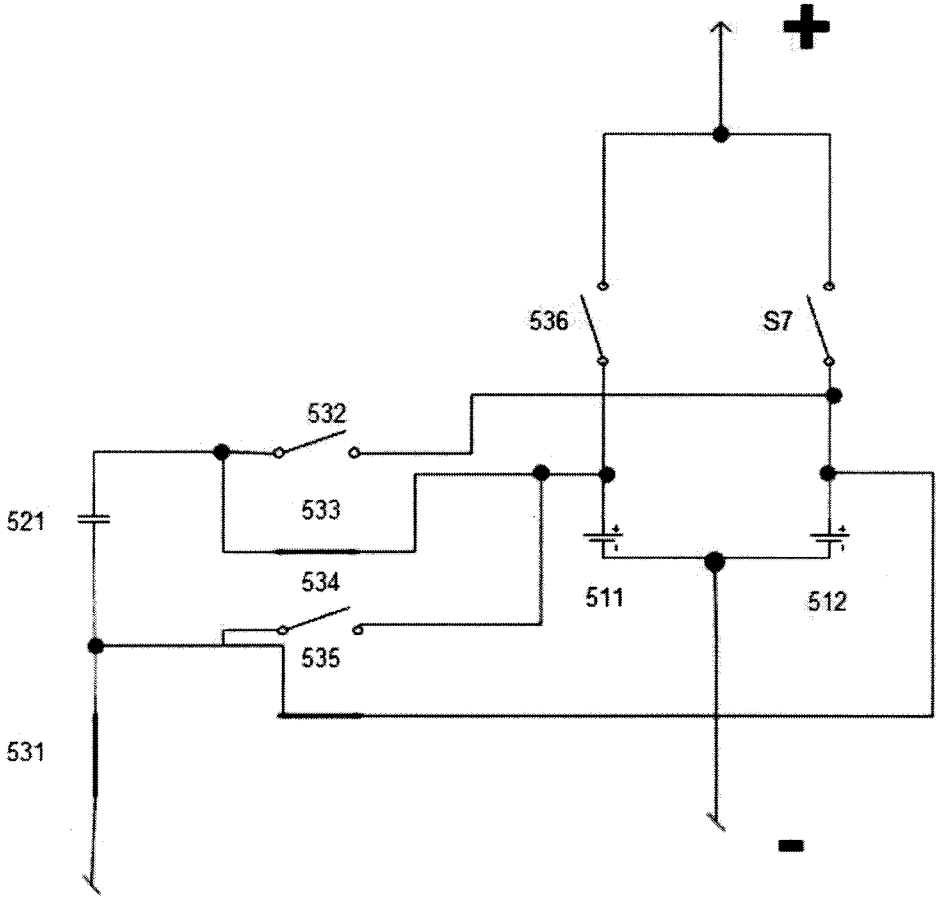


Fig 6A

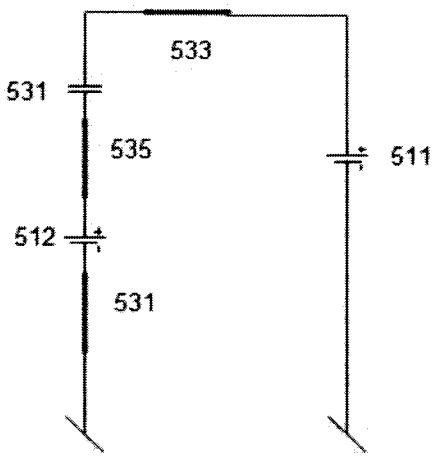


Fig 6B

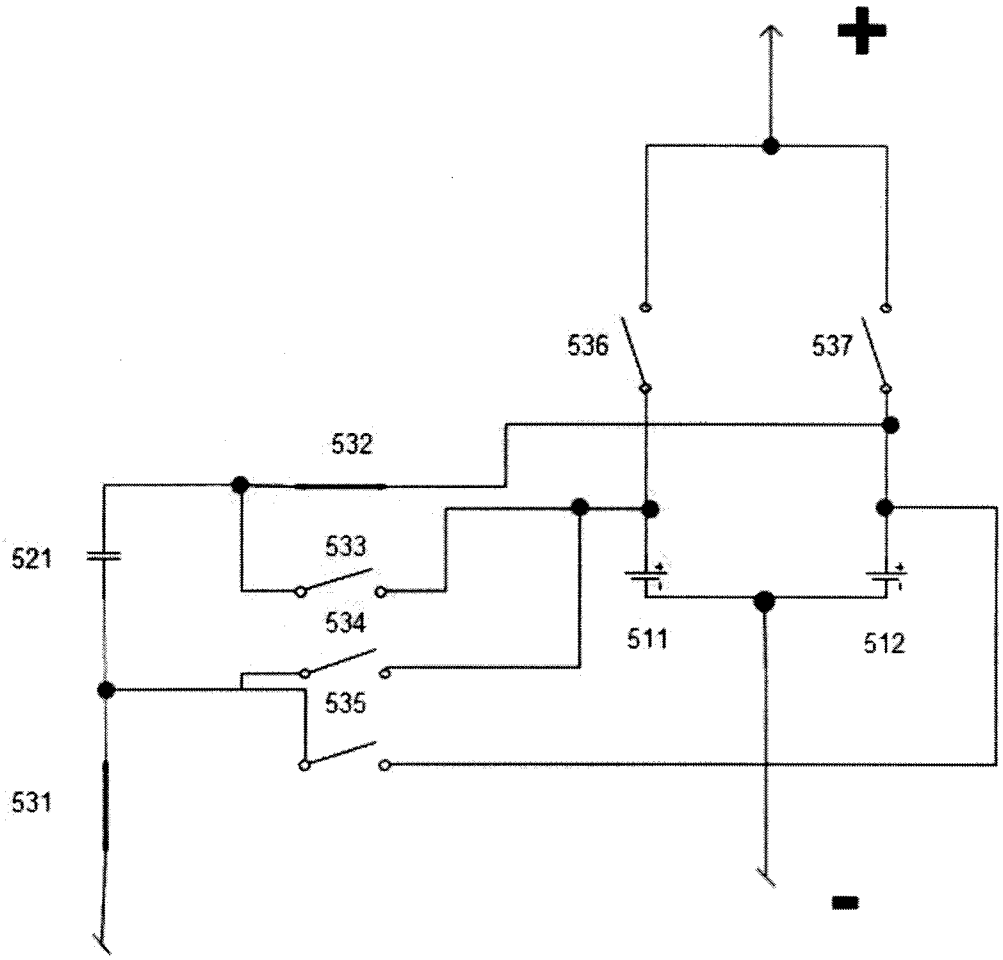


Fig 7A

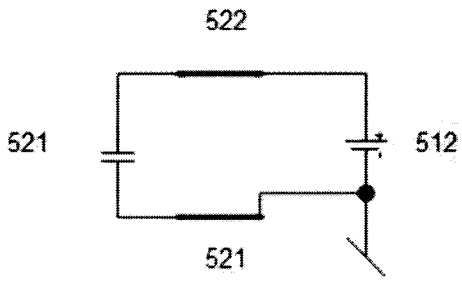


Fig 7B

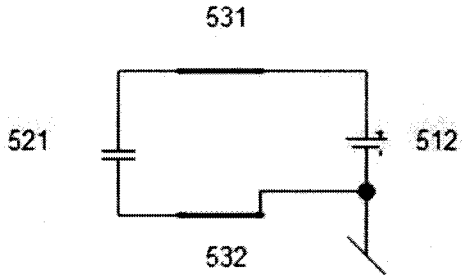

531
521
512
532

Fig 8

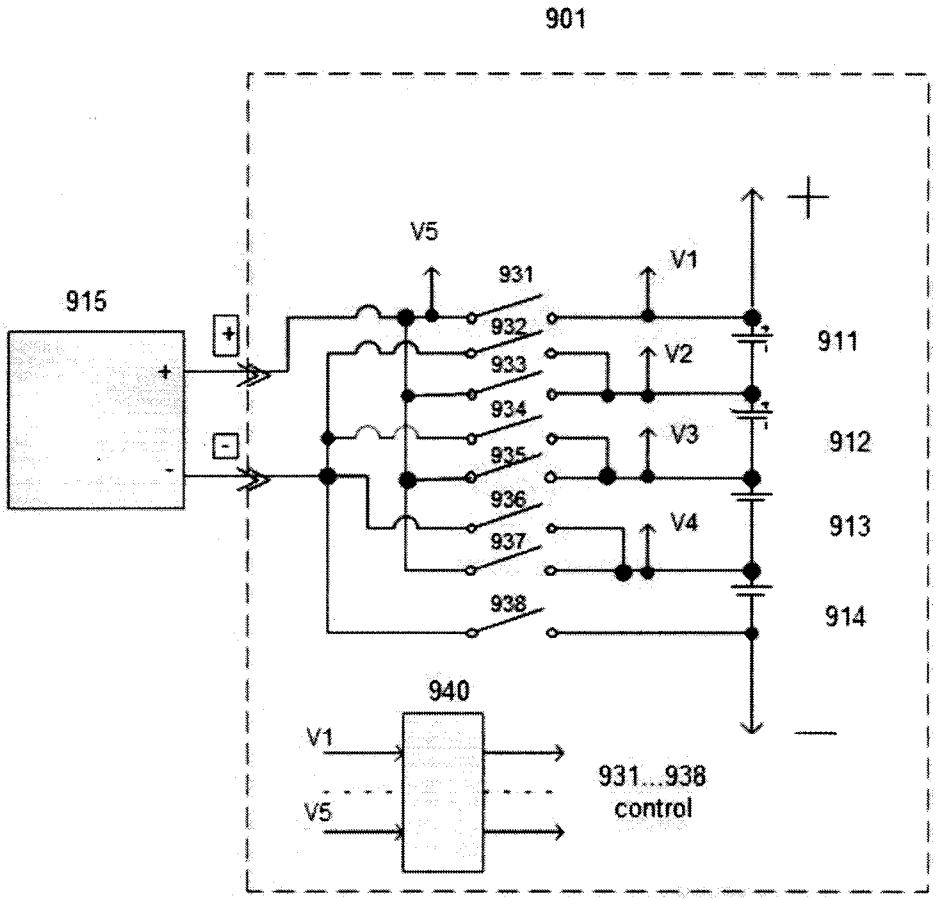

901
915
+
-
V5
931
932
933
934
935
936
937
938
V1
V2
V3
V4
911
912
913
914
940
V1
V5
931...938
control

Fig 9

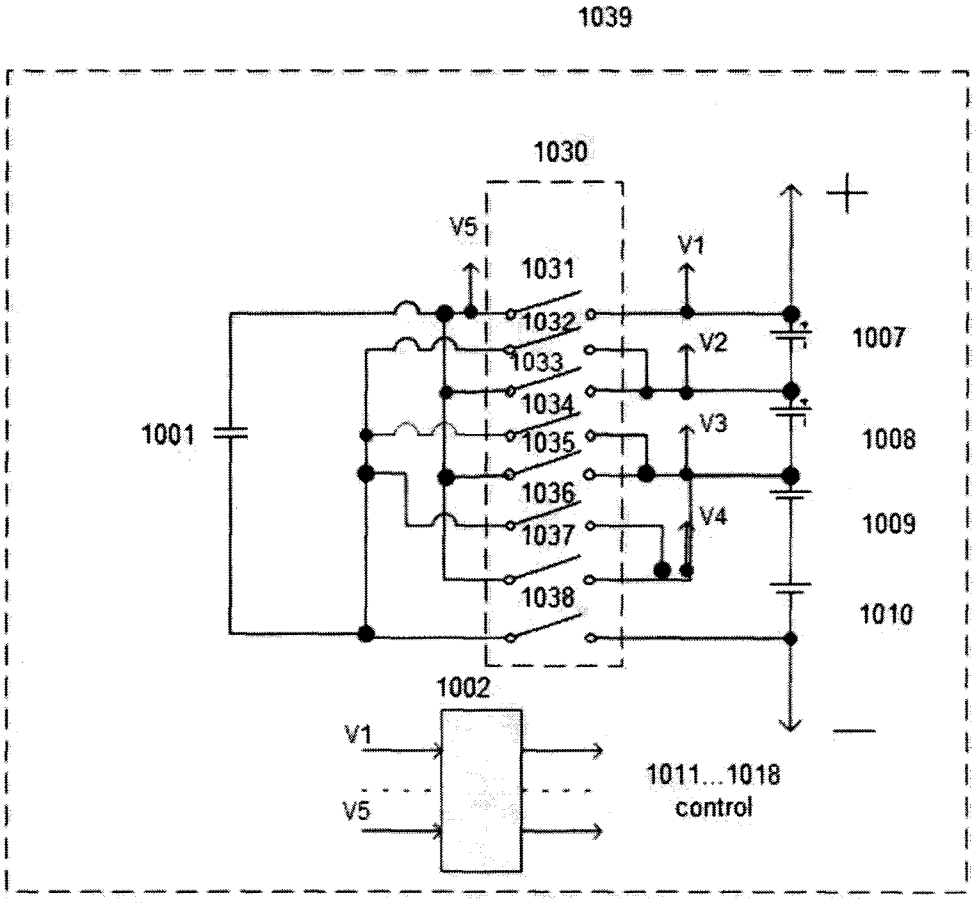

1039
1030
V5
1031
1032
1033
1034
1035
1036
1037
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V1
V2
V3
V4
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1009
1010
1002
V1
V5
1011...1018
control

Fig 10

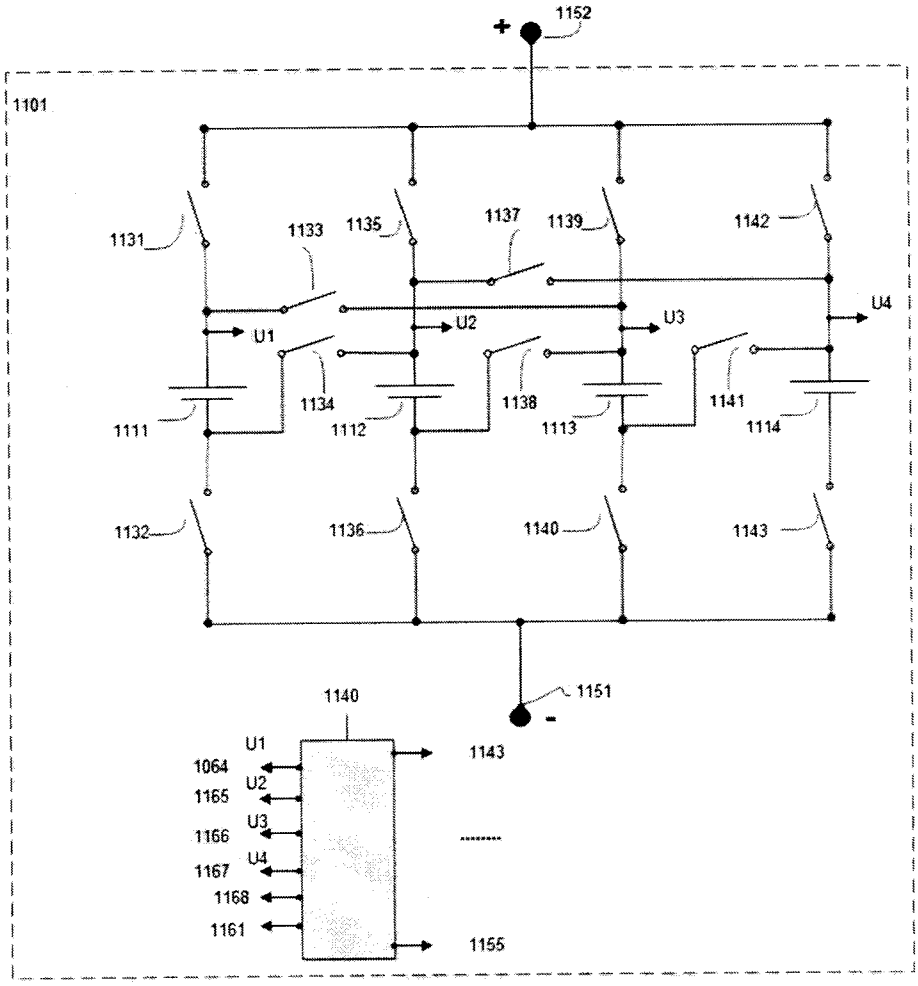

1152
+
1101
1131
1133
1135
1137
1139
1142
U1
U2
U3
U4
1111
1112
1113
1114
1134
1138
1141
1132
1136
1140
1143
1151
-
1140
U1
1064
U2
1165
U3
1166
U4
1167
1168
1161
1143
1155

Fig 11

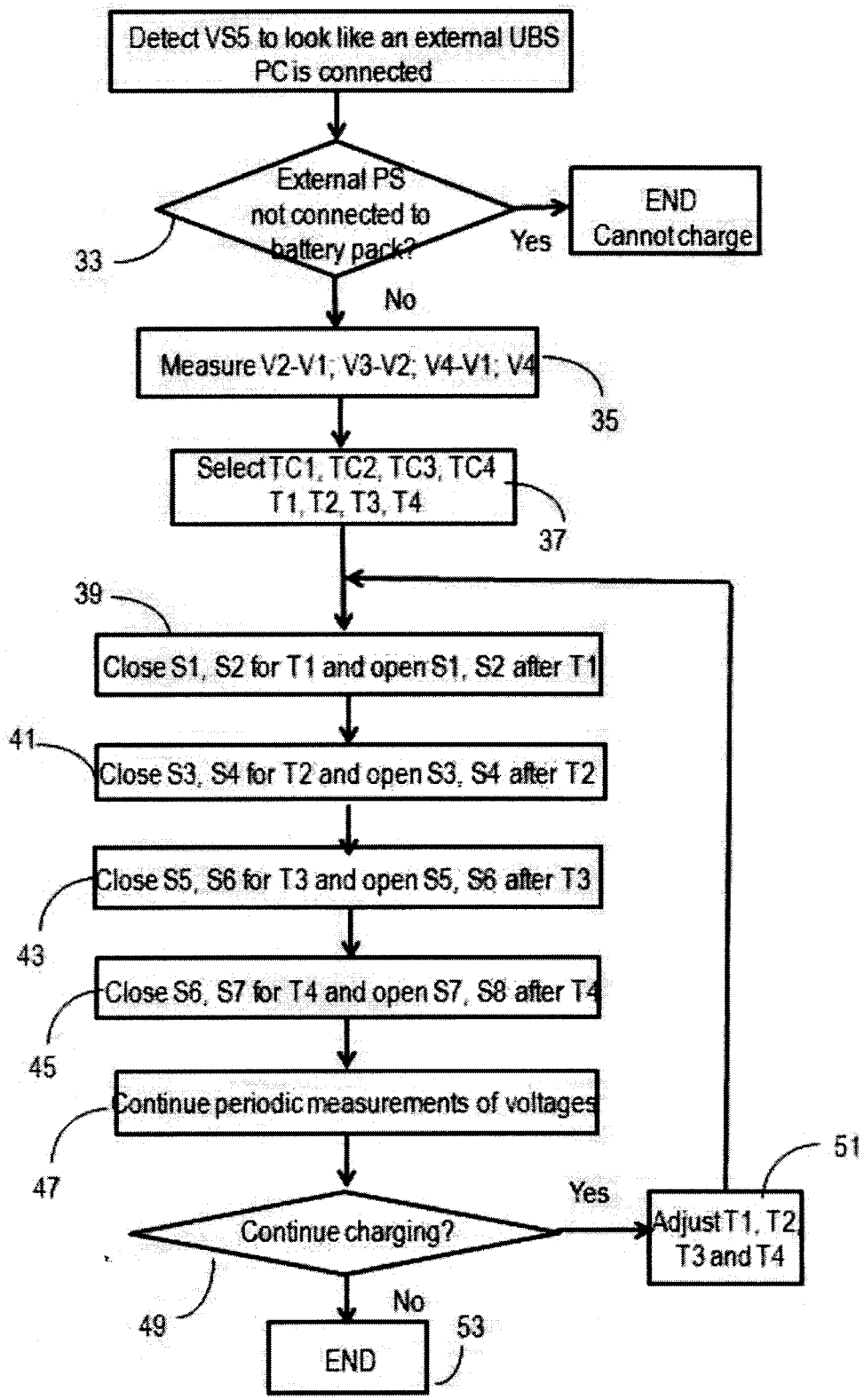

Detect VS5 to look like an external UBS PC is connected
External PS not connected to battery pack?
33
Yes
END Cannot charge
No
Measure V2-V1; V3-V2; V4-V1; V4
35
Select TC1, TC2, TC3, TC4 T1, T2, T3, T4
37
39
Close S1, S2 for T1 and open S1, S2 after T1
41
Close S3, S4 for T2 and open S3, S4 after T2
Close S5, S6 for T3 and open S5, S6 after T3
43
Close S6, S7 for T4 and open S7, S8 after T4
45
Continue periodic measurements of voltages
47
Continue charging?
Yes
51
Adjust T1, T2, T3 and T4
49
No
END
53

Fig 12

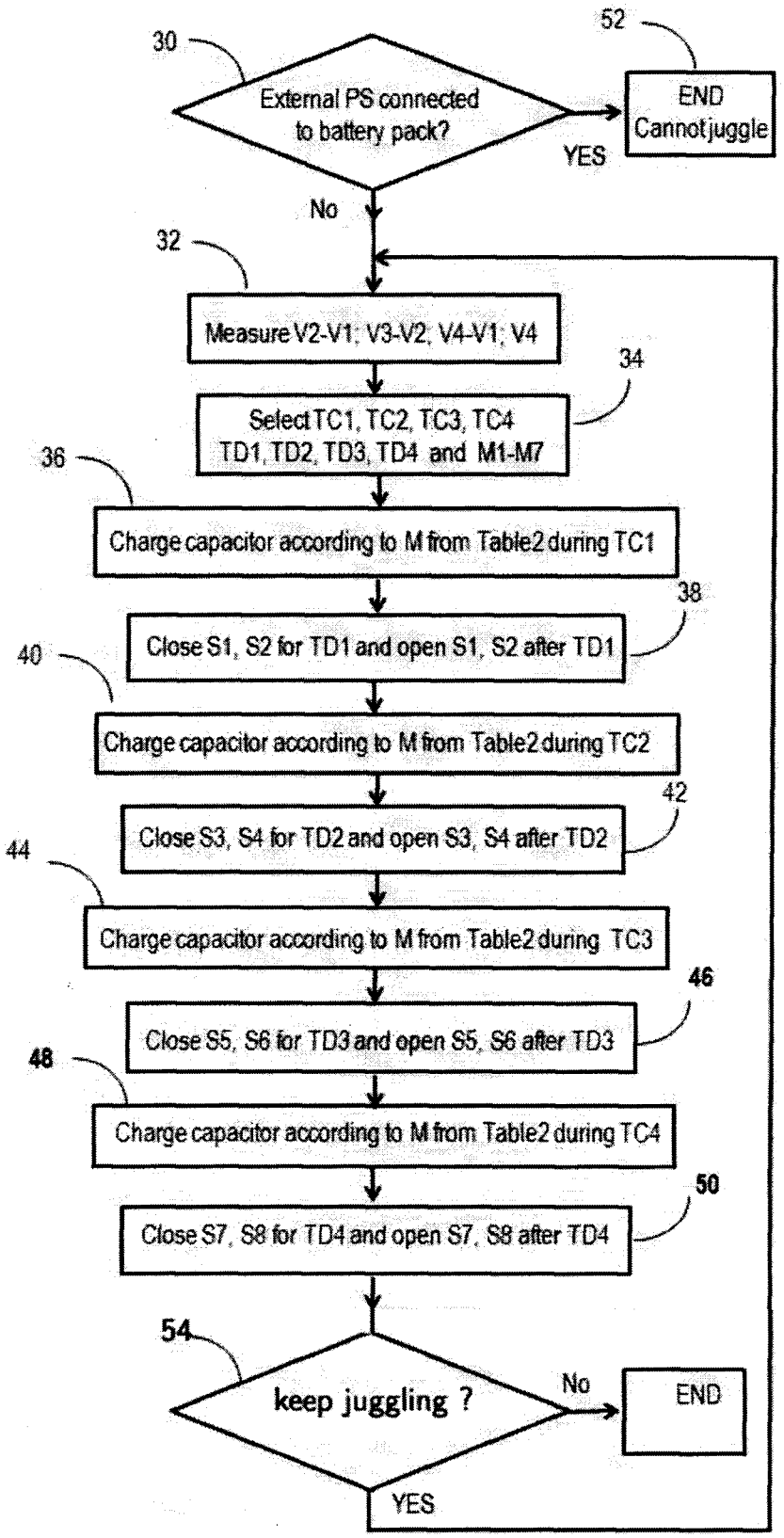

30
External PS connected to battery pack?
YES
52
END Cannot juggle
No
32
Measure V2-V1; V3-V2; V4-V1; V4
34
Select TC1, TC2, TC3, TC4 TD1, TD2, TD3, TD4 and M1-M7
36
Charge capacitor according to M from Table2 during TC1
38
Close S1, S2 for TD1 and open S1, S2 after TD1
40
Charge capacitor according to M from Table2 during TC2
42
Close S3, S4 for TD2 and open S3, S4 after TD2
44
Charge capacitor according to M from Table2 during TC3
46
Close S5, S6 for TD3 and open S5, S6 after TD3
48
Charge capacitor according to M from Table2 during TC4
50
Close S7, S8 for TD4 and open S7, S8 after TD4
54
keep juggling ?
No
END
YES

Fig 13

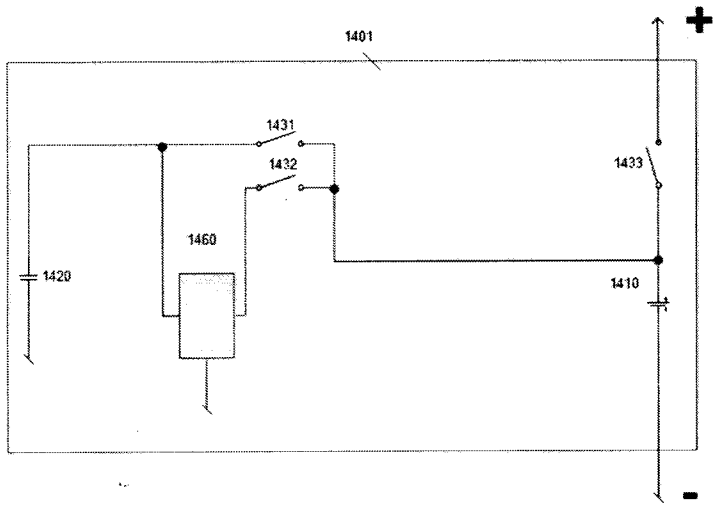


Fig 14

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CA2013/000277

A. CLASSIFICATION OF SUBJECT MATTER
IPC: ***H01M 10/42*** (2006.01) , ***H01M 10/44*** (2006.01)
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC (2006.01): H01M 10/42, H01M 10/44

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic database(s) consulted during the international search (name of database(s) and, where practicable, search terms used)
Databases: EPOQUE (Epodoc), TotalPatent, Canadian Patent Database, SCOPUS
Keywords: cell, battery, capacity, energy, enhanc*, improv*, maintain*, internal*, inside, charge, discharge, pulse, juggle, capacitor,

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2012/0025756 A1 (XU et al.) 2 February 2012 (02-02-2012) *whole document*	1-20
X A	US 2008/0079397 A1 (FEE et al.) 3 April 2008 (03-04-2008) *whole document*	1-4, 6-14, 16-20 5, 15
X A	US 2004/0038087 A1 (SHIUE et al.) 26 February 2004 (26-02-2004) *whole document*	1-4, 6-14, 16-20 5, 15
X A	US 5,500,583 (BUCKLEY et al.) 19 March 1996 (19-03-1996) *whole document*	1-4, 6-14, 16-20 5, 15
X A	US 4,680,241 (DYER) 14 July 1987 (14-07-1987) *whole document*	1-4, 6-14, 16-20 5, 15
A	US 4,016,473 (NEWMAN) 5 April 1977 (05-04-1977) *whole document*	1-20

[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

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"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
10 June 2013 (10-06-2013)	13 June 2013 (13-06-2013)

Name and mailing address of the ISA/CA	Authorized officer
Canadian Intellectual Property Office Place du Portage I, C114 - 1st Floor, Box PCT 50 Victoria Street Gatineau, Quebec K1A 0C9 Facsimile No.: 001-819-953-2476	Philip Gbor (819) 934-9091

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5,828,201 (HOFFMAN, Jr et al.) 27 October, 1998 (27-10-1998) *whole document*	1-20
A	US 2010/0164430 A1 (LU et al.) 1 July 2010 (01-07-2010) *whole document*	1-20
A	US 2011/0076525 A1 (ZHANG et al.) 31 March 2011 (31-03-2011) *whole document*	1-20
A	WO 2011/132300 A1 (YAMASHIGE et al.) 27 October 2011 (27-10-2011) *abstract*	1-20
A	CN 201804941 U (LI et al.) 20 April 2011 (20-04-2011) *abstract*	1-20
A	CN 201532995 U (LIUJUN) 21 July 2010 (21-07-2010) *abstract*	1-20
A	JPh 06163081 (TANAKA et al.) 10 June 1994 (10-06-1994) *abstract*	1-20

Patent Document Cited in Search Report	Publication Date	Patent Family Member(s)	Publication Date
US2012025756A1	02 February 2012 (02-02-2012)	CA2805781A1	02 February 2012 (02-02-2012)
		CA2805797A1	02 February 2012 (02-02-2012)
		CA2806407A1	02 February 2012 (02-02-2012)
		CA2806628A1	02 February 2012 (02-02-2012)
		CA2807002A1	02 February 2012 (02-02-2012)
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		CN202145485U	15 February 2012 (15-02-2012)
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		EP2413461A1	01 February 2012 (01-02-2012)
		EP2413462A1	01 February 2012 (01-02-2012)
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Continuation of Information on patent family members

EP2413464A1	01 February 2012 (01-02-2012)
EP2413465A1	01 February 2012 (01-02-2012)
EP2413466A1	01 February 2012 (01-02-2012)
EP2413467A1	01 February 2012 (01-02-2012)
EP2413468A1	01 February 2012 (01-02-2012)
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EP2421114A1	22 February 2012 (22-02-2012)
HK1158370A1	28 December 2012 (28-12-2012)
HK1158371A1	28 December 2012 (28-12-2012)
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HK1158829A1	01 February 2013 (01-02-2013)
HK1158830A1	16 May 2013 (16-05-2013)
HK1158831A1	16 May 2013 (16-05-2013)
HK1159318A1	05 April 2013 (05-04-2013)
HK1159319A1	05 April 2013 (05-04-2013)
HK1159320A1	16 May 2013 (16-05-2013)
HK1159321A1	16 May 2013 (16-05-2013)
HK1162766A1	16 May 2013 (16-05-2013)
TWM434311U	21 July 2012 (21-07-2012)
TWM436949U	01 September 2012 (01-09-2012)
TWM436950U	01 September 2012 (01-09-2012)
TWM436951U	01 September 2012 (01-09-2012)
TWM436952U	01 September 2012 (01-09-2012)
TWM436953U	01 September 2012 (01-09-2012)
TWM438032U	21 September 2012 (21-09-2012)
TWM438033U	21 September 2012 (21-09-2012)
TWM438034U	21 September 2012 (21-09-2012)
TWM438067U	21 September 2012 (21-09-2012)
TWM439195U	11 October 2012 (11-10-2012)
TWM441227U	11 November 2012 (11-11-2012)
TW201240274A	01 October 2012 (01-10-2012)
TW201240275A	01 October 2012 (01-10-2012)
TW201251261A	16 December 2012 (16-12-2012)
TW201251262A	16 December 2012 (16-12-2012)
US2012024838A1	02 February 2012 (02-02-2012)
US2012025754A1	02 February 2012 (02-02-2012)
US2012025755A1	02 February 2012 (02-02-2012)
US2012025772A1	02 February 2012 (02-02-2012)
US2012025774A1	02 February 2012 (02-02-2012)
US2012025775A1	02 February 2012 (02-02-2012)
US2012025776A1	02 February 2012 (02-02-2012)
US2012025777A1	02 February 2012 (02-02-2012)
US2012025778A1	02 February 2012 (02-02-2012)
US2012025779A1	02 February 2012 (02-02-2012)
US2012025780A1	02 February 2012 (02-02-2012)
US2012025781A1	02 February 2012 (02-02-2012)
US2012025782A1	02 February 2012 (02-02-2012)
US2012025783A1	02 February 2012 (02-02-2012)
US2012031890A1	09 February 2012 (09-02-2012)
US2012032642A1	09 February 2012 (09-02-2012)
US2012279951A1	08 November 2012 (08-11-2012)
US2012280658A1	08 November 2012 (08-11-2012)
US2012280659A1	08 November 2012 (08-11-2012)
US2012306432A1	06 December 2012 (06-12-2012)
US2013127398A1	23 May 2013 (23-05-2013)
US2013134146A1	30 May 2013 (30-05-2013)
US2013134945A1	30 May 2013 (30-05-2013)
US2013141032A1	06 June 2013 (06-06-2013)
WO2012013065A1	02 February 2012 (02-02-2012)
WO2012013066A1	02 February 2012 (02-02-2012)
WO2012013067A1	02 February 2012 (02-02-2012)
WO2012013068A1	02 February 2012 (02-02-2012)
WO2012013069A1	02 February 2012 (02-02-2012)
WO2012013070A1	02 February 2012 (02-02-2012)
WO2012013071A1	02 February 2012 (02-02-2012)

Continued on extra sheet

Continuation of Information on patent family members

		WO2012013072A1	02 February 2012 (02-02-2012)
		WO2012013073A1	02 February 2012 (02-02-2012)
		WO2012013074A1	02 February 2012 (02-02-2012)
		WO2012013075A1	02 February 2012 (02-02-2012)
		WO2012013076A1	02 February 2012 (02-02-2012)
		WO2012013077A1	02 February 2012 (02-02-2012)
		WO2012013078A1	02 February 2012 (02-02-2012)
		WO2012013079A1	02 February 2012 (02-02-2012)
		WO2012013081A1	02 February 2012 (02-02-2012)
		WO2012013082A1	02 February 2012 (02-02-2012)
US2008079397A1	03 April 2008 (03-04-2008)	CN101849341A	29 September 2010 (29-09-2010)
		EP2206215A2	14 July 2010 (14-07-2010)
		US8120324B2	21 February 2012 (21-02-2012)
		US2006208694A1	21 September 2006 (21-09-2006)
		US2006208702A1	21 September 2006 (21-09-2006)
		US2006208703A1	21 September 2006 (21-09-2006)
		US2006208705A1	21 September 2006 (21-09-2006)
		US2008048622A1	28 February 2008 (28-02-2008)
		WO2009035611A2	19 March 2009 (19-03-2009)
		WO2009035611A3	07 May 2009 (07-05-2009)
US2004038087A1	26 February 2004 (26-02-2004)	DE60210175D1	18 May 2006 (18-05-2006)
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		JP2004080984A	11 March 2004 (11-03-2004)
		US7186473B2	06 March 2007 (06-03-2007)
US5500583A	19 March 1996 (19-03-1996)	AU6765094A	08 November 1994 (08-11-1994)
		WO9424753A1	27 October 1994 (27-10-1994)
US4680241A	14 July 1987 (14-07-1987)	None	
US4016473A	05 April 1977 (05-04-1977)	US4016473A	05 April 1977 (05-04-1977)
		US4061956A	06 December 1977 (06-12-1977)
US5828201A	27 October 1998 (27-10-1998)	CA2252231A1	30 April 1999 (30-04-1999)
		CA2252231C	20 December 2005 (20-12-2005)
		DE69806885D1	05 September 2002 (05-09-2002)
		DE69806885T2	21 November 2002 (21-11-2002)
		EP0913288A2	06 May 1999 (06-05-1999)
		EP0913288A3	23 February 2000 (23-02-2000)
		EP0913288B1	31 July 2002 (31-07-2002)
		ES2181109T3	16 February 2003 (16-02-2003)
		JPH11289605A	19 October 1999 (19-10-1999)
		JP4132317B2	13 August 2008 (13-08-2008)
		MXPA98009105A	29 October 2004 (29-10-2004)
		NO985046D0	29 October 1998 (29-10-1998)
		NO985046A	03 May 1999 (03-05-1999)
US2010164430A1	01 July 2010 (01-07-2010)	CN201402987Y	10 February 2010 (10-02-2010)
US2011076525A1	31 March 2011 (31-03-2011)	CN102035010A	27 April 2011 (27-04-2011)
		CN102035010B	01 May 2013 (01-05-2013)
		CN102468673A	23 May 2012 (23-05-2012)
		CN102468673B	08 May 2013 (08-05-2013)
		JP2011083182A	21 April 2011 (21-04-2011)
		TW201249059A	01 December 2012 (01-12-2012)
		US8164305B2	24 April 2012 (24-04-2012)
		US2011241622A1	06 October 2011 (06-10-2011)
		US8339100B2	25 December 2012 (25-12-2012)
		US2012196159A1	02 August 2012 (02-08-2012)

Continued on extra sheet

Continuation of Information on patent family members

		US8344694B2 US2013099723A1	01 January 2013 (01-01-2013) 25 April 2013 (25-04-2013)
WO2011132300A1	27 October 2011 (27-10-2011)	None	
CN201804941U	20 April 2011 (20-04-2011)	None	
CN201532995U	21 July 2010 (21-07-2010)	None	
JP06163081	10 June 1994 (10-06-1994)	None	