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(54) Title: BATTERY HEATING CIRCUIT

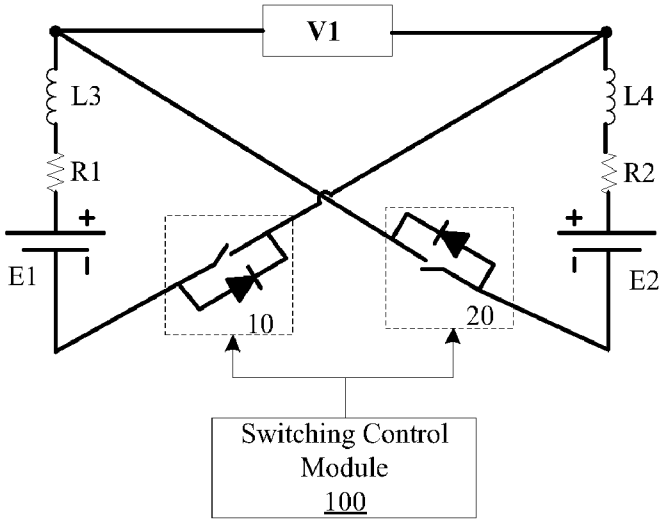

Figure 1

(57) Abstract: A battery heating circuit is provided, wherein the battery comprises a first battery (El) and a second battery (E2), and the heating circuit comprises a first switch unit (10), a second switch unit (20), a damping element Rl, a damping element R2, a current storage element L3, a current storage element L4, a switching control module (100) and an energy storage element VI. The first battery (El), the damping element Rl, the current storage element L3, the energy storage element VI and the first switch unit (10) are connected in series to constitute a first charging/discharging circuit. The second battery (E2), the damping element R2, the current storage element L4, the energy storage element VI and the second switch unit (20) are connected in series to constitute a second charging/discharging circuit. When the energy storage element VI is charged or discharges, the direction of charging/discharging current in the second charging/discharging circuit is reverse to the direction of charging/discharging current in the first charging/discharging circuit. The switching control module (100) is electrically connected with the first switch unit (10) and the second switch unit (20) to switch on in alternate, so as to control the electric energy to flow among the first battery (El), the energy storage element VI and the second battery (E2). The battery heating circuit can achieve high heating efficiency.

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BATTERY HEATING CIRCUIT

Technical Field of the Invention

The present invention pertains to electric and electronic field, in particular to a battery heating circuit.

Background of the Invention

In view cars have to run under complex road conditions and environmental conditions or some electronic devices are used under harsh environmental conditions, the battery, which serves as the power supply unit for electric motor cars or electronic devices, must be adaptive to these complex conditions. In addition, besides these conditions, the service life and charging/discharging cycle performance of battery must be considered; especially, when electric motor cars or electronic devices are used in low temperature environments, the battery must have outstanding low temperature charging/discharging performance and higher input/output power.

Usually, under low temperature conditions, the resistance of battery will increase, and the polarization will increase; therefore, the capacity of battery will be reduced.

To keep the capacity of battery and improve the charging/discharging performance of battery under low temperature conditions, the present invention provides a battery heating circuit.

Summary of the Invention

The object of the present invention is to provide a battery heating circuit, in order to solve the problem of decreased capacity of battery caused by increased resistance and polarization of battery under low temperature conditions.

the present invention provides a battery heating circuit, wherein, the battery comprises a first battery and a second battery; the heating circuit comprises a first switch unit, a second switch unit, a damping element Rl, a damping element R2, a current storage element L3, a current storage element L4, a switching control module

and an energy storage element VI; the first battery, damping element Rl, current stage element L3, energy storage element VI and first switch unit are connected in series to constitute a first charging/discharging circuit; the second battery, damping element R2, current stage element L4, energy storage element VI and second switch unit are connected in series to constitute a second charging/discharging circuit; when the energy storage element VI is charged or discharges, the direction of charging/discharging current in the second charging/discharging circuit is reverse to the direction of charging/discharging current in the first charging/discharging circuit; the switching control module is electrically connected with the first switch unit and second switch unit, and is configured to control the first switch unit and second switch unit to switch on in alternate, so as to control the electric energy to flow among the first battery, energy storage element VI and second battery.

In the heating circuit provided in the present invention, the first switch unit and second switch unit can be controlled by the switching control module to switch on in alternate, so that the electric energy can flow to and fro among the first battery, energy storage element VI and second battery in alternate, and thereby causes the damping element Rl and damping element R2 to generate heat, so as to heat up the first battery and second battery. Since the direction of charging/discharging current in the second charging/discharging circuit is reverse to the direction of charging/discharging current in the first charging/discharging circuit when viewed from the aspect of the energy storage element VI, the energy charged from the first battery into the energy storage element VI can be transferred successfully to the second battery, so that the heating efficiency is improved.

Other characteristics and advantages of the present invention will be further detailed in the embodiments hereunder.

Brief Description of the Drawings

The accompanying drawings are provided here to facilitate further understanding on the present invention, and are a part of this document. They are used together with the following embodiments to explain the present invention, but shall not be

comprehended as constituting any limitation to the present invention. In the figures:

Figure 1 is a schematic diagram of the heating circuit in the first embodiment of the present invention;

Figure 2 is a schematic diagram of a heating circuit in the first embodiment of the present invention;

Figure 3 is a timing sequence diagrams of waveform of the heating circuit in Figure 2;

Figure 4 is a schematic diagram of another heating circuit in the first embodiment of the present invention;

Figure 5 is a timing sequence diagrams of waveform of the heating circuit in Figure 4;

Figure 6 is a schematic diagram of the heating circuit in the second embodiment of the present invention;

Figure 7 is a schematic diagram of a heating circuit in the second embodiment of the present invention;

Figure 8 is a timing sequence diagrams of waveform of the heating circuit in Figure 7;

Figure 9 is a schematic diagram of another heating circuit in the second embodiment of the present invention;

Figure 10 is a timing sequence diagrams of waveform of the heating circuit in Figure 9; and

Figure 11 is a circuit diagram of an embodiment of the first and/or second switch unit in the heating circuit provided in the present invention.

Detailed Description of the Embodiments

Hereunder the embodiments of the present invention will be detailed, with reference to the accompanying drawings. It should be appreciated that the embodiments described here are only provided to describe and explain the present invention, but shall not be deemed as constituting any limitation to the present invention.

Please note: unless otherwise specified, where mentioned in the following text, the term "switching control module" refers to any controller that can output control commands (e.g., pulse waveform) under preset conditions or at preset times and thereby controls the switch unit connected to it to switch on or switch off accordingly, for example, the switching control module can be a PLC; where mentioned in the following text, the term "switch" refers to a switch that achieve ON/OFF control by means of electrical signals or achieve ON/OFF control on the basis of the characteristics of the element or component, which is to say, the switch can be an one-way switch (e.g., a switch composed of a two-way switch and a diode connected in series, which can switch on in one direction) or a two-way switch (e.g., a Metal Oxide Semiconductor Field Effect Transistor (MOSFET) or an IGBT with an anti-parallel freewheeling diode); where mentioned in the following text, the term "two-way switch" refers to a switch that can switch on in two ways, which can achieve ON/OFF control by means of electrical signals or achieve ON/OFF control on the basis of the characteristics of the element or component, for example, the two-way switch can be a MOSFET or an IGBT with an anti-parallel freewheeling diode; where mentioned in the following text, the term "one-way semiconductor element" refers to a semiconductor element that can switch on in one direction, such as an diode; where mentioned in the following text, the term "charge storage element" refers to any device that can implement charge storage, such as a capacitor; where mentioned in the following text, the term "current storage element" refers to any device that can store current, such as an inductor; where mentioned in the following text, the term "forward direction" refers to the direction in which the energy flows from the battery to the energy storage circuit, and the term "reverse direction " refers to the direction in which the energy flows from the energy storage circuit to the battery; where mentioned in the following text, the term "battery" comprises primary battery (e.g., dry battery or alkaline battery, etc.) and secondary battery (e.g., lithium-ion battery, nickel-cadmium battery, nickel-hydrogen battery, or lead-acid battery, etc.); where mentioned in the following text, the term "damping element" refers to any device that inhibits current flowing and thereby achieves energy consumption, such as a resistor;

where mentioned in the following text, the term "main loop" refers to a loop composed of battery, damping element, switch unit and energy storage circuit connected in series.

It should be noted specially: in view different types of batteries have different characteristics, in the present invention, the "battery" refers to an ideal battery that doesn't have internal parasitic resistance and inductance or has very low internal parasitic resistance and inductance, or refers to a battery pack that has internal parasitic resistance and inductance; therefore, those skilled in the art should appreciate: if the battery is an ideal battery that doesn't have internal parasitic resistance and inductance or has very low internal parasitic resistance and inductance, the damping element refers to an damping element external to the battery, and the current storage element refers to a current storage element external to the battery; if the battery is a battery pack that has internal parasitic resistance and inductance, the damping element refers to a damping element external to the battery, or refers to the parasitic resistance in the battery pack; likewise, the current storage element refers to a current storage element external to the battery, or refers to the parasitic inductance in the battery pack.

To ensure the normal service life of the battery, the battery can be heated under low temperature condition, which is to say, when the heating condition is met, the heating circuit is controlled to start heating for the battery; when the heating stop condition is met, the heating circuit is controlled to stop heating.

In the actual application of battery, the battery heating condition and heating stop condition can be set according to the actual ambient conditions, to ensure normal charging/discharging performance of the battery.

Figure 1 is a schematic diagram of the heating circuit in the first embodiment of the present invention. As shown in Figure 1, the present invention provides a battery heating circuit, wherein, the battery comprises a first battery E1 and a second battery E2; the heating circuit comprises a first switch unit 10, a second switch unit 20, a damping element Rl, a damping element R2, a current stage element L3, a current stage element L4, a switching control module 100 and an energy storage element VI; the first battery E1, damping element Rl, current stage element L3, energy storage

element VI and first switch unit 10 are connected in series to constitute a first charging/discharging circuit; the second battery E2, damping element R2, current stage element L4, energy storage element VI and second switch unit 20 are connected in series to constitute a second charging/discharging circuit; when the energy storage element VI is charged or discharges, the direction of charging/discharging current in the second charging/discharging circuit is reverse to the direction of charging/discharging current in the first charging/discharging circuit; the switching control module 100 is electrically connected with the first switch unit 10 and second switch unit 20, and is configured to control the first switch unit 10 and second switch unit 20 to switch on in alternate, so as to control the electric energy to flow among the first battery E1, energy storage element VI and second battery E2.

wherein, the damping element Rl and the damping element R2 can be the parasitic resistances in the first battery E1 and the second battery E2 respectively, and the current storage element L3 and the current storage element L4 can be the parasitic inductances in the first battery E1 and the second battery E2 respectively.

Wherein, the energy storage element VI can be an inductor LI or a capacitor CI. Figure 2 and Figure 4 show the circuit diagrams in the case that the energy storage element VI is an inductor LI or capacitor CI, respectively; Figure 3 and Figure 5 show the timing sequence diagrams of waveform corresponding to Figure 2 and Figure 4, respectively. Hereunder the heating circuit in the first embodiment of the present invention will be described, with reference to Figure 2 to Figure 5.

As shown in Figure 2, the energy storage element VI can be an inductor LI, the switching control module 100 can control the first switch unit 10 and second switch unit 20 to switch theirs ON/OFF states when the current in the inductor LI reaches to a preset value, for example, the first switch unit 10 switches from ON state to OFF state, while the second switch unit 20 switches from OFF state to ON state, so that the electric energy stored in the inductor LI from one battery can flow into the other battery. As the electric energy flows, current is generated; by keeping current flowing through the damping element Rl and damping element R2 continuously, the damping element Rl and damping element R2 generate heat, and thereby heat up the

first battery E1 and second battery E2.

Figure 3 is a timing sequence diagram of the waveform of the circuit shown in Figure 2. Hereunder the working process of the heating circuit provided in the present invention will be described, with reference to Figure 3. First, the switching control module 100 controls the first switch unit 10 to switch on, and controls the second switch unit 20 to switch off; thus, the first battery E1 charges the inductor LI, and therefore the current in the inductor LI increases gradually (as indicated by the time period t1 shown in Figure 3). When the current I_{LI} in the inductor LI rises to a preset value, the switching control module 100 controls the first switch unit 10 to switch off and controls the second switch unit 20 to switch on; the inductor LI transfers the energy charged in it to the second battery E2, and therefore the current in the inductor LI decreases slowly (as indicated by the time period t2). Then, after the energy in the inductor LI is released, the second battery E2 starts charging the inductor LI, and therefore the current $I_{L}i$ in the inductor LI increases slowly. At this time, the flow direction of the current I_{LI} in the inductor LI is reverse to the flow direction in the time period t1 and t2 (as indicated by the time period t3). Then, when the current I_{LI} in the inductor LI rises to a preset value, the switching control module 100 controls the first switch unit 10 to switch on and controls the second switch unit 20 to switch off; the inductor LI transfers the energy charged in it to the first battery E1, and therefore the current I_{LI} in the inductor LI decreases slowly (as indicated by the time period t4; now, the heating circuit has accomplished a complete working cycle). In that way, the cycles continue on and on, so that the current flows through damping element R1 and damping element R2 continuously; as a result, the damping element R1 and damping element R2 generate heat, and thereby heat up the first battery E1 and second battery E2 to the expected condition. It should be noted: U_{LI} in Figure 3 represents the voltage of the inductor LI, which is a constant value in forward direction when the current I_{LI} through the inductor LI increases in forward direction or decreases in reverse direction , and is a constant value in reverse direction when the current I_{LI} through the inductor LI decreases in forward direction or increases in reverse direction .

In the above working process of the heating circuit provided in the present invention, the current can be kept flowing to and fro between the first battery E1 and the second battery E2, so that the two batteries are heated up in alternate, and therefore the heating efficiency is improved. In addition, owing to the existence of the inductor LI, the current flowing through the first and second batteries and the first and second switch units is limited; alternatively, the current flowing through the first and second batteries and the first and second switch units can be limited by means of the preset value, so as to reduce the current flowing through the first and second batteries and the first and second switch units, to attain the purpose of protecting the first and second batteries and the first and second switch units.

As shown in Figure 4, the energy storage element VI is a capacitor CI, the switching control module 100 can control the first switch unit 10 and second switch unit 20 to switch their ON/OFF states when the current in the capacitor CI reaches to zero after each pair of continuous positive and negative half cycles or each pair of continuous negative and positive half cycles, for example, the first switch unit 10 can switch from ON state to OFF state, while the second switch unit 20 can switch from OFF state to ON state, so that the electric energy stored in the capacitor C1 from one battery can flow into the other battery. As the electric energy flows, current is generated; by keeping current flowing through the damping element R1 and damping element R2 continuously, the damping element Rl and damping element R2 generate heat, and thereby heat up the first battery E1 and second battery E2.

Figure 5 is a timing sequence diagram of the waveform of the circuit shown in Figure 4. Hereunder the working process of the heating circuit provided in the present invention will be described, with reference to Figure 5. First, the switching control module 100 controls the first switch unit 10 to switch on, and controls the second switch unit 20 to switch off; the first battery E1, damping element Rl, current stage element L3, capacitor CI and first switch unit 10 form a charging/discharging circuit, which performs charging/discharging operations (as indicated by the time period tl in Figure 5). After the charging/discharging circuit completes a charging/discharging cycle (at this point, the current Ici through the capacitor CI

reaches to zero after the negative half cycle, the voltage Uci of the capacitor CI has passed the peak value in the positive half cycle), the switching control module 100 controls the first switch unit 10 to switch off and controls the second switch unit 20 to switch on; thus, the second battery E2, damping element R2, current stage element L4, capacitor CI and second switch unit 20 form a charging/discharging circuit, which performs charging/discharging operations (as indicated by the time period t2 in Figure 5). After the charging/discharging circuit completes a charging/discharging cycle (at this point, the current Ici through capacitor CI reaches to zero after the positive half cycle, and the entire heating circuit accomplishes a complete working cycle), the switching control module 100 controls the first switch unit 10 to switch on and controls the switch unit 20 to switch off again; in that way, the cycles continue on, so that the current flows through the damping element Rl and damping element R2 continuously; as a result, the damping element Rl and damping element R2 generate heat, and thereby heat up the first battery E1 and second battery E2 to the expected condition.

In the above working process of the heating circuit shown in Figure 4, the current can be kept flowing to and fro between the first battery E1 and the second battery E2, so that the two batteries are heated up in alternate, and therefore the heating efficiency is improved. In addition, in the heating circuit shown in Figure 4, the capacitor is connected in series with the battery. When the battery is heated, safety problems related with failure or short circuit of the switch unit can be avoided owing to the existence of the serially connected capacitor, and therefore the battery can be protected effectively.

Figure 6 is a schematic diagram of the heating circuit in the second embodiment of the present invention. Preferably, as shown in Figure 6, the heating circuit provided in the present invention can further comprise an energy storage element V2; the first battery E1, damping element Rl, current stage element L3, energy storage element V2 and second switch unit 20 are connected in series to form a third charging/discharging circuit; the second battery E2, damping element R2, current stage element L4, energy storage element V2 and first switch unit 10 are connected in

series to form a fourth charging/discharging circuit; when the energy storage element V2 is charged or discharges, the direction of charging/discharging current in the third charging/discharging circuit is reverse to the direction of charging/discharging current in the fourth charging/discharging circuit; the switching control module 100 also controls the electric energy to flow among the first battery E1, energy storage element VI, energy storage element V2 and second battery E2 by controlling the first switch unit 10 and second switch unit 20 to switch on in alternate.

Wherein, the energy storage element V2 can also be an inductor L2 or a capacitor C2. Figure 7 and Figure 9 show the circuit diagrams in the case that the energy storage element V2 is an inductor L2 or capacitor C2, respectively; Figure 8 and Figure 10 show the timing sequence diagrams of waveform corresponding to Figure 7 and Figure 9, respectively. Hereunder the heating circuit in the second embodiment of the present invention will be described, with reference to Figure 7 to Figure 10.

As shown in Figure 7, the energy storage element VI is an inductor LI, the energy storage element V2 is an inductor L2, the switching control module can control the first switch unit 10 and second switch unit 20 to switch their ON/OFF states when the current in the inductor LI or inductor L2 reaches to a preset value. Figure 8 is a timing sequence diagram of the waveform of the circuit shown in Figure 7. Hereunder the working process of the heating circuit provided in the second embodiment of the present invention will be described, with reference to Figure 8.

First, the switching control module 100 controls the first switch unit 10 to switch on, and controls the second switch unit 20 to switch off; thus, the first battery E1 charges the inductor LI, and the second battery E2 charges the inductor L2; as a result, the current I_{Li} and current I_{L2} in the inductor LI and inductor L2 increase slowly (as indicated by the time period t1 shown in Figure 8). When the current I_{LI} in the inductor LI or the current I_{L2} in the inductor L2 rises to a preset value, the switching control module 100 controls the first switch unit 10 to switch off and controls the second switch unit 20 to switch on; the inductor LI transfers the energy stored in it to the second battery E2, and the inductor L2 transfers the energy stored in it to the first

battery E1; therefore the current I_{L1} in the inductor LI and the current I_{L2} in the inductor L2 decrease slowly (as indicated by the time period t2). Then, after the energy in the inductor LI and L2 is released, the second battery E2 turns to charge the inductor LI, and the first battery E1 turns to charge the inductor L2; therefore the current I_{L1} in the inductor LI and the current I_{L2} in the inductor L2 increase slowly. At this time, the flow direction of the current in the inductor LI and L2 is reverse to the flow direction in the time period t_1 and t_2 (as indicated by the time period t3). Then, when the current In in the inductor LI or the current I_{L2} in the inductor L2 rises to a preset value, the switching control module 100 controls the first switch unit 10 to switch on and controls the second switch unit 20 to switch off; the inductor LI transfers the energy stored in it to the first battery E1, and the inductor L2 transfers the energy stored in it to the second battery E2; therefore the current I_{L1} in the inductor L1 and the current I_{L2} in the inductor L2 decrease slowly (as indicated by the time period t4; now, the heating circuit has accomplished a complete working cycle). The cycles continue on and on, till the first battery E1 and second battery E2 are heated up satisfactorily. It should be noted: U_{L1} and U_{L2} in Figure 8 represent the voltage of the inductor LI and the voltage of the inductor L2; the voltage Un is a constant value in forward direction when the current I_{L1} through the inductor LI increases in forward direction or decreases in reverse direction , and is a constant value in reverse direction when the current I_{L1} through the inductor LI decreases in forward direction or increases in reverse direction . The same is true also for voltage U_{L2}.

By adding an inductor L2 in the heating circuit, the first battery E1 and second battery E2 are always in a charging/discharging process, and current always flows through the impedance element R1 and impedance element R2; thus, the heating efficiency is further improved. Alternatively, the current flowing through the first and second batteries and the first and second switch units can be limited by the inductor LI and L2 and the preset value, so that the first and second batteries and the first and second switch units are protected.

In addition, it should be noted: the "preset value" mentioned above shall be set

according to the current endurable by the first battery E1, second battery E2, and other elements/components in the heating circuit, with comprehensive consideration of heating efficiency and protection of the first battery E1 and second battery E2 against damages, as well as the size, weight and cost of the heating circuit.

As shown in Figure 9, the energy storage element V1 is a capacitor C1, the energy storage element V2 is a capacitor C2, the switching control module 100 can control the first switch unit 10 and second switch unit 20 to switch their ON/OFF states when the current in the capacitor C1 or capacitor C2 reaches to zero after each pair of continuous positive and negative half cycles or each pair of continuous negative and positive half cycles. Figure 10 is a timing sequence diagram of the waveform of the circuit shown in Figure 9. Hereunder the working process of another heating circuit in the second embodiment of the present invention will be described, with reference to Figure 9 and Figure 10.

First, the switching control module 100 controls the first switch unit 10 to switch on, and controls the second switch unit 20 to switch off; the first battery E1, damping element R1, current stage element L3, capacitor C1 and first switch unit 10 form a charging/discharging circuit; the second battery E2, damping element R2, current stage element L4, capacitor C2 and first switch unit 10 form another charging/discharging circuit; the two charging/discharging circuits perform charging/discharging operations (as indicated by the time period t1 shown in Figure 10; please note: the voltage waveform and current waveform of capacitor C1 are the same as those of the capacitor C2). After the two charging/discharging circuits complete a charging/discharging cycle (at this point, the current Ici through the capacitor C1 or the current Ic_2 through the capacitor C2 reaches to zero after the negative half cycle, the voltage Uci of the capacitor C1 or the voltage Uc_2 of the capacitor C2 has passed the peak value in the positive half cycle), the switching control module 100 controls the first switch unit 10 to switch off and controls the second switch unit 20 to switch on; thus, the first battery E1, damping element R1, current stage element L3, capacitor C2 and second switch unit 20 form a charging/discharging circuit, and the second battery E2, damping element R2, current

stage element L4, capacitor CI and second switch unit 20 form another charging/discharging circuit; the two charging/discharging circuits perform charging/discharging operations (as indicated by the time period t2 shown in Figure 10; please note: at this point, the voltage waveform and current waveform of the capacitor CI are the same as those of the capacitor C2). After the two charging/discharging circuits complete a charging/discharging cycle (at this point, the current Ici through the capacitor CI or the current Ic_2 through the capacitor C2 reaches to zero after the positive half cycle, and the entire heating circuit accomplishes a complete working cycle), the switching control module 100 controls the first switch unit 10 to switch on and controls the second switch unit 20 to switch off again; in that way, the cycles continue on and on, so that the current flows through the damping element R1 and damping element R2 continuously; thus, the damping element R1 and damping element R2 generate heat, and thereby heat up the first battery E1 and second battery E2 to the expected condition.

By adding a capacitor C2 in the heating circuit, two charging/discharging circuits are formed at the same time in each working cycle, and therefore the first battery E1 and second battery E2 are always in a charging/discharging process, and the current always flows through the damping element R1 and damping element R2; thus, the heating time can be shortened.

Figure 11 is a circuit diagram of an embodiment of the switch unit in the heating circuit provided in the present invention. As shown in Figure 11, the first switch unit 10 and/or the second switch unit 20 can comprise a switch Kll and a one-way semiconductor element Dll connected in parallel with the switch Kll in reverse direction , wherein, the switching control module 100 is electrically connected with the switch Kll, and is configured to control ON/OFF of the forward direction branches of the first switch unit 10 and/or the second switch unit 20 by controlling ON/OFF of the switch Kll. The ON/OFF control of switch Kll can be performed in the grid zone shown in Figure 3, Figure 5, Figure 8 and Figure 10. In Figure 5 and Figure 10, when or after the current flowing through the first switch unit 10 or the second switch unit 20 reaches to zero, the switching control module 100 can control

the first switch unit 10 or the second switch unit 20 to switch off respectively.

While some preferred embodiments of the present invention are described above with reference to the accompanying drawings, the present invention is not limited to the details in those embodiments. Those skilled in the art can make modifications and variations to the technical scheme of the present invention, without departing from the spirit of the present invention. However, all these modifications and variations shall be deemed as falling into the protected domain of the present invention.

In addition, it should be noted: the specific technical features described in above embodiments can be combined in any appropriate form, provided that there is no conflict. To avoid unnecessary repetition, the possible combinations are not described specifically in the present invention. Moreover, the different embodiments of the present invention can be combined freely as required, as long as the combinations don't deviate from the ideal and spirit of the present invention. However, such combinations shall also be deemed as falling into the scope disclosed in the present invention.

Claims

1. A battery heating circuit, the battery comprises a first battery (E1) and a second battery (E2); the heating circuit comprises a first switch unit (10), a second switch unit (20), a damping element Rl, a damping element R2, a current storage element L3, a current storage element L4, a switching control module (100) and an energy storage element VI,

the first battery (E1), the damping element Rl, the current storage element L3, the energy storage element VI and the first switch unit (10) are connected in series to constitute a first charging/discharging circuit;

the second battery (E2), the damping element R2, the current storage element L4, the energy storage element VI and the second switch unit (20) are connected in series to constitute a second charging/discharging circuit; when the energy storage element VI is charged or discharges, the direction of charging/discharging current in the second charging/discharging circuit is reverse to the direction of charging/discharging current in the first charging/discharging circuit;

the switching control module (100) is electrically connected with the first switch unit (10) and second switch unit (20), and the switching control module (100) is configured to control the first switch unit (10) and the second switch unit (20) to switch on in alternate, so as to control the electric energy to flow among the first battery (E1), the energy storage element VI and the second battery (E2).

2. The battery heating circuit according to claim 1, wherein the damping element Rl and the damping element R2 are the parasitic resistances in the first battery (E1) and the second battery (E2) respectively, and the current storage element L3 and the current storage element L4 are the parasitic inductances in the first battery (E1) and the second battery (E2) respectively.

3. The battery heating circuit according to claim 1, wherein the energy storage element VI is an inductor LI.

4. The battery heating circuit according to claim 3, wherein the switching control module (100) is configured to control the first switch unit (10) and the second

switch unit (20) to switch their ON/OFF states when the current in the inductor LI reaches to a preset value.

5. The battery heating circuit according to claim 1, wherein the energy storage element VI is a capacitor CI.

6. The battery heating circuit according to claims 5, wherein the switching control module (100) is configured to control the first switch unit (10) and second switch unit (20) to switch their ON/OFF states when the current in the capacitor CI reaches to zero after each pair of continuous positive and negative half cycles or each pair of continuous negative and positive half cycles.

7. The battery heating circuit according to claim 1, wherein the heating circuit further comprises an energy storage element V2,

the first battery (E1), the damping element Rl, the current storage element L3, the energy storage element V2 and the second switch unit (20) are connected in series to form a third charging/discharging circuit;

the second battery (E2), the damping element R2, the current storage element L4, the energy storage element V2 and the first switch unit (10) are connected in series to form a fourth charging/discharging circuit; when the energy storage element V2 is charged or discharges, the direction of charging/discharging current in the third charging/discharging circuit is reverse to the direction of charging/discharging current in the fourth charging/discharging circuit;

the switching control module (100) is configured to control the electric energy to flow among the first battery (E1), the energy storage element VI, the energy storage element V2 and the second battery (E2) by controlling the first switch unit (10) and the second switch unit (20) to switch on in alternate.

8. The battery heating circuit according to claim 7, wherein the energy storage element VI is an inductor LI, the energy storage element V2 is an inductor L2

9. The battery heating circuit according to claim 8, wherein the switching control module (100) is configured to control the first switch unit (10) and the second switch unit (20) to switch their ON/OFF states when the current in the inductor LI or

the inductor L2 reaches to a preset value.

10. The battery heating circuit according to claim 7, wherein the energy storage element V1 is a capacitor C1, the energy storage element V2 is a capacitor C2.

11. The battery heating circuit according to claim 10, wherein the switching control module (100) is configured to control the first switch unit (10) and the second switch unit (20) to switch their ON/OFF states when the current in the capacitor C1 or capacitor C2 reaches to zero after each pair of continuous positive and negative half cycles or each pair of continuous negative and positive half cycles.

12. The battery heating circuit according to any one of claims 1 to 11, wherein the first switch unit (10) and/or the second switch unit (20) comprises a switch K11 and a one-way semiconductor element D11 connected in parallel with the switch K11 in reverse direction , and the switching control module (100) is electrically connected with the switch K11, and the switching control module (100) is configured to control ON/OFF of the forward direction branches of the first switch unit (10) and/or the second switch unit (20) by controlling ON/OFF of the switch K11.

AMENDED CLAIMS
received by the International Bureau on 24 October 2011 (24.10.2011)

1. A battery heating circuit, the battery comprises a first battery (E1) and a second battery (E2); the heating circuit comprises a first switch unit (10), a second switch unit (20), a damping element R1, a damping element R2, a current storage element L3, a current storage element L4, a switching control module (100) and an energy storage element V1,

the first battery (E1), the damping element R1, the current storage element L3, the energy storage element VI and the first switch unit (10) are connected in series to constitute a first charging/discharging circuit;

the second battery (E2), the damping element R2, the current storage element L4, the energy storage element VI and the second switch unit (20) are connected in series to constitute a second charging/discharging circuit; when the energy storage element V1 is charged or discharges, the direction of charging/discharging current in the second charging/discharging circuit is reverse to the direction of charging/discharging current in the first charging/discharging circuit;

the switching control module (100) is electrically connected with the first switch unit (10) and second switch unit (20), and the switching control module (100) is configured to control the first switch unit (10) and the second switch unit (20) to switch on in alternate, so as to control the electric energy to flow among the first battery (E1), the energy storage element VI and the second battery (E2),

wherein the heating circuit further comprises an energy storage element V2,

the first battery (E1), the damping element Rl, the current storage element L3, the energy storage element V2 and the second switch unit (20) are connected in series to form a third charging/discharging circuit;

the second battery (E2), the damping element R2, the current storage element L4, the energy storage element V2 and the first switch unit (10) are connected in series to form a fourth charging/discharging circuit; when the energy storage element V2 is charged or discharges, the direction of charging/discharging current in the third charging/discharging circuit is reverse to the direction of charging/discharging current in the fourth charging/discharging circuit;

the switching control module (100) is configured to control the electric energy to flow among the first battery (E1), the energy storage element VI, the energy storage element V2 and the second battery (E2) by controlling the first switch unit (10) and the second switch

unit (20) to switch on in alternate.

2. The battery heating circuit according to claim 1, wherein the damping element R1 and the damping element R2 are the parasitic resistances in the first battery (E1) and the second battery (E2) respectively, and the current storage element L3 and the current storage element L4 are the parasitic inductances in the first battery (E1) and the second battery (E2) respectively.

3. The battery heating circuit according to claim 1, wherein the energy storage element VI is an inductor L1.

4. The battery heating circuit according to claim 3, wherein the switching control module (100) is configured to control the first switch unit (10) and the second switch unit (20) to switch their ON/OFF states when the current in the inductor LI reaches to a preset value.

5. The battery heating circuit according to claim 1, wherein the energy storage element V 1 is a capacitor Cl.

6. The battery heating circuit according to claims 5, wherein the switching control module (100) is configured to control the first switch unit (10) and second switch unit (20) ro switch their ON/OFF states when the current in the capacitor C1 reaches to zero after each pair of continuous positive and negative half cycles or each pair of continuous negative and positive half cycles.

7. (canceled)

8. The battery heating circuit according to claim 7, wherein the energy storage element V 1 is an inductor LI, the energy storage element V2 is an inductor L2

9. The battery heating circuit according to claim 8, wherein the switching control module (100) is configured to control the first switch unit (10) and the second switch unit (20) to switch their ON/OFF states when the current in the inductor L 1 or the inductor L2 reaches to a preset value,

10. The battery heating circuit according to claim 7, wherein the energy storage element V 1 is a capacitor C1, the energy storage element V2 is a capacitor C2.

11. The battery heating circuit according to claim 10, wherein the switching control module (100) is configured to control the first switch unit (10) and the second switch unit (20) to switch their ON/OFF states when the current in the capacitor CI or capacitor C2 reaches to zero after each pair of continuous positive and negative half cycles or each pair of continuous negative and positive half cycles.

12. The battery heating circuit according to any one of claims 1 to 11, wherein the first switch unit (10) and/or the second switch unit (20) comprises a switch Kl 1 and a one-way semiconductor element D11 connected in parallel with the switch Kl 1 in reverse direction , and the switching control module (100) is electrically connected with the switch K 11, and the switching control module (100) is configured to control ON/OFF of the forward direction branches of the first switch unit (10) and/or the second switch unit (20) by controlling ON/OFF of the switch Kl 1.

STATEMENT UNDER ARTICLE 19 (1)

The claims as originally filed are amended under Article 19 as follow;

(1) Incorporating the technical features of claim 7 into claim 1;

(2) Claims 2-6 and 8-1-2 are unchanged.

After the amendment, the new added technical features in claim 1 are not disclosed by D1 (US5990661A). And, the prior art, considered individually or in combination, does not teach the new added technical features in claim 1, Accordingly, the amended claim 1 and its dependent claims shall have inventive steps in the sense of PCT Article 33(3).

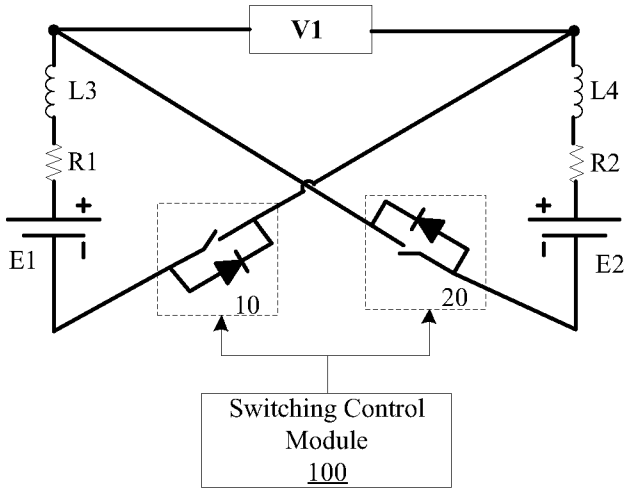


Figure 1

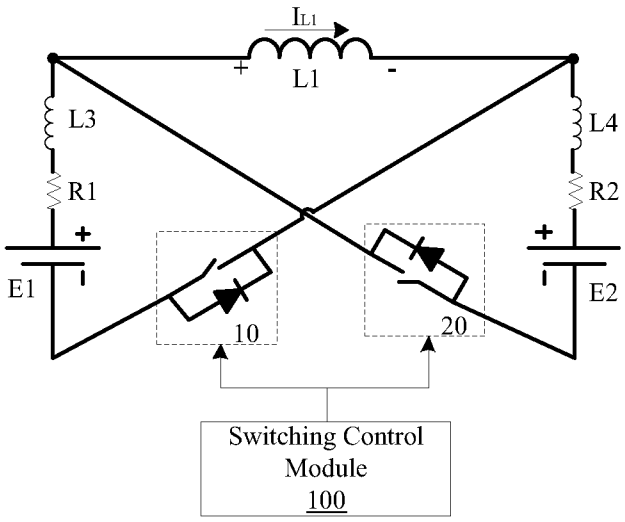


Figure 2

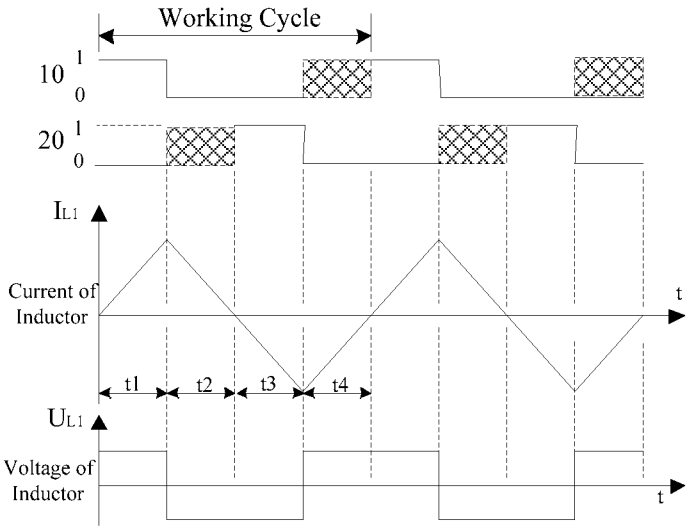
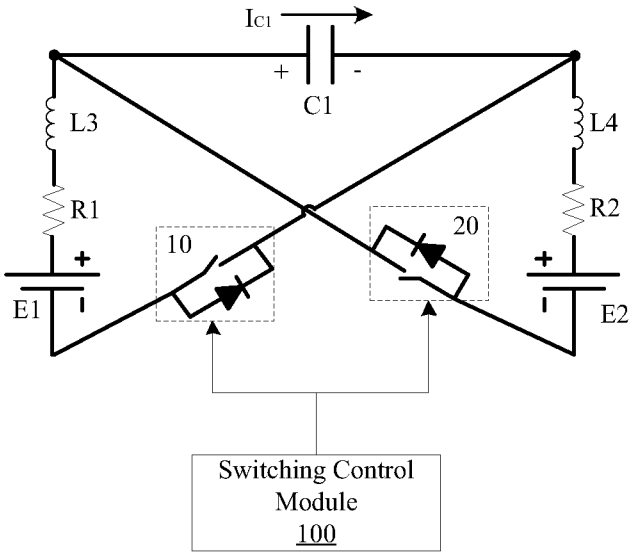


Figure 3



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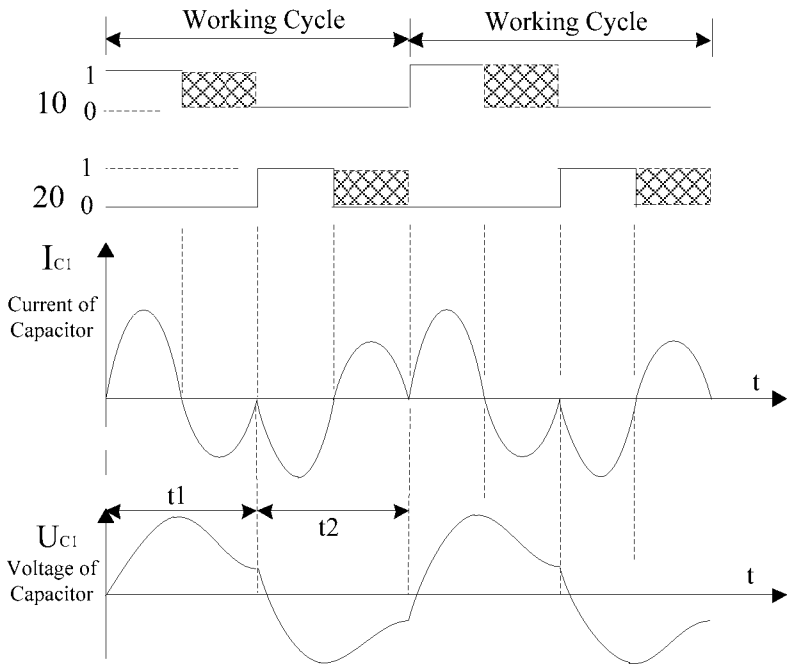

Figure 5

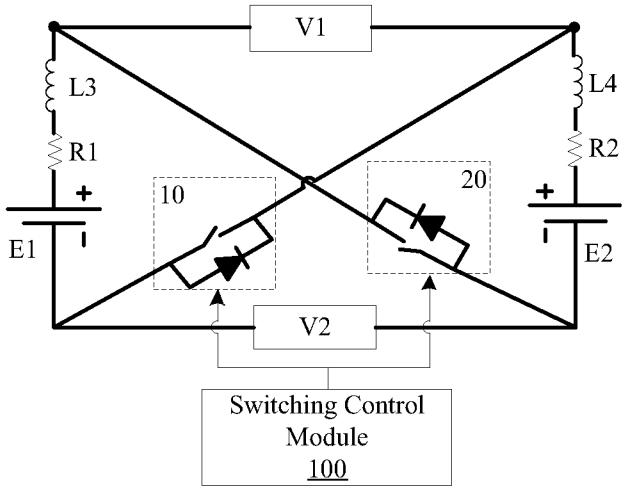

Figure 6

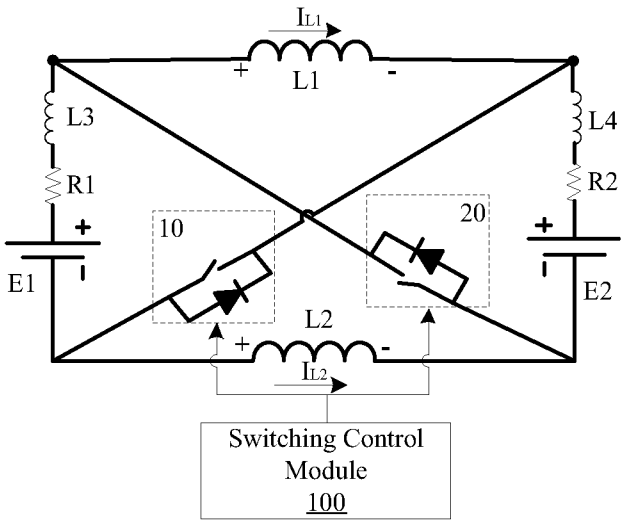

Figure 7

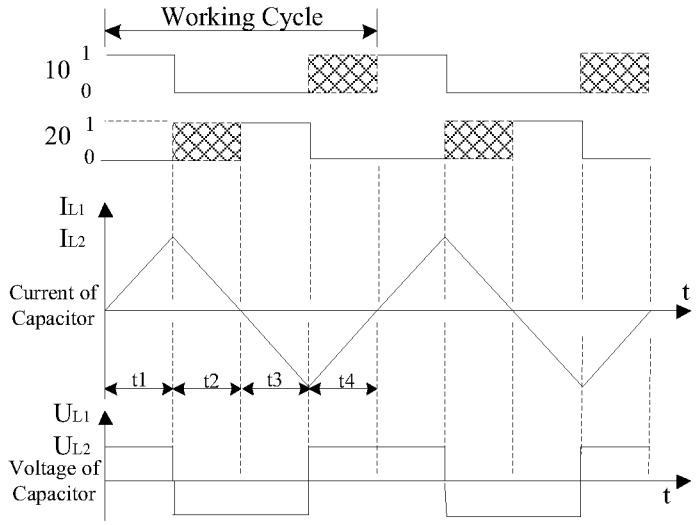

Figure 8

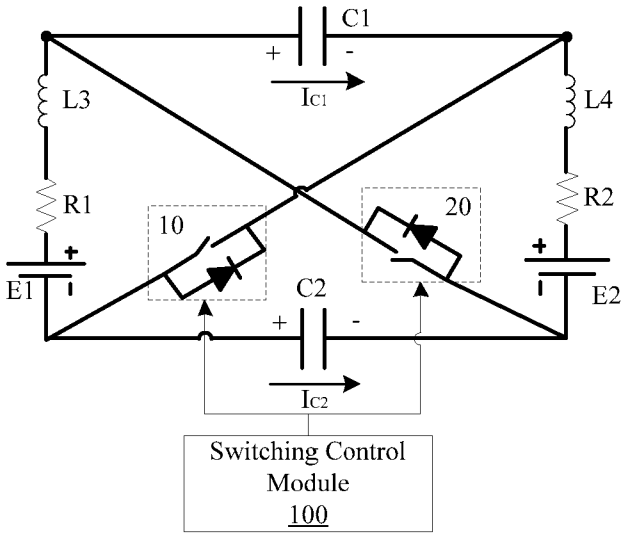

Figure 9

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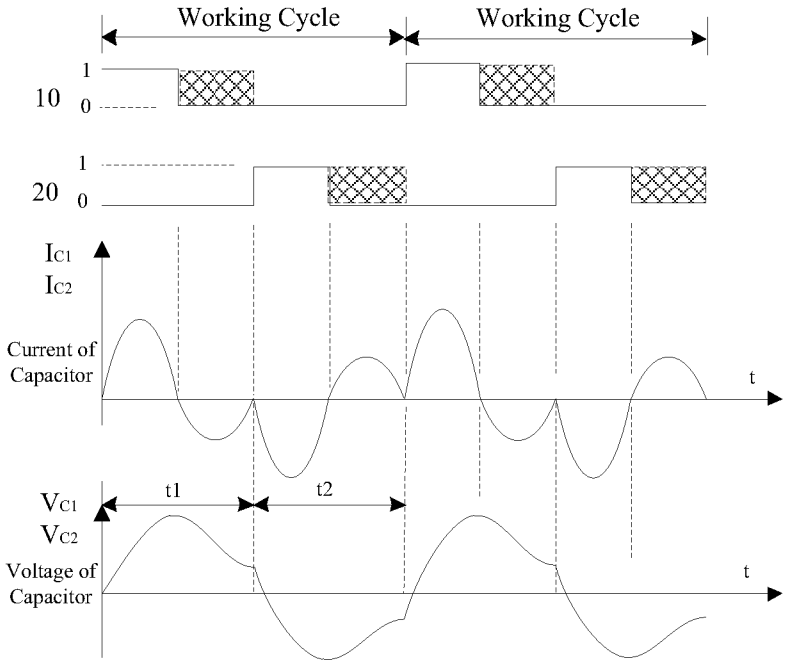

Figure 10

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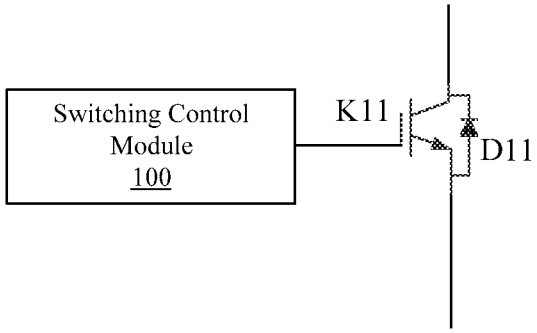

Figure 11

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN201 1/074436

A. CLASSIFICATION OF SUBJECT MATTER

See Extra Sheet

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: H01M; H02J7/+; H05B

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

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

VEN; CNPAT; CNKI: heat, thermal, charge, discharge, circuit, battery, accumulator

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US5990661A (DAIMLERCHRYSLER CORP et al) 23 Nov.l999(23.11.1999) column 2 line 48- column 4 line 33 in the description, figures 1-2	1-6,12
A	US5362942A (INTERDIGITAL TECHNOLOGY CORP) 08 Nov.1994(08. 11. 1994) the whole document	1-12
A	US6882061B1 (DAIMLERCHRYSLER CORP et al) 19 Apr. 2005(19.04.2005) the whole document	1-12
A	US6259229B1 (DAIMLERCHRYSLER CORP et al) 10 Jul.2001(10.07.2001) the whole document	1-12
A	US4222000A (LUCAS IND LTD JOSEPH) 09 Sep.1980 (09.09.1980) the whole document	1-12

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim (S) or which is cited to establish the publication date of another citation or other special reason (as specified)

"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
07 Jul. 2011(07.07.2011)	**18 Aug. 2011 (18.08.2011)**
Name and mailing address of the ISA/CN The State Intellectual Property Office, the P.R.China 6 Xitucheng Rd., Jimen Bridge, Haidian District, Beijing, China 100088 facsimile No. 86-10-62019451	Authorized officer LI,Hua Telephone No. (86-10)6241 1623

Form PCT/ISA /210 (second sheet) (July 2009)

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/CN201 1/074436

Patent Documents referred in the Report	Publication Date	Patent Family	Publication Date
US5990661A	23.11.1999	NONE	
US5362942A	08.11.1994	NONE	
US6882061B1	19.04.2005	NONE	
US6259229B1	10.07.2001	NONE	
US4222000A	09.09.1980	GB2001211A	24.01.1979
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		IT1097144B	26.08.1985
		DE2830930C	03.05.1989

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN20 11/074436

Classification of subject matter:

H01M 10/42 (2006.01)i

H01M 10/50 (2006.01)i

H05B 3/00 (2006.01)i

H02J 7/00 (2006.01)i