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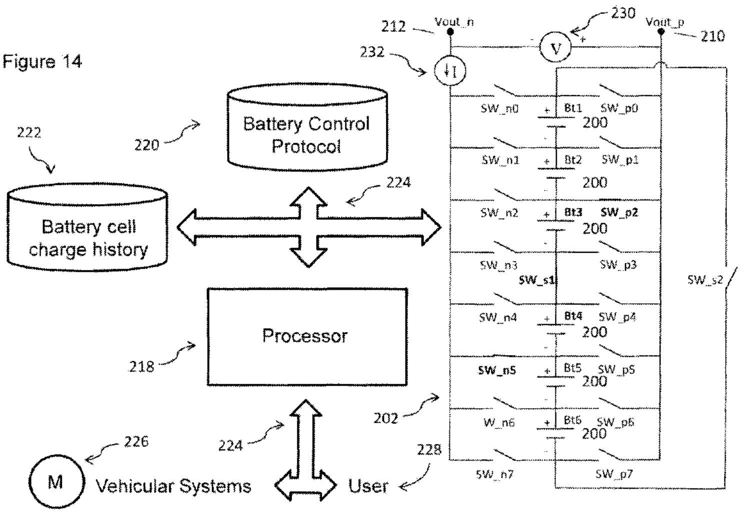
(54) Title: RECONFIGURABLE BATTERY

Figure 14



(57) Abstract: A reconfigurable battery has at least one bank of statically joined series connected battery cells, each cell including a positive and a negative pole. The poles connect through switches to respective output connections. Activating a set of processor controlled switches reconfigures at least some of the battery cells into a configuration to provide a voltage across the output connections. The output battery voltage may vary intermediately between zero volts and the maximum voltage produced by the series connected battery cells. An alternative configuration of switches divides groups of series connected battery cells into separate battery banks that permit other battery cell configurations. Duty cycle modulation of the switches allows intermediate control of output voltage with reduced switching transients. Reconfigurable battery cells used in combination with an electric motor permit selectable speed control and battery regeneration schemes matched to motor output.

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RECONFIGURABLE BATTERY

BACKGROUND OF THE INVENTION

The present invention relates to the field of electric batteries designed for use with electric motors which are rechargeable using regenerative charging, such as batteries for electric bicycles. More specifically, the present invention relates to a reconfigurable battery, reconfigurable electric motors for use with such a reconfigurable battery, methods for reconfiguring a battery for driving variable electrical loads, and methods for reconfiguring a battery for charging and for reconfiguring electric motors for charging a battery.

The present invention is described in connection with electric bicycles where a rechargeable battery drives an electric motor. In prior art electric bicycles, in some instances the current from the battery is regulated by a speed controller that controls the motor which provides assistance to the rider. In other instances, where the rider wants to slow down or brake going downhill, the motor acts as a generator and supplies the current back to the battery, thereby achieving regenerative braking that recovers part of the energy that would otherwise be lost when using a mechanical brake alone.

An electric motor typically uses a set of magnets, for example, electro magnets and permanent magnets. As the motor turns, the attractive and repulsive forces of these magnets are regulated electrically such that the motor turns continuously in the desired direction. This could be done by electro-mechanical switches (e.g. commutators), or could be done by solid state switches (e.g. FETs – Field Effects Transistors). Figure 1 shows an example of a motor 12 connected to a battery 10. As the current I_m flows into the motor 12 and the motor turns, the motor generates a back EMF (Electro Motive Force) which is a voltage roughly proportional to the speed of the motor 12. The current I_m is defined as $(V_B-V_M)/(R_M+R_B)$ where R_M is the internal resistance of the motor 12 and R_B is the internal resistance of the battery. Given a fixed applied voltage V_B (e.g. from the battery 10) the back EMF reduces the amount of current that flows into the motor 12, because the current flow is proportional to the difference between the motor voltage V_M (back EMF) and the battery voltage V_B. For example, if the motor 12 is turning (with some outside assistance) at a rate such that the back EMF equals the battery voltage V_B, than there will be no current flow. If the motor 12 turns faster than this such that the back EMF is higher than the battery voltage V_B, then the current flows the other way, thereby recharging the battery 10. One extreme case is a stall, when the motor 12 is at rest. In such a case, the back EMF is zero since the motor is at rest, the current flow from the battery 10 will be at its maximum, and the motor 12 will produce its highest torque.

When the bicycle is moving and the motor 12 produces a finite back EMF, the motor 12 can be used as a generator to recharge the battery 10, while achieving a desired level of braking. In order to achieve this, the voltage out of the motor 12 is increased to a level higher than the battery 10 using a device known as an inverter.

A block diagram of a typical prior art electric bicycle system without regenerative braking is shown in Figure 2. A battery 10 provides current to a motor 12 though a speed controller 11. The speed controller 11 governs the current flow to the motor 12, thereby controlling its speed. The speed controller 11 may be set to a desired speed by a rider using a control knob 13.

A block diagram of a further prior art electric bicycle system that provides regenerative braking is shown in Figure 3. Figure 3 is similar to Figure 2 but also includes an inverter 14 in parallel with the controller 11. A switch 15 is provided for coupling the motor 12 to the controller 11 (in a drive mode) or the inverter 14 (in a braking mode). During the braking mode, current is generated by the motor 12 and passed to the battery 10 by the inverter 14, in order to charge the battery.

It should be noted that a practical system involves two distinct operations, one that drives the motor and the bicycle wheel(s) by supplying current from the battery to the motor(s), and another that uses the current from the motor(s) to charge the battery to achieve regenerative braking, thereby slowing down the bicycle. It should be further apparent from Figure 3 that in order to recharge the battery, one needs an inverter that increases the voltage from the motor to a value higher than the battery voltage, in order for the current to flow back into the battery.

For a typical rechargeable battery, the charging voltage must be higher than the battery voltage. The higher the charging voltage relative to the battery voltage, the more current flows into the battery. Controlling the charging voltage is one of the ways to control the rate of recharging, as well as the rate of braking. Another way to control the recharging rate is pulse width modulation (PWM), where a switch between the charging source and the battery regulates an on-off duty cycle. Of course, the charging voltage still needs to be higher than the battery voltage for such a device to work.

In most electric vehicles such as electric bicycles and electric cars that utilize regenerative braking, the electrical system typically consists of several subsystems, namely a motor, a speed controller, an inverter, and a battery. Sometimes the speed controller regulates both the drive and braking current via PWM. Potentially, a clever inverter design could regulate both driving and braking by regulating the voltage to the motor for driving, and regulating the voltage to the battery for regenerative braking, thereby eliminating the need for a separate speed controller.

However, an inverter is not an easy device to design or cheaply produce, as it must handle a large amount of current (especially during quick braking) and sometimes a high output voltage, while its input voltage can fluctuate over a wide range. The input voltage in this case is the back EMF from the motor, typically close to zero when the bicycle is coming to a stop, and close to the maximum battery voltage when the bicycle is coasting on a level ground at its maximum speed (usually the battery voltage limits the top speed).

Also an inverter typically achieves its functionality using rapid switching devices. One inverter design could turn the DC current from the motor to AC current first, increase the voltage using a step-up transformer, and convert the AC current back to DC in order to recharge the battery. Another inverter design could use temporary energy storage elements such as capacitors and inductors in a charge-pump configuration in order to raise the voltage. The switching frequency involved is typically in the order of 1-100 KHz. In most of the known inverter designs, the energy loss is significant, and the cost is very high due to the high current requirement (100 Amps or more) in addition to the weight. For this reason, only a small percentage of electric bicycle products incorporate regenerative braking in their design.

It would be advantageous to provide a battery and/or electric motor configuration that provides driving and regenerative braking, for example in an electric bicycle, over a reasonable range of operations without the need for an inverter.

It would also be useful to provide a reconfigurable battery and battery control system that provides duty cycle modulation of an array of battery cells for intermediate output voltage control without incurring large switching losses, while simultaneously reducing switching induced transient signals.

The methods and apparatus of the present invention provide a series connected reconfigurable battery having these and other advantages.

SUMMARY OF THE INVENTION

The present invention relates to reconfigurable batteries, e.g., for use in the drive systems of electric vehicles such as bicycles, automobiles, trucks, locomotives, utility carts, and the like. In particular, the present invention relates to a reconfigurable battery with a plurality of series connected battery cells and reconfigurable electric motors for use with such a reconfigurable battery in an electric vehicle drive system, and methods for reconfiguring a battery for charging and discharging through variable electrical loads.
In accordance with the invention, a reconfigurable battery is disclosed having at least one bank of batteries made from a statically joined plurality of series connected battery cells. Each battery cell has a first voltage pole and a second voltage pole. At least one processor controlled switch electrically connects between the first voltage pole of each battery cell and a first electrical output connection. At least one processor controlled switch electrically connects between the second voltage pole of each battery cell and a second electrical output connection. The processor controlled switches are adapted to electrically reconfigure the battery cells by coupling a first voltage pole of a battery cell to the first electrical output connection and a second voltage pole of a battery cell to the second electrical output connection to provide a reconfigurable battery output voltage between the first and second electrical output connections.

The reconfigurable battery output voltage is approximately equal to the voltage summation of the electrically reconfigured battery cells, and is in a range between zero volts and a maximum absolute output voltage (e.g., positive or negative) for the statically joined plurality of series connected battery cells.

In another example embodiment, the reconfigurable battery further includes at least one switching means electrically connected between the first voltage pole of a beginning battery cell in the statically joined plurality of series connected battery cells and the second electrical output connection.

The reconfigurable battery can also include at least one switch electrically connected between the second voltage pole of an end battery cell in the statically joined plurality of series connected battery cells and the first electrical output connection.

In another example embodiment, the reconfigurable battery further includes a plurality of banks connected in a parallel configuration.

In another example embodiment, the reconfigurable battery includes a series joining of a first bank of battery cells to a second bank of battery cells. A first intermediate processor controlled switch is connected between a second voltage pole of an end positioned battery cell in a first bank and a first voltage pole of a beginning positioned battery cell in a second bank. A second intermediate processor controlled switch is connected between a first voltage pole of a beginning positioned battery cell in a first bank and a second voltage pole of an end positioned battery cell in a second bank. The first electrical output connection of the first bank is connected to the first electrical output connection of the second bank, and the second electrical output connection of the first bank is connected to the second electrical output connection of the second bank. In operation, the first intermediate processor controlled switch and the second intermediate processor controlled switch cannot simultaneously be in a closed state.

In addition, in the reconfigurable battery of the preceding example embodiment, the second bank of statically joined plurality of series connected battery cells may be substituted by a single battery cell.

In another example embodiment, the reconfigurable battery of the preceding example embodiments can further include a capacitive element and/or an inductive element for voltage and/or current waveform filtering.

Any of the preceding example embodiments can include a voltage monitoring means and a current monitoring means, where the voltage monitoring means is a voltmeter connected across the first electrical output connection and the second electrical output connection. Alternatively, the current monitoring means is an ammeter either connected in series with the first electrical output connection or the second electrical output connection. Yet another alternative is that the voltage and current monitoring means may be part of a battery condition control system. Still further, temperature monitoring of the battery cells can be provided for use in charge and discharge control, as well as for diagnosing failing or failed cells.

The battery condition control system includes at least one electronic processor, at least one data storage device, at least one communication channel, at least one reconfigurable battery control protocol, and a user interface protocol to allow communication and control by a user.

In the example embodiments, the switches and the intermediate switches can include power MOSFET and/or other solid state (e.g., semiconductor) switches with, e.g., Pulse Width Modulation or Pulse Density Modulation control circuitry. Mechanical switches could also be used alone or in combination with other solid state switches. In addition, the first voltage pole can be set to a higher voltage potential than the second voltage pole.

In an example embodiment, the battery provides energy for an electrical load, where the electrical load can be a vehicle with at least one electrical motor. The vehicle is one of an electric bicycle, an electric scooter, an electric vehicle, a hybrid automobile, a hybrid truck, an electric powered wheelchair, and an electric powered golf cart.

In another example embodiment, the reconfigurable battery is charged by connecting at least one power source to the battery. The power source can be, for example, a vehicle electrical system adapted for regenerative charging, or a rectified (or direct) AC power source.

In an example embodiment, a method for reconfiguring a battery includes the steps of arranging a portion of a statically joined plurality of series connected battery cells into a first configuration adapted to provide a first battery voltage. Another step includes reconfiguring at least a portion of the statically joined plurality of series connected battery cells into a second configuration adapted to provide a second battery voltage. The reconfiguring includes the steps of closing a first processor controlled switch electrically connecting a first voltage pole of a battery cell in the statically joined plurality of series connected battery cells and a first electrical output connection. Next, closing a second processor controlled switch electrically connecting a second voltage pole of a battery cell in the statically joined plurality of series connected battery cells and a second electrical output connection.

In another example embodiment, a method is disclosed where reconfiguring a series joined first bank to a second bank further includes one of two steps. Closing a first intermediate processor controlled switch connected between a second voltage pole of an end positioned battery cell in the first bank and a first voltage pole of a beginning positioned battery cell in the second bank. Alternatively, closing a second intermediate processor controlled switch connected between a first voltage pole of a beginning positioned battery cell in the first bank and a second voltage pole of an end positioned battery cell in the second bank.

In the method of the preceding example embodiment, the processor controlled switch can include one of a pulse width modulation processor controlled switch or a pulse density modulation processor controlled switch. Also, the first voltage pole can be at a higher voltage potential than the second voltage pole.

A further example embodiment includes a method whereby the second processor controlled switch is alternatively switched by pulse width modulation switching or pulse density modulation switching between a first configuration of series connected battery cells exhibiting a first voltage and a second configuration of series connected battery cells exhibiting a second voltage producing an intermediate output voltage between the first voltage and the second voltage.

Another example embodiment includes a method where the reconfigurable battery is alternatively configured to provide energy to at least one electrical load or to receive energy for recharging.

One example electrical load is a vehicle with at least one electrical motor, where the vehicle is one of an electric bicycle, an electric scooter, an electric vehicle, a hybrid automobile, a hybrid truck, an electric powered wheelchair, and an electric powered golf cart.

One example method of recharging the reconfigurable battery is by connecting at least one power source to the battery. One such power source is regenerative charging by applying a vehicle braking action that activates at least one electric motor, inducing current flow to the battery. Another method of recharging is by applying either a rectified AC power source or a direct AC power source, depending on the battery configuration. For example, with dynamic polarity reversal of the battery, a direct AC source can be used without rectification.

A further example embodiment includes a method of monitoring voltage and current of battery power discharge. The method includes the steps of monitoring voltage and current of battery power charge, and controlling the reconfiguration of a plurality of series connected battery cells based on the monitoring. An auxiliary power source for monitoring, for controlling, and for reconfiguring of a plurality of series connected battery cells can also be applied.

Another example embodiment describes a method where a reconfigurable battery voltage output signal includes the steps of smoothing and filtering by providing a capacitive and/or inductive element.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will hereinafter be described in conjunction with the appended drawing figures, wherein like reference numerals denote like elements, and:

Figure 1 shows a conventional electric motor and battery configuration;

Figure 2 shows a block diagram of a prior art electric bicycle system;

Figure 3 shows a block diagram of a further prior art electric bicycle system;

Figure 4 shows an example embodiment of an electric bicycle in accordance with the present invention;

Figure 5a shows an example embodiment of a reconfigurable battery in a first battery cell configuration in accordance with the present invention;

Figure 5b shows an example embodiment of a reconfigurable battery in a second battery cell configuration in accordance with the present invention;

Figure 5c shows an example embodiment of a reconfigurable battery in a further battery cell configuration in accordance with the present invention;

Figure 6 shows a further example embodiment of a reconfigurable battery in accordance with the present invention;

Figure 7a shows an example embodiment of a reconfigurable electric motor assembly in a first configuration in accordance with the present invention;

Figure 7b shows an example embodiment of a reconfigurable electric motor assembly in a second configuration in accordance with the present invention;

Figure 8 shows an example embodiment of a reconfigurable electric motor assembly with unequal distribution of load in accordance with the present invention;

Figure 9a shows an example embodiment of a reconfigurable battery in accordance with the present invention;

Figure 9b shows an example embodiment of a configured reconfigurable battery with maximum output voltage in accordance with the present invention;

Figure 9c shows an example embodiment of a configured reconfigurable battery with single battery cell output voltage in accordance with the present invention;

Figure 9d shows an alternative example embodiment of a configured reconfigurable battery with single battery cell output voltage in accordance with the present invention;

Figure 9e shows an example embodiment of a configured reconfigurable battery with single battery cell output voltage in accordance with the present invention;

Figure 9f shows an example embodiment of a configured reconfigurable battery with two battery cell output voltage in accordance with the present invention;

Figure 9g shows an alternative example embodiment of a configured reconfigurable battery with two battery cell output voltage in accordance with the present invention;

Figure 9h shows a second alternative example embodiment of a configured reconfigurable battery with two battery cell output voltage in accordance with the present invention;

Figure 10a shows an example embodiment of a reconfigurable battery with two banks of battery cells in accordance with the present invention;

Figure 10b shows an example embodiment of a configured reconfigurable battery with two banks of battery cells in accordance with the present invention;

Figure 10c shows an alternative example embodiment of a configured reconfigurable battery with two banks of battery cells in accordance with the present invention;

Figure 11 shows an example embodiment of duty cycle modulation of a configured reconfigurable battery with two banks of battery cells in accordance with the present invention;

Figure 12 shows an example embodiment of duty cycle modulation with capacitance filtering of a configured reconfigurable battery with two banks of battery cells in accordance with the present invention;

Figure 13 shows an example embodiment of a configured reconfigurable battery with two banks of battery cells and voltage and current monitoring in accordance with the present invention; and

Figure 14 shows an example embodiment of a configured reconfigurable battery and a switching control system in accordance with the present invention.

DETAILED DESCRIPTION

The following detailed description provides example embodiments only, and is not intended to limit the scope, applicability, or configuration of the invention. Rather, the detailed description of the example embodiments will provide those skilled in the art with an enabling description for implementing an embodiment of the invention. It should be understood that various changes may be made in the function and arrangement of elements without departing from the spirit and scope of the invention as set forth in the appended claims.

Although the present invention is described in connection with electric bicycles where a rechargeable battery drives an electric motor, those skilled in the art will appreciate that it is equally applicable to other types of electric vehicles and battery charging systems.

In many electro-mechanical system designs (such as an electric bicycle), the complexity of the design problem is managed by breaking the system into separate sub-systems, each providing a specific functionality so that the overall system works well. Each sub-system can be designed more or less independently of the other sub-systems, as long as it meets its given design requirement. A typical prior art electric vehicle design such as an electric bicycle may be divided into the following subsystems: drive train with an electric motor, a speed controller, an inverter, a battery, and perhaps an intelligent central controller that coordinates the other subsystems. As an example, the battery sub-system may typically be supplied by a battery manufacturer with specifications including voltage and current ratings; an inverter designer may work with a specification for a range of possible input voltages from the motor that can be raised high enough to recharge the battery; a mechanical designer would design the drive train and the interface to the motor, and so on, for the other sub-systems. With such an approach, it may be easy to miss system level simplifications or synergies between sub-systems when focusing on one sub-system at a time.

The fundamental problem to be solved when recharging a battery from a motor is to keep the charging voltage higher than the battery voltage. The present invention solves this by effectively lowering the battery voltage during charging periods. This is accomplished in accordance with the present invention by means of a reconfigurable battery. As long as the battery voltage is lower than the voltage generated by the motor, recharging is accomplished. Accordingly, with the present invention, there is no need to raise the voltage out of the motor using an inverter.

A typical battery needed in an electric bicycle must generate 10s of volts, requiring half a dozen to dozens of battery cells. For example, a typical prior art electric bicycle uses a 36V, 13Ah NiMH battery. Each battery cell would typically generate between 1.2V (e.g. NiCd or NiMH cells) and 3.6 V (LiIo or LiPo cells). Many of these cells must be connected in series to generate the required voltage for the motor.

With the present invention, a reconfigurable battery is provided which is adapted to dynamically re-connect and reconfigure the battery cells as the needs of the system change (e.g., from providing current for driving the motor to receiving current for recharging the battery, and *vice versa*). Figure 4 shows a simplified embodiment of an electric bicycle 40 in accordance with the present invention. A configurable battery 42 with a plurality of cells is mounted to a bicycle frame 44. At least one motor 46 is mounted on the frame 44 and adapted to drive a wheel 48 of the bicycle 40. The battery 42 and the motor 46 are both in communication with a controller 50. The controller 50 may be adapted to control the current supplied to the motor 46 from the battery 42 for driving the wheel 48, to control the current supplied from the motor 46 to the battery 42 for recharging the battery 42, and for reconfiguring the battery 42 (or reconfiguring a plurality of motors 46) as discussed in detail below.

Figures 5a and 5b illustrate one example embodiment of a reconfigurable battery in accordance with the present invention. Figure 5a shows a plurality of battery cells 52 of a battery 42 arranged in a first configuration adapted to provide a first battery voltage to an electric motor 46. Figure 5b shows the battery cells 52 reconfigured into a second configuration adapted to provide a second battery voltage. It should be appreciated that only a portion of the plurality of battery cells may be reconfigured to provide a second configuration. The second battery voltage may be lower than the first battery voltage. The battery 42 can then be charged when the plurality of cells 52 are arranged in the second configuration.

In the first configuration as shown in Figure 5a, the plurality of battery cells 52 may be arranged in series. In the second configuration as shown in Figure 5b, the plurality of battery cells 52 may be arranged in parallel.

Alternatively, in the second configuration, only a first portion of the plurality of battery cells 52 may be arranged in parallel and a second portion of the battery cells 52 may be arranged in series. In addition, in a variation of the second configuration as shown in Figure 5c, the plurality of battery cells 52 may be arranged with at least a first portion of the battery cells in series and a second portion of the battery cells in series, with the first portion and the second portion of the battery cells arranged in parallel. For example, it is noted that in the examples shown with four battery cells 52, the battery 42 can be reconfigured to at least three possible voltages (where Vb is the voltage across each cell 52): 4xVb (all 4 cells in series as in Figure 5a), 1xVb (all 4 cells in parallel as shown in Figure 5b), and 2xVb (two pairs of cells in series, with the resulting two pairs arranged in parallel, as shown in Figure 5c),

The charging may comprise regenerative charging provided by the electric motor(s) 46 during a vehicle braking action. In such an example embodiment, at least one of the motor voltage and current of the motor 46 may be monitored. The reconfiguring of the plurality of battery cells 52 may be controlled based on the monitoring. For example, a current sensor 49 could be used to monitor the current through the motor and/or a voltage sensor 58 could be used to monitor the motor voltage, and the sensors 49 and 58 could relay the voltage and/or current information needed to a controller (e.g., controller 50 of Figure 4) to make a decision on how to reconfigure the battery 42 to the desired battery voltage. Alternatively, a sensor could monitor the motor speed in order to provide equivalent information to the controller 50. In addition, an auxiliary power source (e.g., backup battery 56) may be provided for powering the controller 50 and the sensors 49 and 58.

In addition, an amount of braking power required by the braking action may be monitored and provided to the controller 50, and the reconfiguring of the plurality of battery cells 52 may be controlled based on the monitoring. The applied braking force may be monitored by current sensor 49 (or by circuitry provided within the electric motor 46 itself) and communicated to the controller 50.

Switching means 57 may be provided, enabling the reconfiguring of the plurality of battery cells. The switching means 57 may be connected to at least one of the battery cells. For example, the switching means 57 may comprise one of pulse width modulation switching means or pulse density modulation switching means controlled by the controller 50.

A speed control switch 59 may also be provided. Switch 59 may be a pulse width modulation switching mechanism and the controller 50 may be a PWM control system adapted to adjust the on-off duty cycle of the PWM switch 59 between the motor 46 and the battery 42. The current sensor 49 may be used to calculate the average amount of current flowing. For example, if the desired amount of current cannot be maintained because the voltage difference between the motor 46 and the battery 42 is too small, the battery 42 may be reconfigured to provide a lower voltage during regenerative charging, or a higher battery voltage for driving or accelerating. For a typical DC motor, the torque of a motor (or the braking force of the motor) is proportional to the current flowing in (or out) of the motor.

The backup battery 56 may or may not be needed, and may be used to run the control circuits and the sensors 49 and 58. This backup battery 56 can be kept charged whenever the motor voltage is higher, with the additional switch 55 controlling the amount of charging.

In one example embodiment, the battery 42 maybe provided in an electric vehicle and be adapted for regenerative charging. For example, the battery 42 may be provided in an electric bicycle (as shown in Figure 4). Those skilled in the art will appreciate that the reconfigurable battery 42 may be used in other types of electric vehicles, such as an electric scooter, an electric automobile, a hybrid vehicle, an electric powered wheelchair, an electric powered golf cart, or the like. Also, it should be appreciated that the reconfigurable battery of the present invention may be adapted for use in virtually any type of device that requires the use of rechargeable batteries, in order to reduce the time needed to charge such batteries.

Thus, with the present invention, the battery 42 may be dynamically reconfigured (e.g., via the controller 50) during operation of the system. For example, the controller 50 may configure the battery cells 52 in a series configuration when the electric vehicle is in a drive mode, as shown in Figure 5a, and may configure the battery cells 52 in a parallel configuration during recharging or regenerative braking, as shown in Figure 5b.

Figure 6 shows an alternative embodiment where the main PWM switch (switch 59 of Figures 5a and 5b) is not needed. In this example embodiment, the reconfiguration switches 57 are controlled in PWM fashion (or alternatively PDM – Pulse Density Modulation).

In some electric bicycle designs, it may be advantageous to use more than one electric motor. For example, one motor may be provided for the front wheel and one motor may be provided for the rear wheel in order to double the drive torque and be able to provide regenerative braking at both wheels. Other possible configurations may call for more motors, possibly two for each wheel. With the present invention, multiple electric motors can be reconfigured to gain certain advantages, similar to reconfiguring of the battery as discussed above. One motivation for reconfiguring an arrangement of electric motors would be to increase or decrease the over-all motor voltage to help regenerative braking, especially at low speeds where each individual motor voltage could be too low to charge even a single battery cell.

Another motivation would be to increase the torque of the motors by arranging the motors in parallel. More current can flow to the aggregate motor(s) when in a parallel arrangement, as if the vehicle is in a "low gear." If the battery is reconfigured into a parallel arrangement as well, it will be able to supply the higher current the motor demands. Thus, by reconfiguring the arrangement of multiple electric motors as well as the arrangement of multiple battery cells, one may be able to find the optimum combination of series/parallel arrangements for the motors and series/parallel arrangements for the battery cells to accomplish varying situations for the electric vehicle, whether in a drive mode or in a regenerative braking mode.

Accordingly, the present invention also includes methods and apparatus for reconfiguring electric motors, which as discussed below may be combined with the methods and apparatus for reconfiguring a battery.

In one example embodiment as shown in Figure 7a, two or more electric motors 46 are arranged in a first configuration adapted to provide at least one of a first torque output during a driving action and a first regenerative voltage output during a braking action. As shown in Figure 7b, the two or more electric motors 46 may be reconfigured into a second configuration adapted to provide at least one of a second torque output during the driving action and a second regenerative voltage output during the braking action.

The first configuration as shown in Figure 7a may comprise the two or more electric motors arranged in parallel. The second configuration as shown in Figure 7b may comprise the two or more electric motors arranged in series.

In one example embodiment, a battery 42 for operating the two or more electric motors 46 may be provided (e.g., a battery 42 as shown in Figures 5a, 5b, 5c, or Figure 6). The battery 42 may comprise a plurality of battery cells, and one of the first or second configuration of the two or more electric motors 46 may be selected for regenerative charging of the battery 42.

The battery 42 may comprise a plurality of battery cells 52, which may be arranged in a first battery configuration (e.g., as shown in Figure 5a) adapted to provide a first battery voltage for operating the two or more electric motors 46 during the driving action. At least a portion of the plurality of battery cells 52 may be reconfigured into a second battery configuration (e.g., as shown in Figure 5b) adapted to provide a second battery voltage during the braking action, where the second battery voltage is lower than the first battery voltage. The battery 42 can then be charged when the two or more electric motors 46 are arranged in the second configuration and the plurality of cells 52 are arranged in the second battery configuration.

In the first battery configuration, the plurality of battery cells 52 may be arranged in series as shown in Figure 5a. In the second battery configuration, the plurality of battery cells may be arranged in parallel as shown in Figure 5b.

Alternatively, in the second battery configuration, a first portion of the plurality of battery cells 52 may be arranged in parallel and a second portion of the battery cells 52 may be arranged in series. In addition, in the second battery configuration, the plurality of battery cells 52 may be arranged with at least a first portion of the battery cells 52 in series and a second portion of the battery cells 52 in series, with the first portion and the second portion of the battery cells 52 arranged in parallel (as shown in Figure 5c).

The voltage (or current) of the motors 46 may be monitored (e.g., via sensors 58 and 49 discussed above in connection with Figures 5a and 5b). Based on the monitoring, at least one of the reconfiguring of the plurality of battery cells 52 and the reconfiguring of the two or more electric motors 46 may be controlled (e.g., by controller 50). An auxiliary power source (e.g., backup battery 56) may be provided for powering the controller 50 and the sensors 49 and 58.

In addition, at least one of an amount of braking power required by the braking action and an amount of drive power required by the driving action may be monitored. For example, the applied braking force may be monitored by current sensor 49 (or by the circuitry provided within the electric motor 46 itself), and communicated to the controller 50. At least one of the reconfiguring of the plurality of battery cells 52 and the reconfiguring of the two or more electric motors 46 may be controlled based on the monitoring.

Battery cell switching means 57 may be provided to enable the reconfiguring of the plurality of battery cells 52 (as discussed above). Motor switching means 62 (Figures 7a, 7b and 8) may be provided to enable the reconfiguring of the two or more electric motors 46. The motor switching means 62 may be connected to at least one of the electric motors 46. The motor switching means 62 may comprise, for example, one of pulse width modulation switching means or pulse density modulation switching means.

In one example embodiment, two or more electric motors 46 may be provided in an electric vehicle adapted for regenerative braking. For example, the two or more electric motors 46 may be provided in an electric bicycle, an electric scooter, an electric automobile, a hybrid vehicle, an electric powered wheelchair, an electric golf cart, or the like.

In embodiments of a reconfigurable battery, a reconfigurable electric motor assembly, or a combination thereof in which a single PWM switch (e.g., switch 59) is used, the controller 50 may be a PWM control system adapted to adjust the on-off duty cycle of the PWM switch between the motor and the battery. The current sensor 49 may be used to calculate the average amount of current flowing. If the desired amount of current cannot be maintained because the voltage difference between the motor 46 and the battery 42 is too small, either the battery 42 or the motor 46 is reconfigured to increase the voltage difference in the right direction (higher motor voltage for regenerative braking, or higher battery voltage for driving or accelerating.)

As discussed above, a speed control switch 59 may also be provided, which may comprise a pulse width modulation switching mechanism. Those skilled in the art will appreciate that an efficient switch is needed to accomplish the electric motor reconfiguration, and that it may also be possible to use multiple FET switches in place of the single PWM switch 59, especially when a parallel motor and a parallel battery combination is needed. It should also be appreciated that the single PWM switch 59 can be replaced by a variable resistance system, as long as the current flow can be regulated. A true variable resistor would dissipate more heat than a PWM switch, but should provide a workable alternative.

Figure 8 shows a further example embodiment which provides different drive torque and regenerative braking for each motor 46, using two PWM switches 59 and three motor switching means 62. For example, with the Figure 8 embodiment it is possible to apply greater torque from a motor 46 to a rear wheel of an electric bicycle 40 than from a motor 46 to a front wheel of the electric bicycle 40 during acceleration, and to obtain greater regenerative charging from a motor 46 at the front wheel of an electric bicycle than from a motor 46 at a rear wheel of an electric bicycle during braking.

Figures 9a through 9h illustrate an alternative example embodiment of a variable voltage reconfigurable battery and method in accordance with the present invention. The Figures show a single bank of a statically joined plurality of series connected battery cells 200 of a battery 202. A statically joined plurality of series connected battery cells 200 have no additional circuit elements, such as switches, that can break an electrical connection between adjacent battery cells. Each such group of statically joined plurality of series connected battery cells 200, is designated as a "Bank". Banks of battery cells 200 can be configured together in series or parallel connection.

In Figures 9a through 9h a bank of seven (7) battery cells 200 of a battery 202 arranged in a series configuration is shown. The battery cells are designated Bt1 through Bt7. Each battery cell 200 has a first voltage pole 204 and a second voltage pole 206. The first voltage pole 204 of each battery cell 200 shown is at a higher direct current (DC) voltage potential than the second voltage pole 206, and therefore the first voltage pole 204 is designated as "+" and the second voltage pole 206 is designated as "-". A first electrical output connection 210 is designated as Vout_p, and a second electrical output connection 212 is designated as Vout_n. The first electrical output connection 210 may function as the positive terminal of a battery 202, while the second electrical output connection 212 may function as the negative terminal of a battery 202. At least one switching means 208 provides electrical connection between the first voltage pole 204 of each battery cell 200 in the series to a first electrical output connection 210 (designated Vout_p).

In the Figures, the switching means 208 designated sequentially SW_p0 through SW_p6 connect the positive pole of each battery cell to Vout_p. Also, at least one switching means 208 provides electrical connection of a second voltage pole 206 of each battery cell 200 in the series to a second electrical output connection 212 (designated Vout_n). The switching means 208 designated sequentially SW_n1 through SW_n7 connect the negative pole of each battery cell to Vout_n. Additionally, at least one switching means 208 can electrically connect the first voltage pole 204 of a battery cell 200 at the beginning of the plurality of series connected battery cells 200 to the second electrical output connection 212.

The switching means 208 designated SW_n0 connects the positive pole of BT1 to Vout_n, At least one switching means 208 can electrically connect the second voltage pole 206 of an end battery cell 200 in the statically joined plurality of series connected battery cells 200 to the first electrical output connection 210. In the Figures, switching means 208 designated SW_p7 connects the negative pole of BT7 to Vout_p. The switching means 208 may, for example, comprise MOSFET transistors. In some implementations, Pulse Width Modulation or Pulse Density Modulation circuitry is included as part of the switching means. In other embodiments, the MOSFET transistors can be configured without PWM or PDM.

Closing a switching means 208 between a first voltage pole 204 and the first electrical output connection 210, and closing a switching means 208 between a second voltage pole 206 and the second electrical output connection 212 provides a voltage differential at the electrical output connections, and allows current to flow when the battery 202 is connected to a load (or to a battery charging circuit). In the Figures, output voltage Vout, is the difference in potential between the first electrical output connection 210 designated Vout_p, and the second electrical output connection 212 designated Vout_n.

The battery cells 200 are reconfigured to provide an output voltage that is approximately equal to the voltage summation of the electrically reconfigured battery cells 200, and is in a range between zero volts and a maximum output voltage for the plurality of series connected battery cells 200. The voltage is determined by the number and technology of the cells provided.

Any of the well known battery types can be used with the inventive structure. One such battery technology that is particularly suited for use with the present invention is the nano phosphate based lithium ion battery technology. Such batteries can handle more than an order of magnitude more current than prior battery technologies without becoming unstable. It is expected that other battery technologies that are developed in the future will also be suitable for use with the series battery embodiments disclosed herein.

FIG 9a shows a configuration with all switches 208 in an open state such that no current flow occurs, and Vout = 0 volts. FIG 9b shows a configuration whereby maximum voltage is realized from the bank of statically joined plurality of series connected battery cells 200 by closing the switching means 208 (in particular, switch SW_p0) connecting the positive pole of the first battery cell, Bt1, to Vout_p and closing the switching means 208 (in particular, switch SW_n7) connecting the negative pole of the last battery cell, Bt7, to Vout_n. Vout equals the sum of the voltages of connected battery cells in the series Bt1 through Bt7. For example, if each battery cell 200 is Lithium Ion technology with nominal voltage of 3.6V, for this configuration of seven battery cells, Vout = 25.2 volts minus switching and other losses.

FIG 9c shows an example configuration whereby a single cell voltage is realized at the output from the statically joined plurality of series connected battery cells 200. Voltage of cell Bt1 is realized between output connections Vout_p and Vout_n by closing switches SW_p0 and SW_n1.

Figure 9d shows an alternative example configuration, where the output voltage is also about equal to a single cell voltage by connecting battery cell Bt2 to the first electrical output connection 210 and the second electrical output connection 212. Voltage of cell Bt2 is realized between output connections Vout_p and Vout_n by closing switches SW_p1 and SW_n2.

Figure 9e shows another alternative example configuration, where output voltage is about equal to the voltage of a single battery cell, Bt7. Voltage of cell Bt7 is realized between output connections Vout_p and Vout_n by closing switches SW_p6 and SW_n7.

In any series configuration of a plurality of battery cells as described in this embodiment, there are N ways to realize a single cell voltage, where N is the number of cells in the battery.

Figure 9f shows a configuration whereby an intermediate voltage is realized at the voltage output from the series configured plurality of battery cells 200. In this example, the voltage sum of two (2) battery cells 200 is realized. In particular, the voltage sum of cells Bt1 and Bt2 is realized between output connections Vout_p and Vout_n by closing switches SW_p0 and SW_n2. Figure 9g and Figure 9h show two additional alternate configurations of connecting two series connected battery cells to the voltage output.

In a series configuration of a plurality of battery cells 200, as described in this exemplary embodiment, there are N-1 ways to realize a two-cell voltage, where N is the number of cells 200 in the battery.

Without including configurations of voltage polarity reversal, for any number of N statically joined plurality of series connected battery cells 200 as described in this exemplary embodiment, with a switched set of P electrically contiguous battery cells 200, there are (N-P)+1 ways to configure them.

Voltage polarity may be selectively reversed by activating a switching means 208 that would connect a first voltage pole 204 of a battery cell 200 to a second electrical output connection 212 instead of connecting it to a first voltage electrical output connection 210, and connecting a second voltage pole 206 to a first electrical output connection 210. For example, in the example configuration shown in Figure 9c, closing switching means SW_n0 instead of SW_p0, and SW_p1 instead of SW_n1 would cause polarity reversal at the electrical output connections 210 and 212. Such polarity reversal may be useful for motor activated braking.

One useful consequence of having (N-P)+1 ways to configure P cells is that it allows cells to be load balanced in a time sequential manner, maintaining nominal voltage by alternating drain on sets of P electrically connected cells.

A useful consequence of connecting the battery cells 200 in a series configuration without switching means 208 between the cells allows switch induced voltage loss to be kept minimal because only two switching means 208 need be activated when an electrical load is applied.

Another alternative example embodiment of a reconfigurable battery and method in accordance with the present invention is shown in Figures 10a through 10c. These Figures show a first bank of statically joined plurality of series connected battery cells 200, designated Bt1 through Bt3, that is joined to a second bank of statically joined plurality of series connected battery cells 200, designated Bt4 through Bt6, in a series connection. The switching means 208 designated sequentially SW_p0 through SW_p7 connect the batteries Bt1 through Bt6 to Vout_p. The switching means 208 designated sequentially SW_n1 through SW_n7 connect the batteries Bt1 through Bt6 to Vout_n A first intermediate switching means 214, designated as SW_s1, is connected between a second ("-") voltage pole 206 of an end positioned battery cell in a first bank, designated as Bt3, and a first ("+") voltage pole 204 of a beginning positioned battery cell in a second bank, designated as Bt4. A second intermediate switching means 216 is connected between a first ("+") voltage pole 204 of a beginning positioned battery cell, designated as Bt1, in a first bank and a second ("-") voltage pole 206 of an end positioned battery cell in a second bank, designated as Bt6. Essentially two (2) groupings of three (3) battery cells 200, referred to as banks, are configured in the example configuration. The first electrical output connection of the two banks are commonly connected, designated as Vout_p. Also, the second electrical output connection of the two banks are commonly connected, designated as Vout_n. It should be appreciated that additional banks can be provided in a similar configuration.

The placement of a switching means intermediate between the banks of battery cells effectively separates connectivity between two adjacent cells when the switches are open, resulting in the two banks of battery cells that can be independently configured. Each independent bank of statically joined plurality of series connected battery cells 200 functions in the manner described in the example embodiment of Figures 9a through 9h. The switching means 208, first intermediate switching means 214, and second intermediate switching means 216 may be MOSFET transistors with, e.g., Pulse width Modulation or Pulse Density Modulation circuitry included.

If the battery cells to be configured sit in a single bank, closing a switching means 208 between a first voltage pole 204 and the first electrical output connection 210, and closing a switching means 208 between a second voltage pole 206 and the second electrical output connection 212 manifests output voltage. However, if connection is desired between a battery cell 200 that sits in one bank and a battery cell 200 that sits in another bank, either the first intermediate switching means 214 or the second intermediate switching means 216 must be closed to realize voltage between the output connectors 210 and 212. To prevent a short circuit in the series configured battery 202, the first and second intermediate switches 214 and 216 may not both be simultaneously closed. With the first and second intermediate switches 214 and 216 both set in an open state, the two banks are connected in parallel.

Figure 10a shows an example configuration of a series connected reconfigurable battery 202 with all switching means in an open state such that no voltage appears at the output. Intermediate switches SW_s1 and SW_s2 are open, such that the two banks of cells are in a parallel connection. All switches 208 in the banks are also open so that Vout is equal to zero volts.

Figure 10b shows an example configuration where two battery cells 200 on opposite ends of the two banks, battery cells Bt1 and Bt6, are electrically connected in series through switching means SW_s2. Closed switching means SW_n1 connects battery cell Bt1 to Vout_n and closed switching means SW_p6 connects Bt6 to Vout_p. At the same time, closed second intermediate switching means SW_s2 configures voltage summation of battery cells Bt1 and Bt6.

Figure 10c shows a configuration where two adjacent battery cells Bt3 and Bt4, one in each bank, are configured through the first intermediate switching means 214. Closed switching means SW_p2 connects battery cell Bt3 to Vout_p, closed switching means SW_n5 connects Bt4 to Vout_n, and closed first intermediate switching means SW_s1 configures voltage summation of battery cells Bt3 and Bt4..

The present embodiment is useful because it permits series connection between battery cells 200 on opposite ends of a plurality of battery cells 200 without requiring electrical connection with cells occupying the middle section of battery cells 200. This helps with battery discharge load distribution and selective charging of cells. This example embodiment affords increased configuration flexibility while only increasing active switching overhead by the two switching means 214 and 216 over the embodiment of Figure 9a through 9h.

Another alternative example embodiment of a method of reconfiguring a battery 202 in accordance with the present invention for series connected battery cells 200 is shown in Figure 11. The switching means 208 further includes Duty Cycle Modulation ("DCM") by alternatively switching between a first configuration of series connected battery cells 200 exhibiting a first voltage and a second configuration of series connected battery cells 200 exhibiting a second voltage. Duty cycle modulation produces an intermediate output voltage ranging between a first voltage and a second voltage. The example configuration illustrated in Figure 11 shows modulation of switching means SW_n5 connected to battery Bt4 alternatively switching between an open and closed state. Switching means SW_n6 connected to battery Bt5 inversely mirrors the cycle of switching means SW_n5 by alternatively switching between a closed and open state. As a result, output voltage is averaged between a voltage of two series connected cells 200 and three series connected cells 200. This causes a relatively small voltage difference during switch cycling. The small voltage change is contrasted with a significantly larger voltage change that would occur if the three series connected batteries were to toggle between an off and on state. The result of duty cycle modulation is intermediate control of output voltage with reduced switching transient for voltage, current, and resulting motor torque.

A simulated digital pulse trace 218 and a simulated voltage trace 220 are shown in Figure 11. The simulated digital pulse trace 218 demonstrates timing of alternating on and off states of switches SW_n5 and SW_n6. The simulated voltage trace 220 shows the corresponding output voltage, Vout, as a function of time. For this example embodiment, the on state duty cycle of switching means SW_n6 is a quarter of that for switching means SW_n5. As a result, the average output voltage for this example embodiment is equal to 3/4(voltage(BT3) + voltage(BT5))+ 1/4(voltage(BT3) +voltage(BT5) + voltage(BT6)) = 2.25 Voltage (BT) if all battery cell 200 voltages are equal. An illustrative voltage trace using full voltage on-off pulse width modulation 222 is shown for comparison. Note the larger voltage swing between the on and off states without a variable voltage battery, as shown in simulated trace 222.

At least one capacitance filter 224, as shown in Figure 12, may be added to the above described embodiments to smooth out the output voltage. In the example embodiment of the present invention, a single capacitor 224 is placed across the output voltage connections 210 and 212. The capacitor is connected in a circuit using duty cycle modulation as described in the preceding embodiment. A simulated digital pulse trace 226 and a simulated voltage trace 228 demonstrate the resulting smoothed waveform obtained by adding the filter to the variable voltage battery ("VVB") of the present invention. Depending on the switch type, switching method, and waveform filter used in this embodiment, switching rates can be reduced, possibly resulting in energy savings. Inductive filtering can be substituted for (or used in conjunction with) the capacitive filtering, e.g., by providing an inductor in series between the battery and the load. An illustrative voltage trace 229 illustrates, for comparison, the case where the variable voltage battery of the present invention is not used. Note the larger voltage swing between the on and off states without the VVB, as shown in simulated trace 229.

The previously described embodiments may include voltage monitoring 230 and current monitoring 232 as shown in the example embodiment of a reconfigurable series connected plurality of battery cells in Figure 13. Voltage and current monitoring systems and methods in combination with switching means 208 described herein, allow identification and status monitoring of battery cell 200 charge and discharge states.

The reconfigurable battery 202 described in the preceding embodiments used in combination with at least one electric motor 226 allows motor speed control by regulating battery output voltage based on the number of cells configured in series. Also, battery cell 200 recharge schemes may be customized by selectively configuring the number and relative position of series connected battery cells 200 that match motor 226 output voltage during regenerative braking and charging.

Figure 14 shows a battery reconfiguration control system that can interface with vehicular systems (e.g. motors 226) and communicate with users 228 to control the reconfiguration of switches 208 to bypass weak or dead battery cells 200, short out dying cells 200 if necessary to regain current handling capacity, and balance battery cell 200 usage. An electronic processor 218 such as a microprocessor with associated primary and secondary memory 220 and 222, voltage 230 and current 232 sensors, and associated software can maintain charge/discharge history to help regulate battery cell life and provide load balancing during discharge and recharge states. Battery cell 200 temperature monitoring may also be included since battery duty cycle varies as a function of temperature. Such temperature monitoring is particularly useful for charge and discharge control, as well as for diagnosis of failing cells. Control signals may be exchanged between the sensors 230 and 232, the battery 202, motors 226, and processors 218 using dedicated communication pathways 224 or over power connections 210 and 212.

Powering the battery reconfiguration control system down and powering it up again requires following a predetermined protocol. Power down occurs, for example, when the reconfigurable battery 202 becomes discharged, and requires that all switching means 208 and 214 and 216 be placed in an inactive state (open) as shown in Figures 9a and 10a. Powering the system up again begins with activation of the processor 218, perhaps a microprocessor, followed by accessing configuration settings, status of the battery cells, past history and exception states from memory 220 and 222. If a charging cycle is begun, control logic analyzes the information received from memory 220 and 222 and configures switching means 208 to accomplish the task most effectively.

It is noted that measuring the average current flow can take time that may result in an undesirable amount of delay. An alternative is to calculate the current flow expected so that the resistance or the PWM duty cycle can be adjusted in synchrony with the reconfiguration of the battery, the motor, or both.

It should now be appreciated that the present invention provides advantageous methods and apparatus for reconfiguring a battery having a plurality of battery cells, reconfiguring an electric motor assembly, or a combination thereof.

In accordance with the invention, potential loss is avoided when full current output is needed by keeping the battery cells in a series connection without intervening switches within the series path. Moreover, by tapping at different points in the series connected batteries, the voltage output can be varied with only two switch losses being incurred. The output voltage of the battery can even be set to zero, and if desired (e.g., for emergency braking), the voltage polarity of the battery can be reversed. If all of the series battery cells are used (e.g., the bottom switch on one side and the top switch on the other side are closed), maximum output voltage is achieved. If less than the total number of cells is used, the voltage will be lower. With a battery structure according to the invention, there are many different combinations of switch closings for the same (lower) voltage output. These combinations can be selected in a time sequential manner to even out the drain on the cells without taxing any one cell too much, while maintaining a constant voltage output.

A key benefit of the inventive variable voltage battery is that it allows speed control and regenerative braking in a battery powered vehicle to be easily achieved. This is due to the fact that the battery voltage adapts to the needs of the motor when driving and to the voltage output of the motor during regenerative braking. For example, one of the two switches used to set the battery voltage can be modulated (e.g., using PWM) to provide the motor speed control. Alternatively, it is possible to modulate between two voltage output values to achieve a finer control of the average battery voltage output to the motor. In an all-or-nothing PWM speed control, the voltage to the motor instantly changes from its maximum value to zero when the switch is opened. In such a scenario, there will be a large voltage spike when the motor gets disconnected from the battery since the magnetic field in the motor must collapse. With the disclosed finer voltage control between two voltages, there is much less transient since the circuit is still closed with the battery.

The switching for “reconfiguration” of the battery and for modulation of the switches can occur at a very high rate, e.g., at KHz or even MHz frequencies if the switches (e.g. power MOSFETs) are turned on and off quickly. A lower switching rate, however, can potentially save a bit of power since large MOSFET transistors require more current as the switching rate increases. Thus, there is a tradeoff between switching speed and power requirements.

Moreover, since the voltage fluctuation during the switching operations in accordance with the invention can be as small as one battery cell voltage (e.g. 3.6V for Lithium Ion battery cells as compared to the 48V battery pack used in conventional small electric vehicles such as bicycles), the switching transients are smaller both in voltage, current, and torque. If a motor powered by a normal battery is controlled using PWM, there will usually be a large voltage spike whenever the PWM switch is open due to the inductive nature of the motor. In fact, when the switch is open a large voltage can develop causing a spark thereacross as the inductor tries to maintain the current flow. With the present invention, the provision of a variable voltage battery keeps the circuit from opening completely. The battery simply goes from one voltage to another, and part of the battery is always connected to the motor. This provides a continuous current path at all times, except when the voltage has to ramp down to zero. With the inventive VVB, even when the voltage is ramped down to zero a current path can be provided by properly reconfiguring the battery. Therefore, the VVB based operation of the present invention is much gentler, both for driving and for regenerative braking. Adding a filter capacitor as described hereinabove can help to some degree where a VVB is not used, but using the inventive VVB results in better performance for a given size capacitor.

The invention also provides significant advantages over designs using an inverter (e.g. DC to DC converter), as such inverters suffer from significant conversion losses and introduce complexities when trying to charge the battery in a regenerative braking mode.

The configurations of the present invention can also "short-out" (i.e., bypass) a dead or weak battery cell so that the entire battery does not suffer a failure due to a single bad cell. Even multiple bad cells can be bypassed and the battery pack will still perform well, albeit at a reduced maximum voltage. An algorithm can be used to sniff out a weak or bad cell that does not maintain reasonable voltage or current during discharge or misbehaves during re-charging. As will be appreciated by those skilled in the art, such a feature would require current and voltage sensors and a suitable controller. Another algorithm that can be provided in accordance with the invention is one that provides load balancing to keep all the battery cells evenly charged during re-charging or regenerative braking.

It should further be appreciated that the included embodiments describing a plurality of battery cells may also be interpreted as a plurality of battery banks or a plurality of batteries, without departing from the scope of the present invention. For example, each battery cell described herein may consist of two or more battery cells in a series or parallel connection.

Although the invention has been described in connection with various illustrated embodiments, numerous modifications and adaptations may be made thereto without departing from the spirit and scope of the invention as set forth in the claims.

What is claimed is:

1. A reconfigurable battery, comprising at least one bank of:

a statically joined plurality of series connected battery cells;

each of said battery cells comprising a first voltage pole and a second voltage pole;

at least one processor controlled switch electrically connected between said first voltage pole of each of said battery cells and a first electrical output connection;

at least one processor controlled switch electrically connected between said second voltage pole of each of said battery cells and a second electrical output connection;

wherein said processor controlled switches are adapted to electrically reconfigure said battery cells by coupling a first voltage pole of one of said battery cells to said first electrical output connection and a second voltage pole of one of said battery cells to said second electrical output connection to provide a reconfigurable battery output voltage between said first and second electrical output connections.

2. The reconfigurable battery according to claim 1, wherein said reconfigurable battery output voltage is approximately equal to the voltage summation of the electrically reconfigured battery cells, and is in a range between zero volts and a maximum absolute output voltage for said statically joined plurality of series connected battery cells.

3. The reconfigurable battery according to claim 1 further comprising:

at least one switch electrically connected between said first voltage pole of a beginning battery cell in said statically joined plurality of series connected battery cells and said second electrical output connection.

4. The reconfigurable battery according to claim 1 further comprising:

at least one switch electrically connected between said second voltage pole of an end battery cell in said statically joined plurality of series connected battery cells and said first electrical output connection.

5. The reconfigurable battery according to claim 1 further comprising a plurality of banks of said statically joined plurality of series connected battery cells connected in a parallel configuration.

6. The reconfigurable battery according to claim 1, wherein a series joining of a first bank of said statically joined plurality of series connected battery cells to a second bank of said statically joined plurality of series connected battery cells comprises:

a first intermediate processor controlled switch connected between a second voltage pole of an end positioned battery cell in a first bank and a first voltage pole of a beginning positioned battery cell in a second bank;

a second intermediate processor controlled switch connected between a first voltage pole of a beginning positioned battery cell in a first bank and a second voltage pole of an end positioned battery cell in a second bank;

connection of said first electrical output connection of said first bank to said first electrical output connection of said second bank; and

connection of said second electrical output connection of said first bank to said second electrical output connection of said second bank;

wherein said first intermediate processor controlled switch and said second intermediate processor controlled switch cannot simultaneously be in a closed state.

7. The reconfigurable battery according to claim 6, wherein said second bank comprising a statically joined plurality of series connected battery cells is substituted by a single battery cell.

8. The reconfigurable battery according to claim 1, further comprising at least one of an inductive or a capacitive element for at least one of voltage and current waveform filtering.

9. The reconfigurable battery according to claim 1, further comprising a voltage monitoring means and a current monitoring means.

10. The reconfigurable battery according to claim 9, wherein said voltage and current monitoring means comprise a battery cell condition control system.

11. The reconfigurable battery according to claim 10, wherein said battery cell condition control system comprises at least one electronic processor, at least one data storage device, at least one communication channel, at least one reconfigurable battery control protocol, and a user interface protocol.

12. The reconfigurable battery according to claim 6, wherein said switches and said intermediate switches comprise at least one of solid state and mechanical switches.

13. The reconfigurable battery according to claim 1, wherein said first voltage pole is at a higher voltage potential than said second voltage pole.

14. The reconfigurable battery according to claim 1, wherein said battery provides energy for an electrical load comprising a vehicle with at least one electrical motor.

15. The reconfigurable battery according to claim 14, wherein said vehicle is one of an electric bicycle, an electric scooter, an electric vehicle, a hybrid automobile, a hybrid truck, an electric powered wheelchair, and an electric powered golf cart.

16. The reconfigurable battery according to claim 1, wherein:

said battery is charged by connecting at least one power source to said battery, and

said power source is a vehicle electrical system adapted for regenerative charging.

17. A method for reconfiguring a battery comprising:

arranging a portion of a statically joined plurality of series connected battery cells into a first configuration adapted to provide a first battery voltage; and

reconfiguring at least a portion of said statically joined plurality of series connected battery cells into a second configuration adapted to provide a second battery voltage;

wherein said reconfiguring comprises:

closing a first processor controlled switch to electrically couple a first voltage pole of a battery cell in said statically joined plurality of series connected battery cells to a first electrical output connection; and

closing a second processor controlled switch to electrically couple a second voltage pole of a battery cell in said statically joined plurality of series connected battery cells to a second electrical output connection.

18. A method in accordance with claim 17, wherein said reconfiguring for a series joined first bank of said statically joined plurality of series connected battery cells to a second bank of said statically joined plurality of series connected battery cells comprises alternatively closing:

a) a first intermediate processor controlled switch connected between a second voltage pole of an end positioned battery cell in said first bank and a first voltage pole of a beginning positioned battery cell in said second bank, or

b) a second intermediate processor controlled switch connected between a first voltage pole of a beginning positioned battery cell in said first bank and a second voltage pole of an end positioned battery cell in said second bank.

19. A method in accordance with claim 18, wherein said processor controlled switches comprise one of pulse width modulation processor controlled switches or pulse density modulation processor controlled switches.

20. A method in accordance with claim 18, wherein said first voltage pole is at a higher voltage potential than said second voltage pole.

21. A method in accordance with claim 18, wherein said second processor controlled switch comprises alternatively switching by pulse width modulation switching or pulse density modulation switching between a first configuration of series connected battery cells exhibiting a first voltage and a second configuration of series connected battery cells exhibiting a second voltage to produce an intermediate output voltage.

22. A method in accordance with claim 18, wherein said reconfigurable battery is alternatively configured to provide energy to at least one electrical load or to receive energy for recharging.

23. A method in accordance with claim 22, wherein said electrical load comprises a vehicle with at least one electrical motor.

24. A method in accordance with claim 23, wherein:

said reconfigurable battery is recharged by connecting at least one power source to said battery; and

said power source provides regenerative charging via a vehicle braking action that activates at least one electric motor, inducing current flow to said battery.

25. A method in accordance with claim 18, further comprising:

monitoring voltage and current of battery power discharge;

monitoring voltage and current of battery power charge; and

controlling said reconfiguring based on said monitoring.

26. A method in accordance with claim 25, further comprising:

providing an auxiliary power source for said monitoring, for said controlling, and for said reconfiguring of a plurality of series connected battery cells.

27. A method in accordance with claim 18, further comprising:

monitoring temperature of said battery cells; and

controlling said reconfiguring based on said monitoring.

28. A method in accordance with claim 17, wherein said processor controlled switches comprise one of pulse width modulation processor controlled switches or pulse density modulation processor controlled switches.

29. A method in accordance with claim 17, wherein said first voltage pole is at a higher voltage potential than said second voltage pole.

30. A method in accordance with claim 17, wherein said second processor controlled switch comprises alternatively switching by pulse width modulation switching or pulse density modulation switching between a first configuration of series connected battery cells exhibiting a first voltage and a second configuration of series connected battery cells exhibiting a second voltage to produce an intermediate output voltage.

31. A method in accordance with claim 17, wherein said reconfigurable battery is alternatively configured to provide energy to at least one electrical load or to receive energy for recharging.

32. A method in accordance with claim 31, wherein said electrical load comprises a vehicle with at least one electrical motor.

33. A method in accordance with claim 32, wherein:

said reconfigurable battery is recharged by connecting at least one power source to said battery; and

said power source provides regenerative charging via a vehicle braking action that activates at least one electric motor, inducing current flow to said battery.

34. A method in accordance with claim 17, further comprising:

monitoring voltage and current of battery power discharge;

monitoring voltage and current of battery power charge; and

controlling said reconfiguring based on said monitoring.

35. A method in accordance with claim 34, further comprising:

providing an auxiliary power source for said monitoring, for said controlling, and for said reconfiguring of a plurality of series connected battery cells.

36. A method in accordance with claim 17, further comprising:

monitoring temperature of said battery cells; and

controlling said reconfiguring based on said monitoring.

Figure 1
(Prior Art)

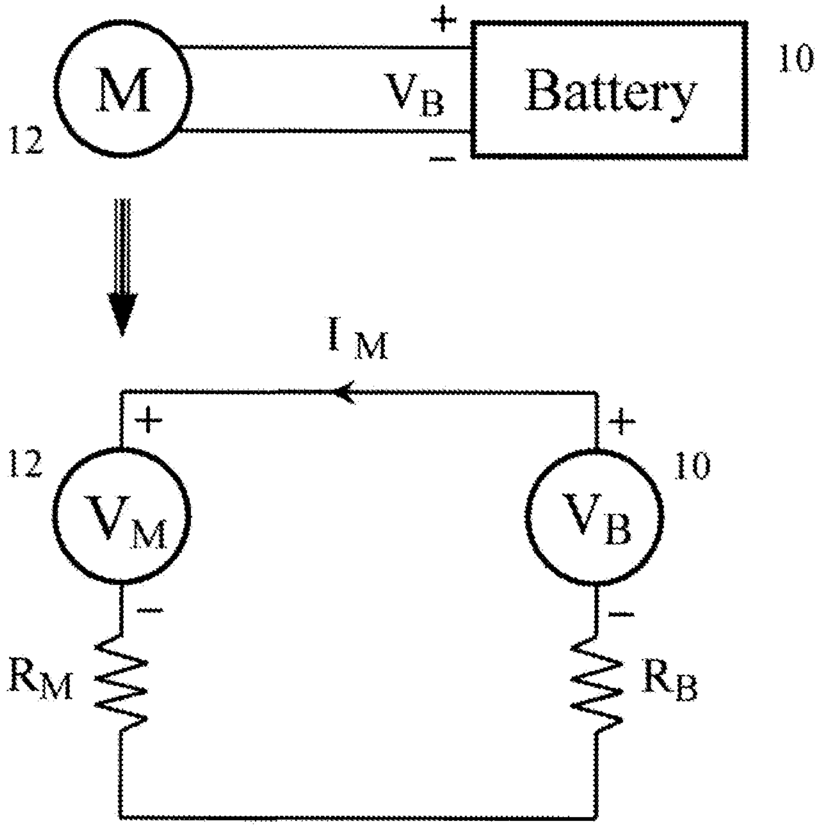


Figure 2
(Prior Art)

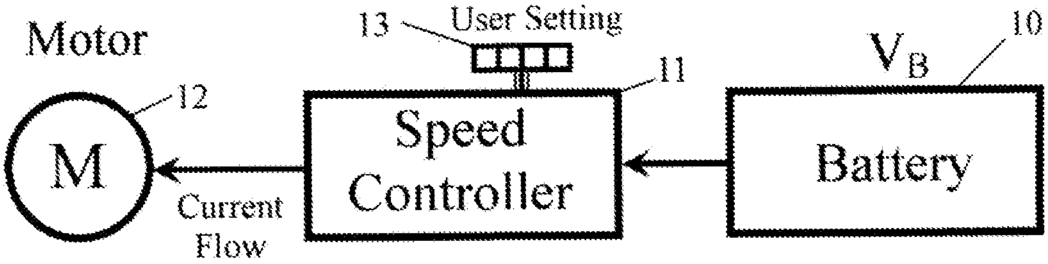


Figure 3
(Prior Art)

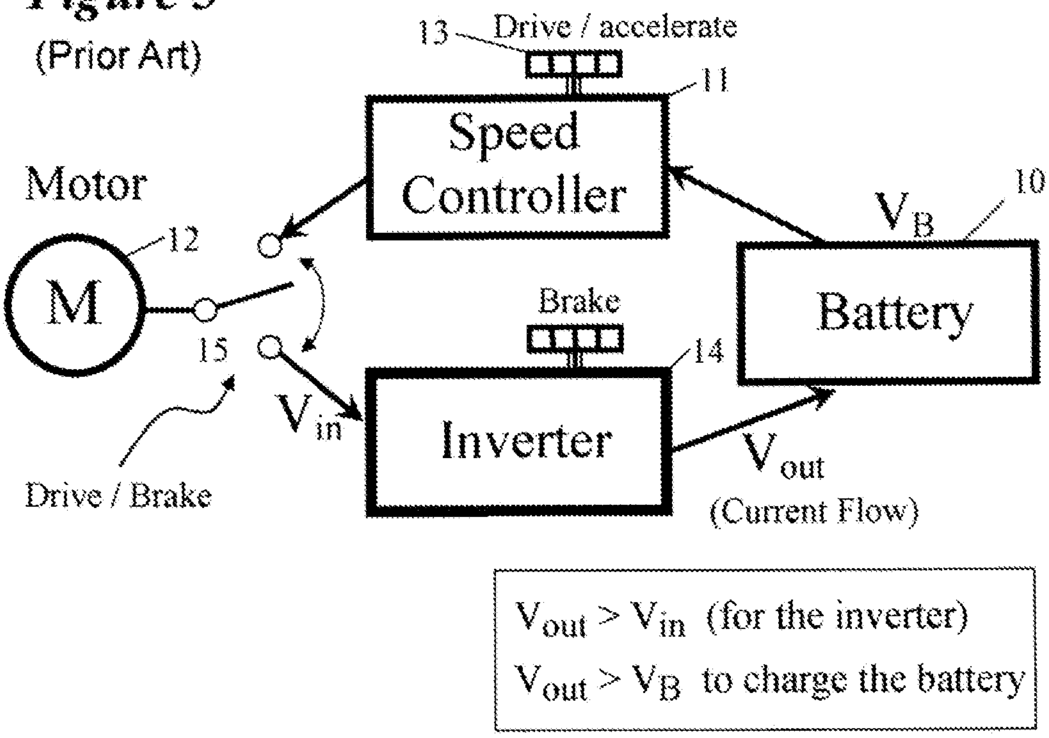


Figure 4

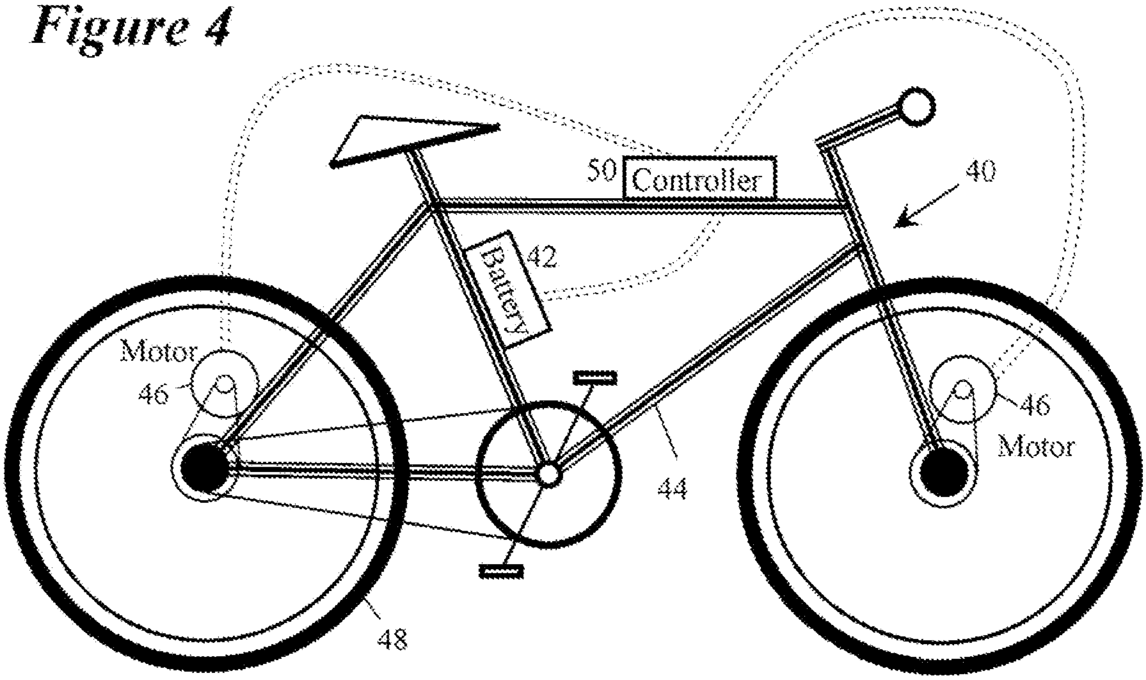


Figure 5a : Driving mode (series cells)

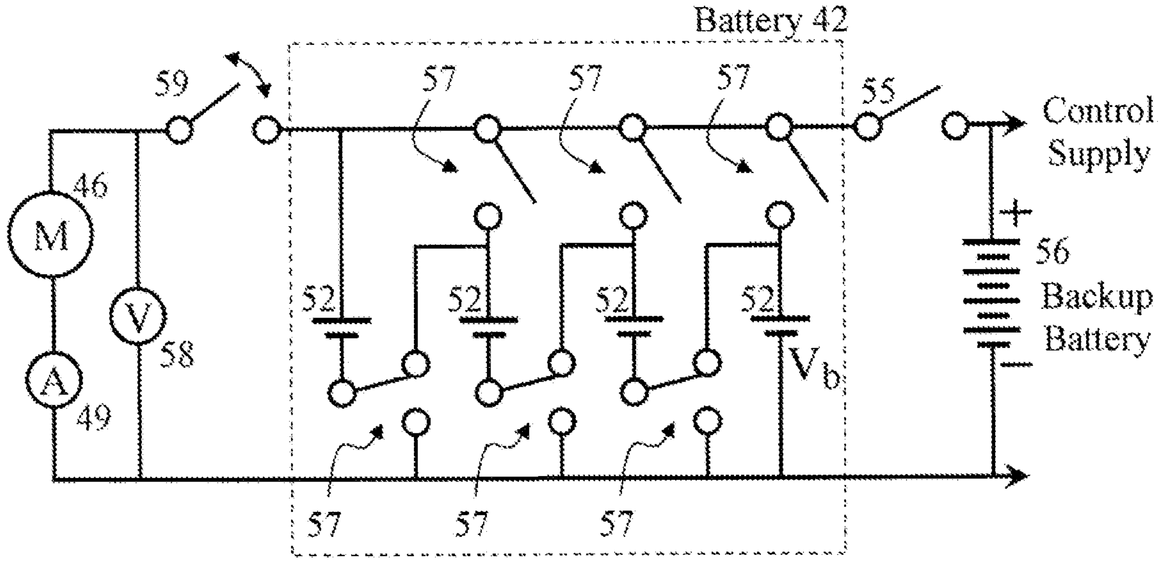


Figure 5b : Regenerative mode (parallel cells)

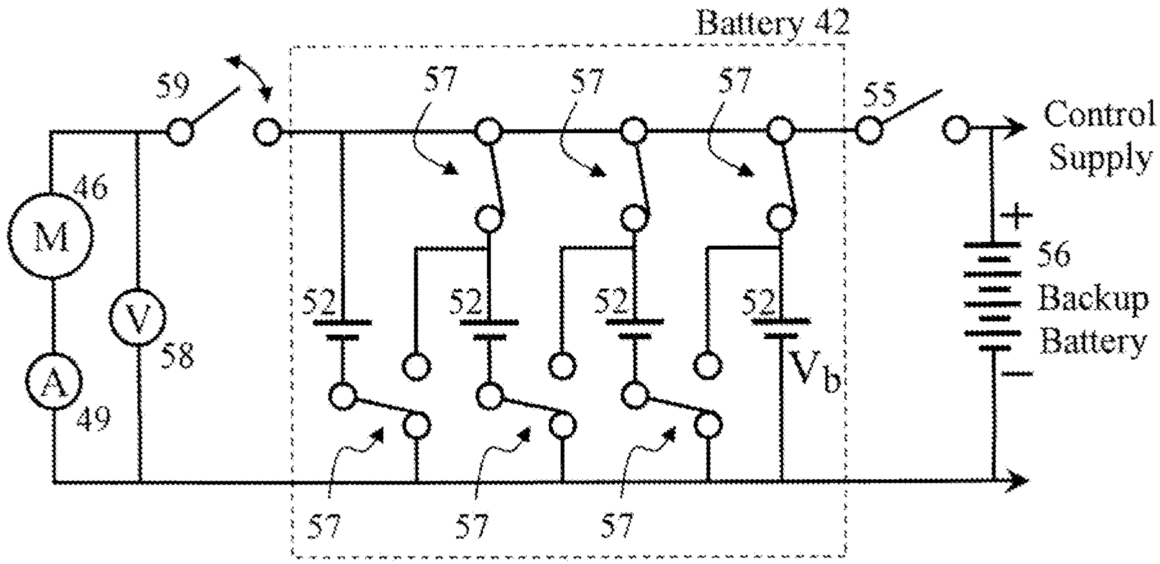


Figure 5c : Example of Intermediate Voltage

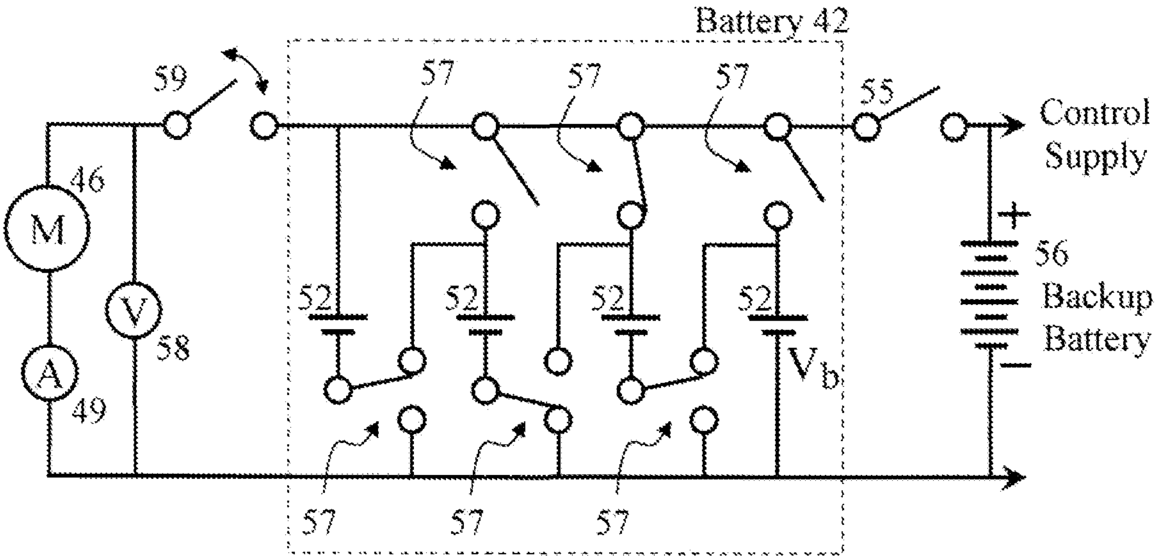


Figure 6

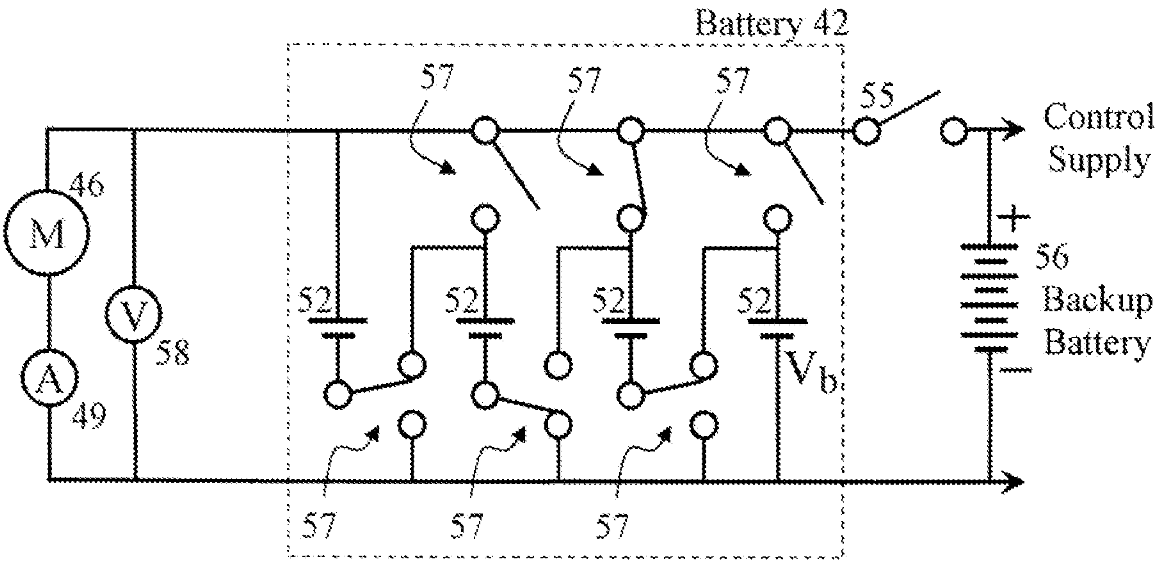


Figure 7a : Parallel motors

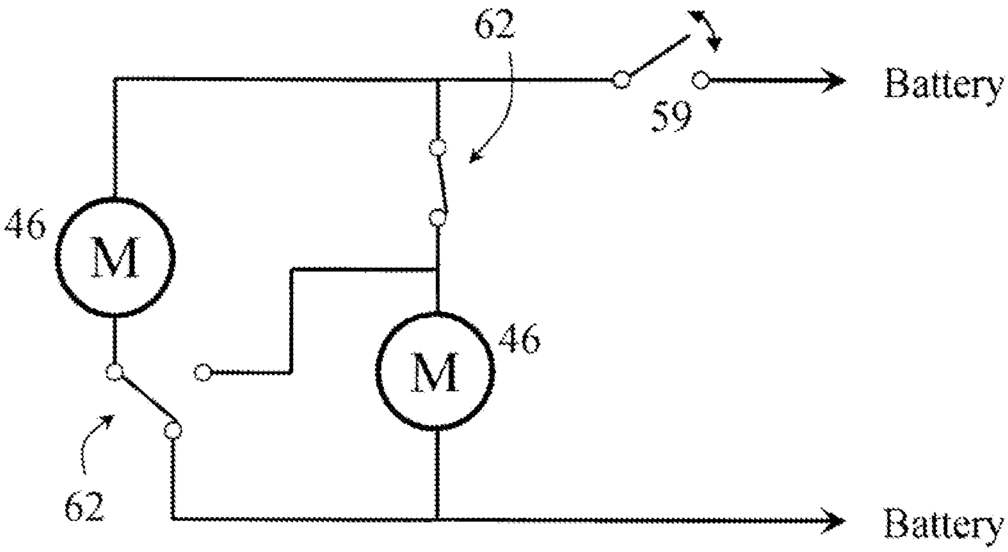


Figure 7b : Serial motors

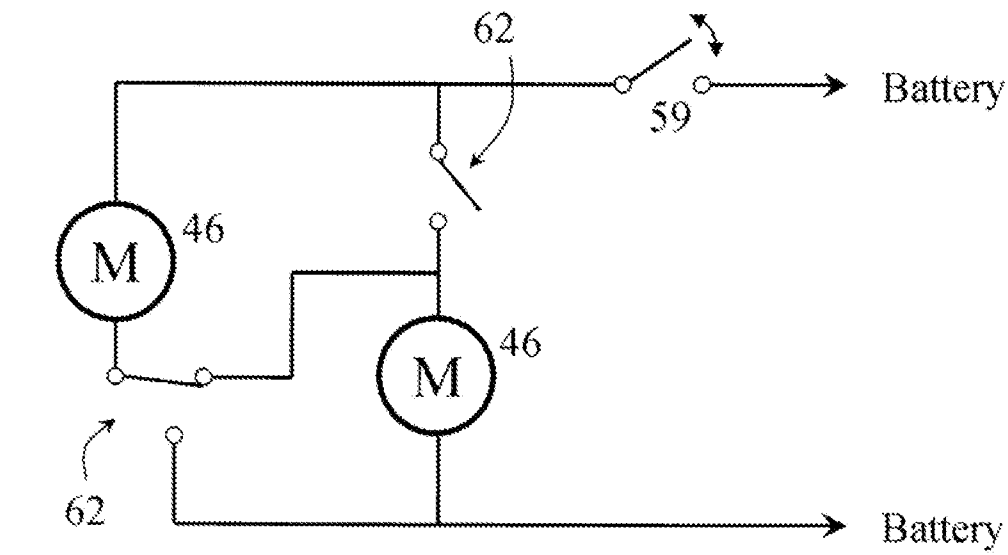
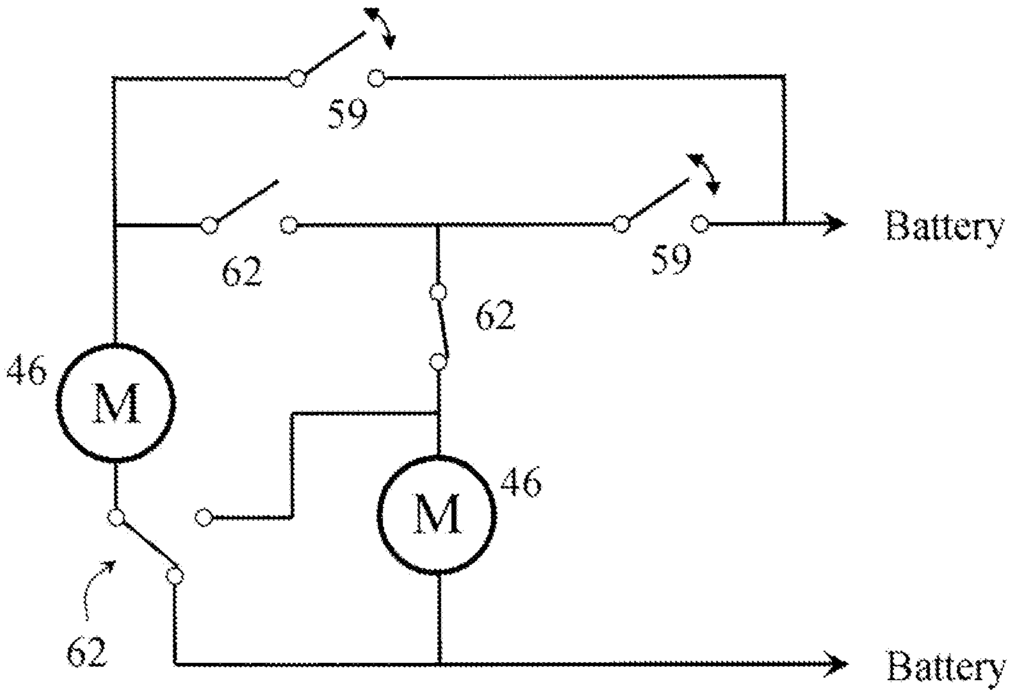


Figure 8 : Variable driving / braking between motors



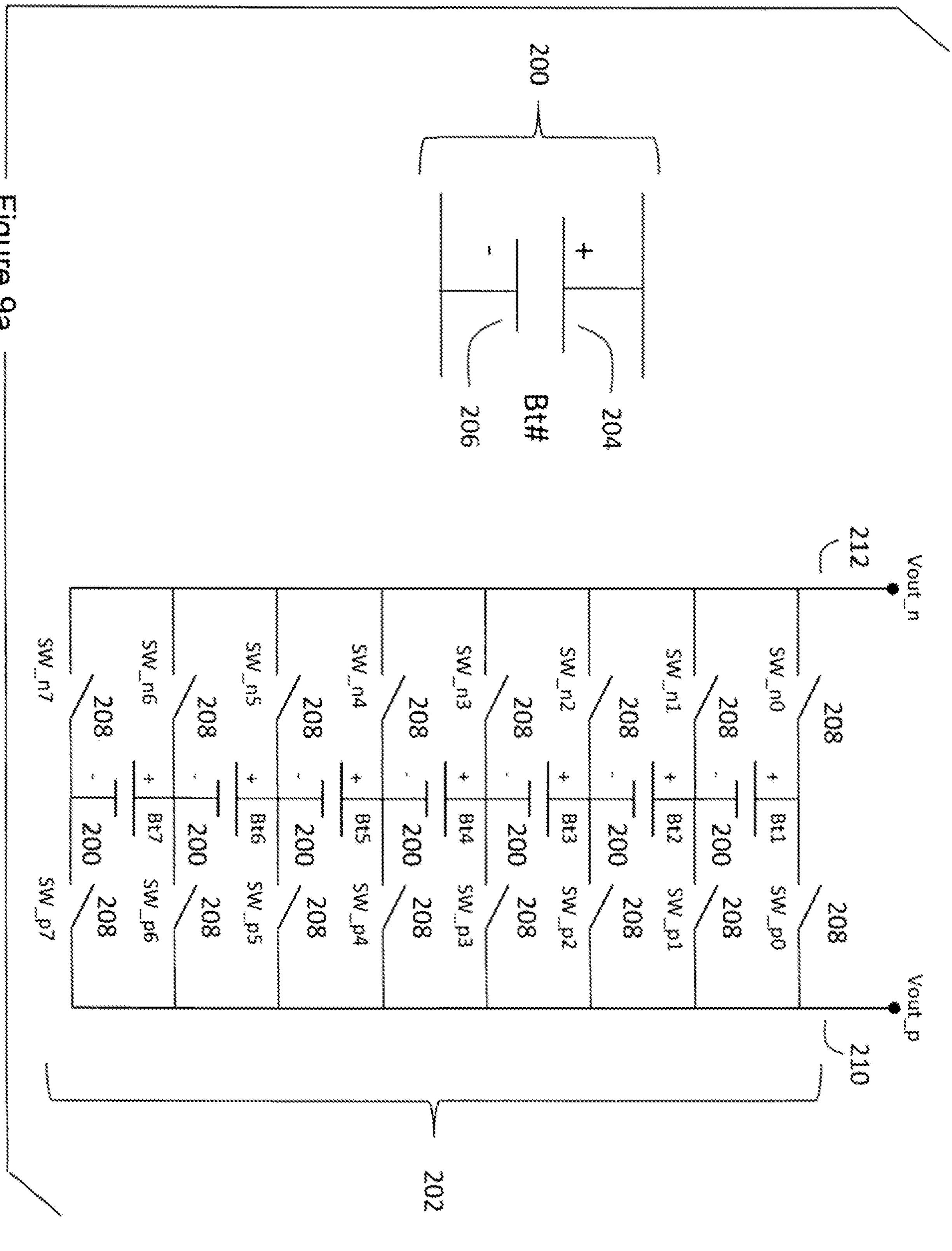

200
+
-
Bt#
204
206
Vout_n
212
Vout_p
210
SW_n0
SW_n1
SW_n2
SW_n3
SW_n4
SW_n5
SW_n6
SW_n7
SW_p0
SW_p1
SW_p2
SW_p3
SW_p4
SW_p5
SW_p6
SW_p7
Bt1
Bt2
Bt3
Bt4
Bt5
Bt6
Bt7
208
200
202

Figure 9a

Figure 9b

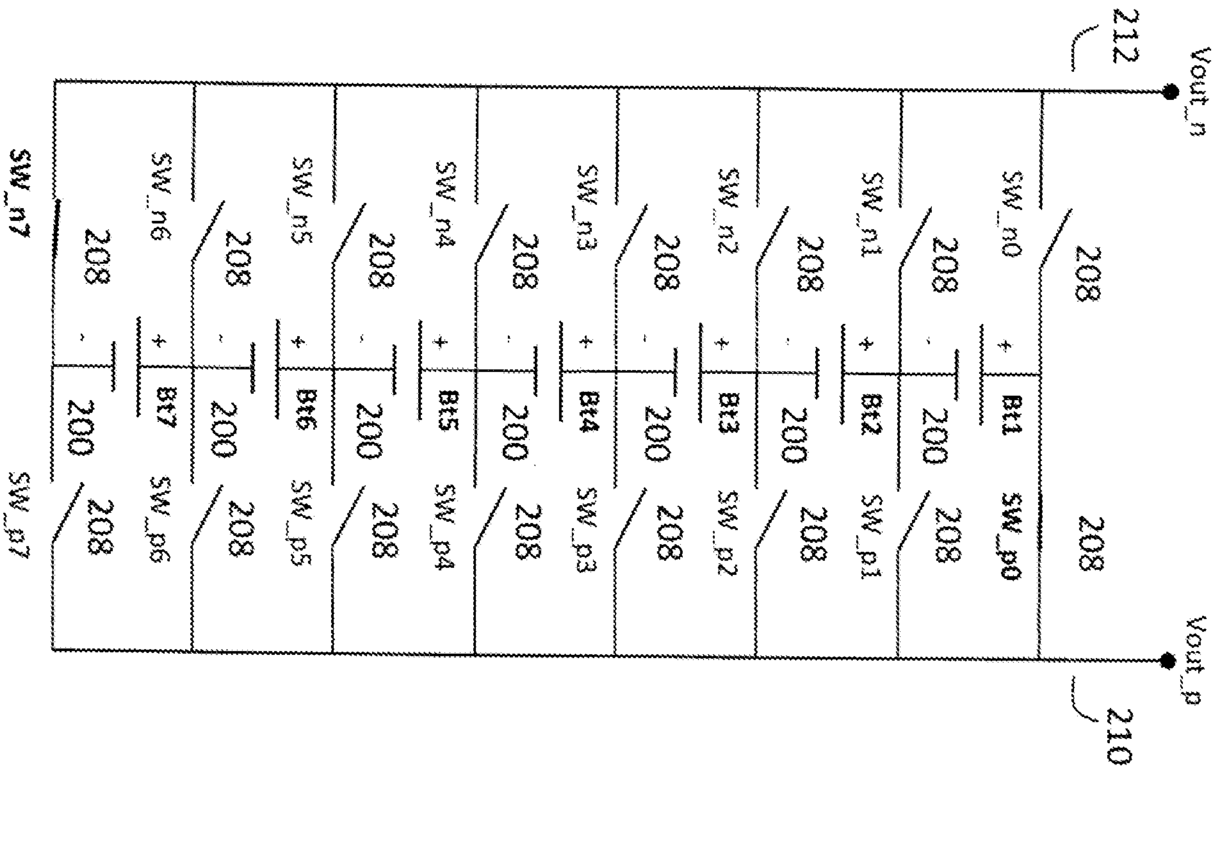

Vout_n
212
Vout_p
210
SW_n0
SW_n1
SW_n2
SW_n3
SW_n4
SW_n5
SW_n6
SW_n7
SW_p0
SW_p1
SW_p2
SW_p3
SW_p4
SW_p5
SW_p6
SW_p7
Bt1
Bt2
Bt3
Bt4
Bt5
Bt6
Bt7
208
200
+
-

Figure 9c

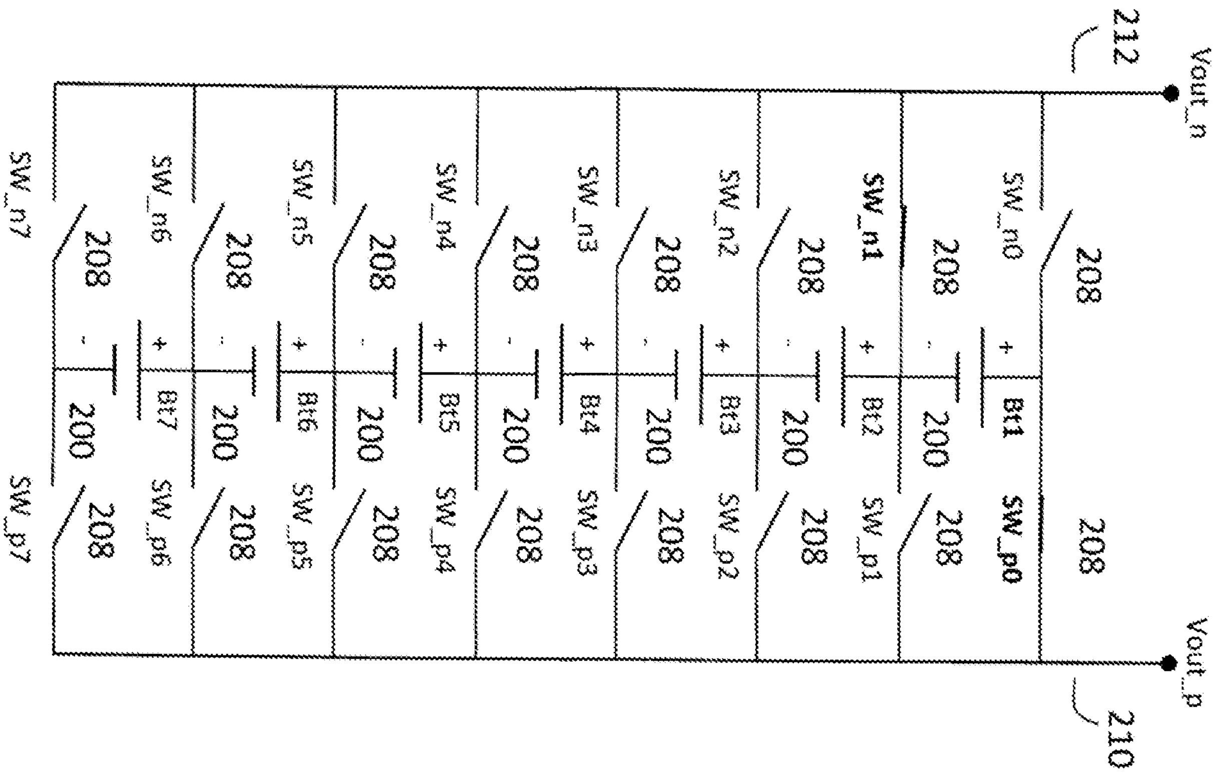

Vout_n
212
Vout_p
210
SW_n0
SW_n1
SW_n2
SW_n3
SW_n4
SW_n5
SW_n6
SW_n7
SW_p0
SW_p1
SW_p2
SW_p3
SW_p4
SW_p5
SW_p6
SW_p7
Bt1
Bt2
Bt3
Bt4
Bt5
Bt6
Bt7
208
200
+
-

Figure 9d

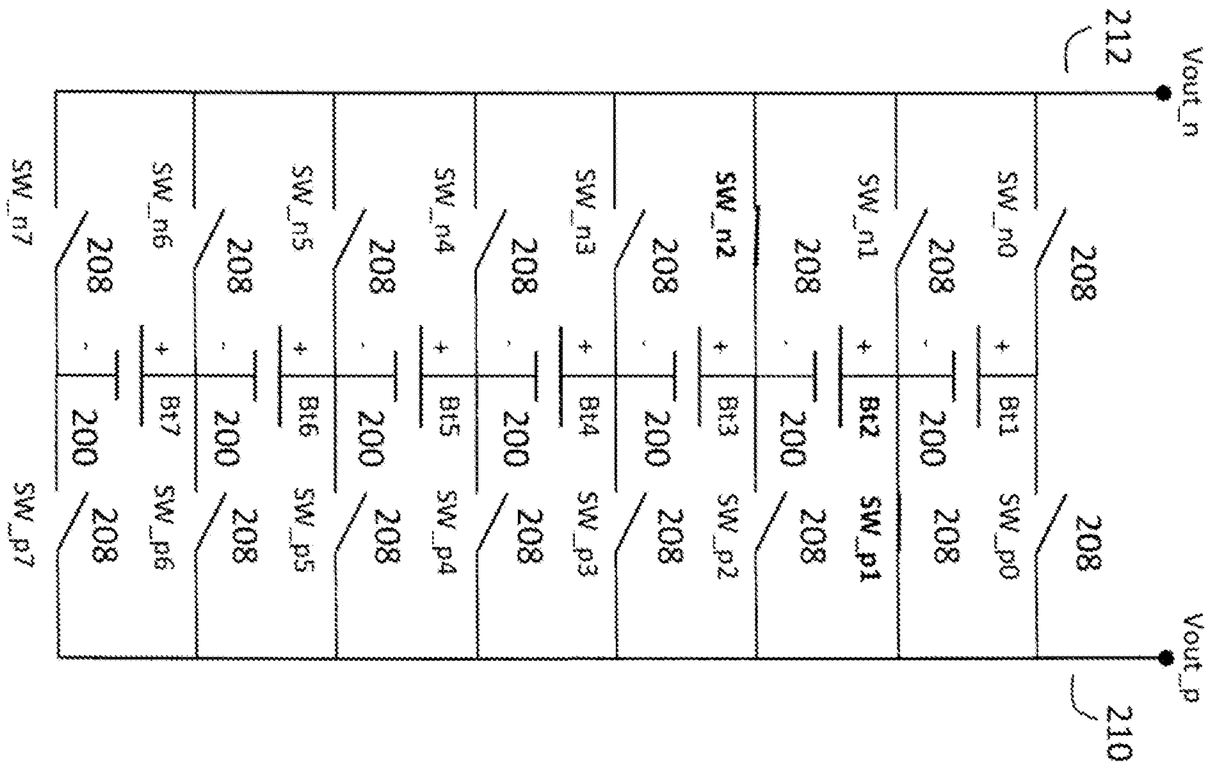
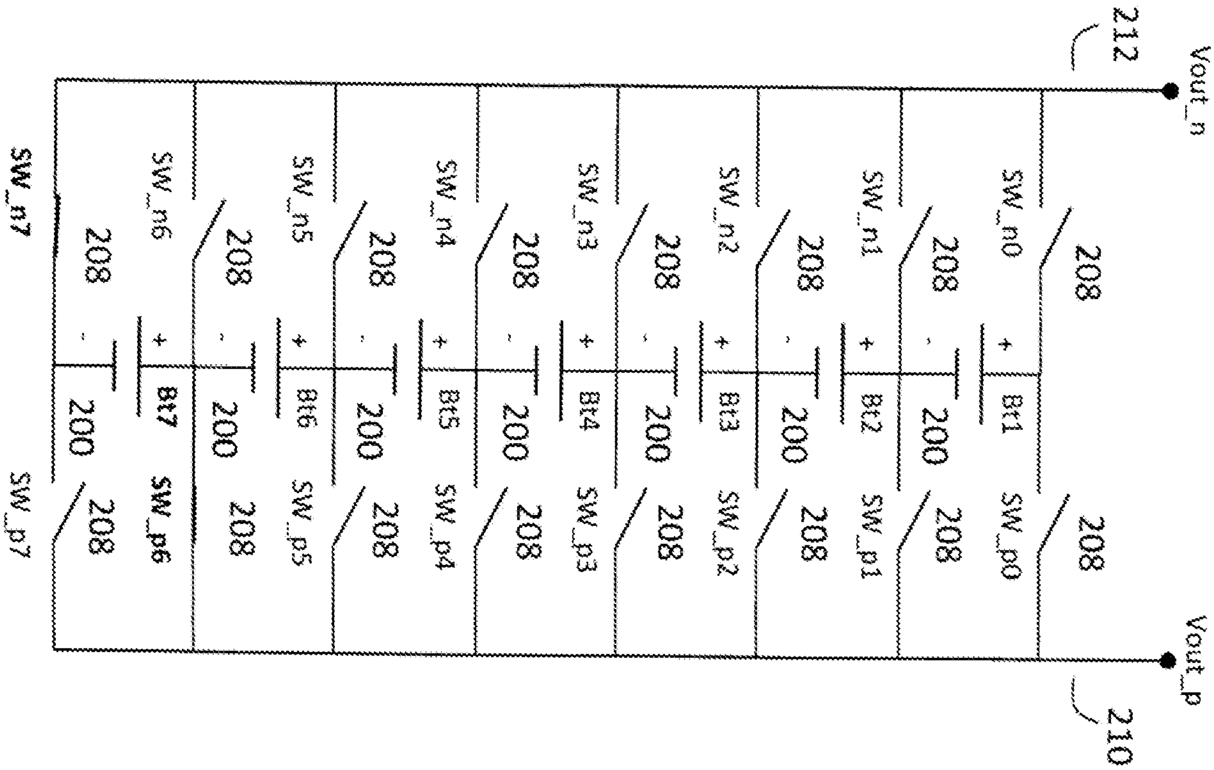

Vout_n
212
Vout_p
210
SW_n0
SW_n1
SW_n2
SW_n3
SW_n4
SW_n5
SW_n6
SW_n7
SW_p0
SW_p1
SW_p2
SW_p3
SW_p4
SW_p5
SW_p6
SW_p7
Bt1
Bt2
Bt3
Bt4
Bt5
Bt6
Bt7
208
200

Figure 9e


Vout_n
212
Vout_p
210
SW_n0
SW_n1
SW_n2
SW_n3
SW_n4
SW_n5
SW_n6
SW_n7
SW_p0
SW_p1
SW_p2
SW_p3
SW_p4
SW_p5
SW_p6
SW_p7
208
200
Bt1
Bt2
Bt3
Bt4
Bt5
Bt6
Bt7
+
-

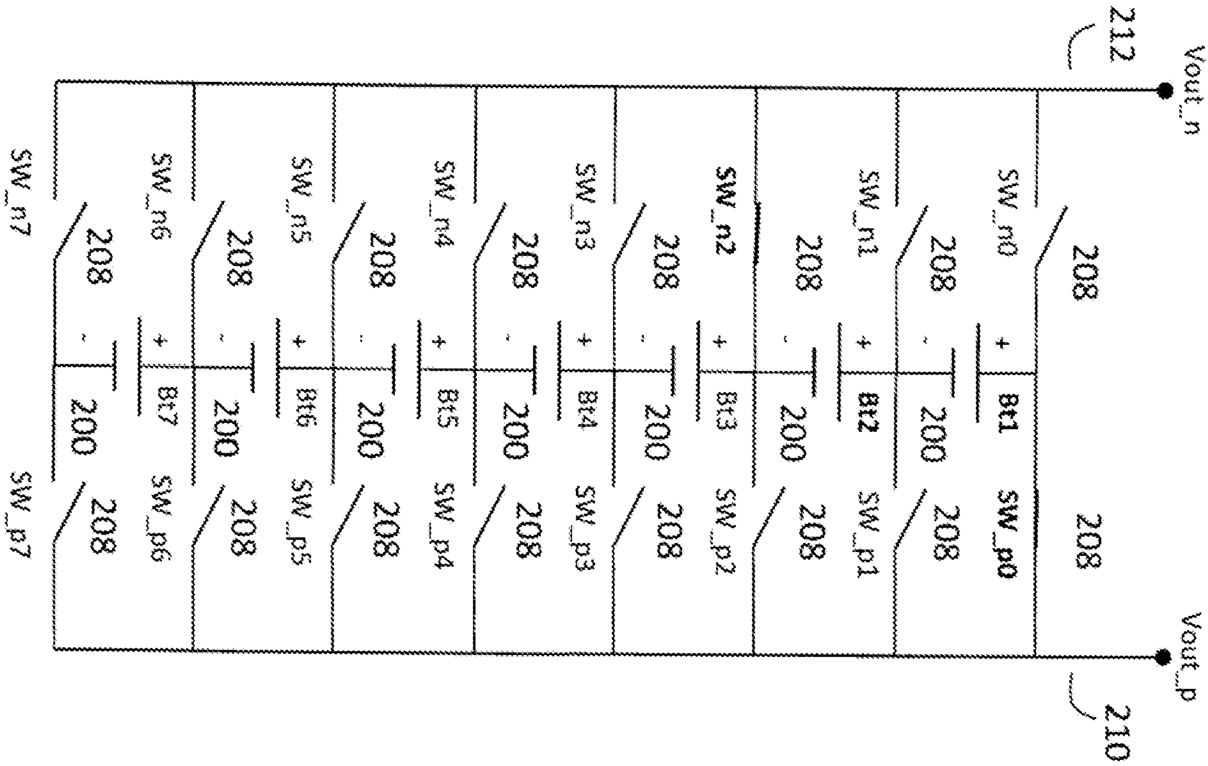
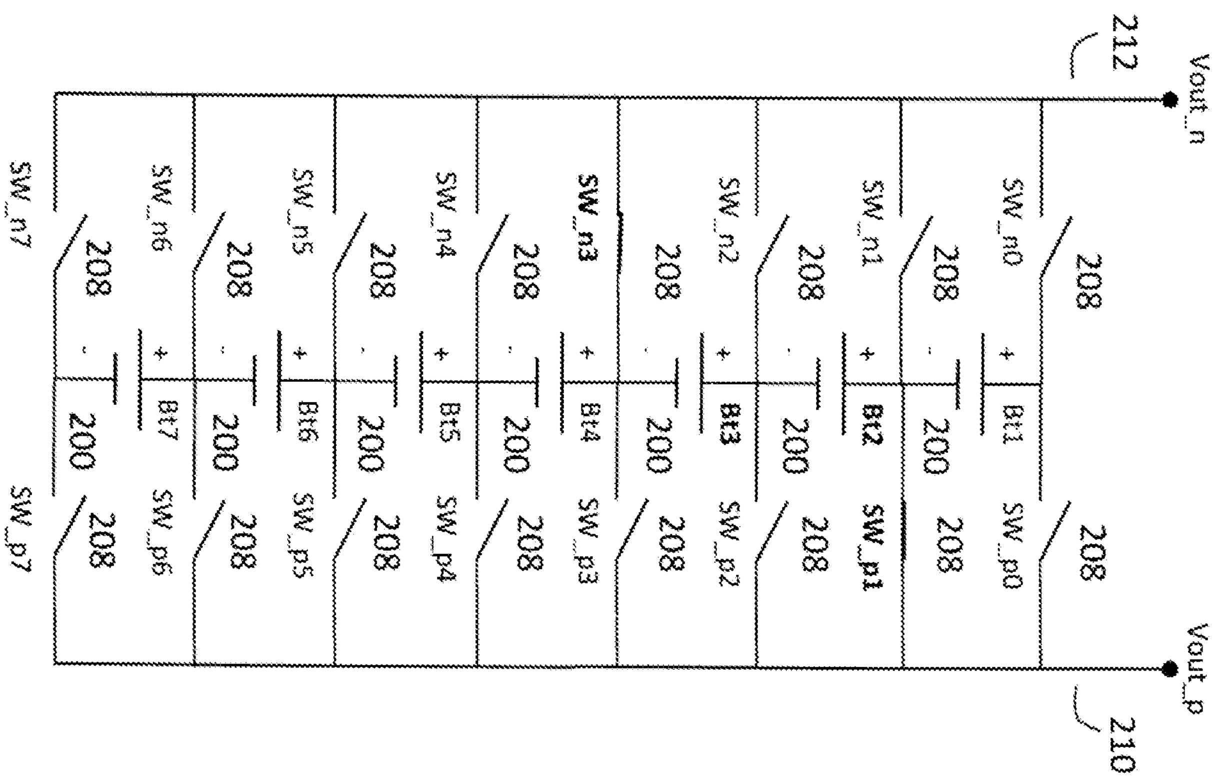

Vout_n
212
Vout_p
210
SW_n0
SW_n1
SW_n2
SW_n3
SW_n4
SW_n5
SW_n6
SW_n7
SW_p0
SW_p1
SW_p2
SW_p3
SW_p4
SW_p5
SW_p6
SW_p7
Bt1
Bt2
Bt3
Bt4
Bt5
Bt6
Bt7
208
200
+
-

Figure 9f

Figure 9g


Vout_n
212
Vout_p
210
SW_n0
SW_n1
SW_n2
SW_n3
SW_n4
SW_n5
SW_n6
SW_n7
SW_p0
SW_p1
SW_p2
SW_p3
SW_p4
SW_p5
SW_p6
SW_p7
Bt1
Bt2
Bt3
Bt4
Bt5
Bt6
Bt7
208
200
+
-

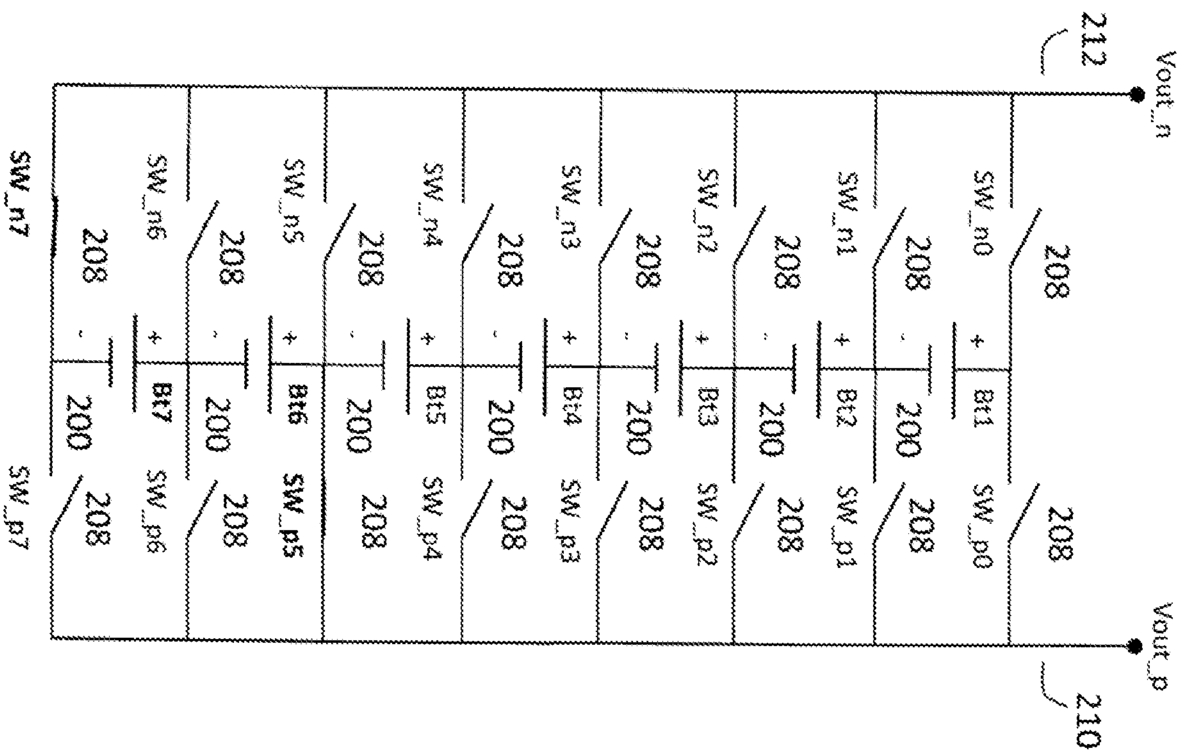

Vout_n
212
Vout_p
210
SW_n0
SW_n1
SW_n2
SW_n3
SW_n4
SW_n5
SW_n6
SW_n7
SW_p0
SW_p1
SW_p2
SW_p3
SW_p4
SW_p5
SW_p6
SW_p7
Bt1
Bt2
Bt3
Bt4
Bt5
Bt6
Bt7
208
200
+
-

Figure 9h

Figure 10a

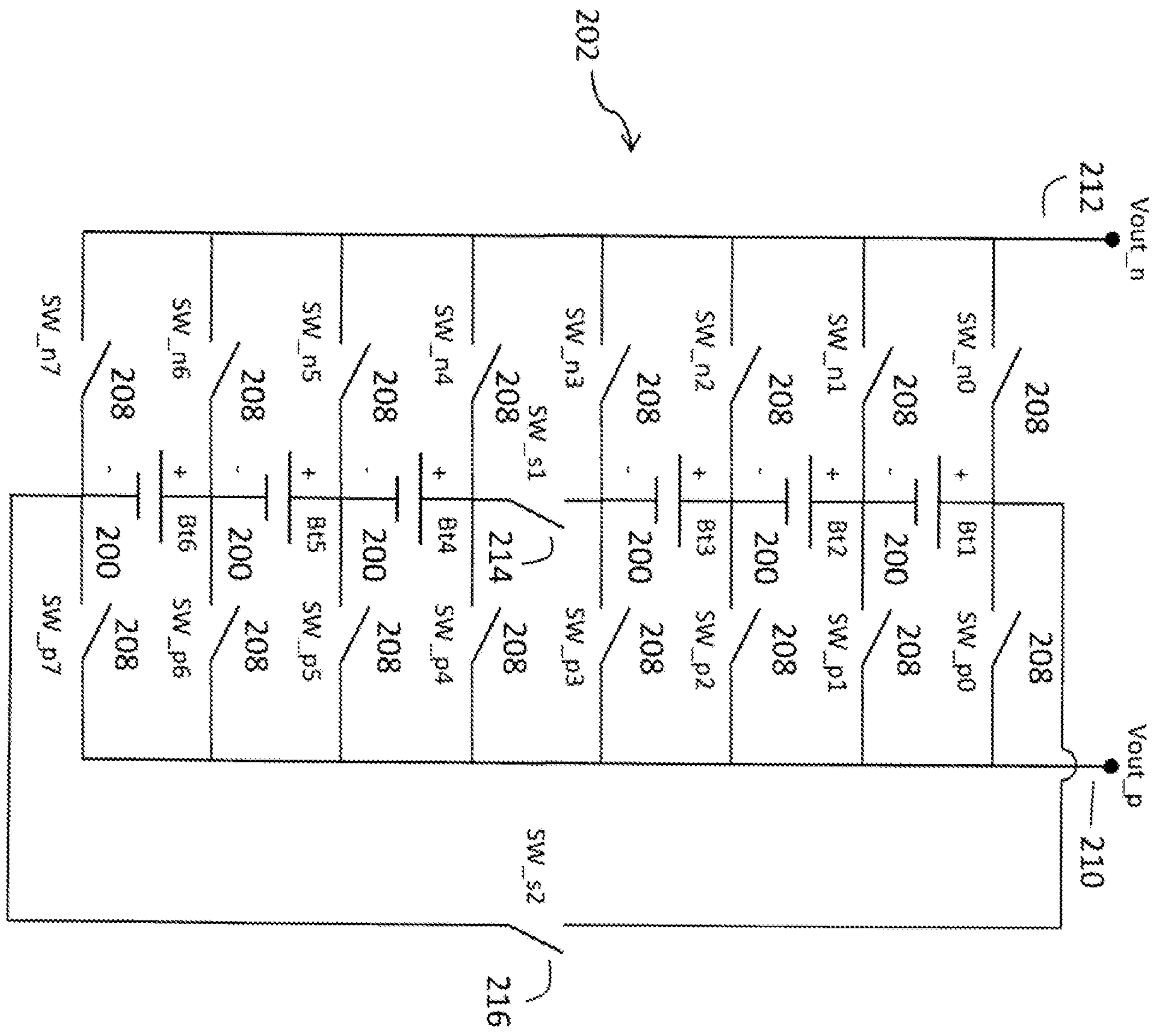

202
212
Vout_n
Vout_p
210
SW_n0
SW_n1
SW_n2
SW_n3
SW_n4
SW_n5
SW_n6
SW_n7
SW_p0
SW_p1
SW_p2
SW_p3
SW_p4
SW_p5
SW_p6
SW_p7
SW_s1
SW_s2
208
200
214
216
Bt1
Bt2
Bt3
Bt4
Bt5
Bt6
+
-

Figure 10b

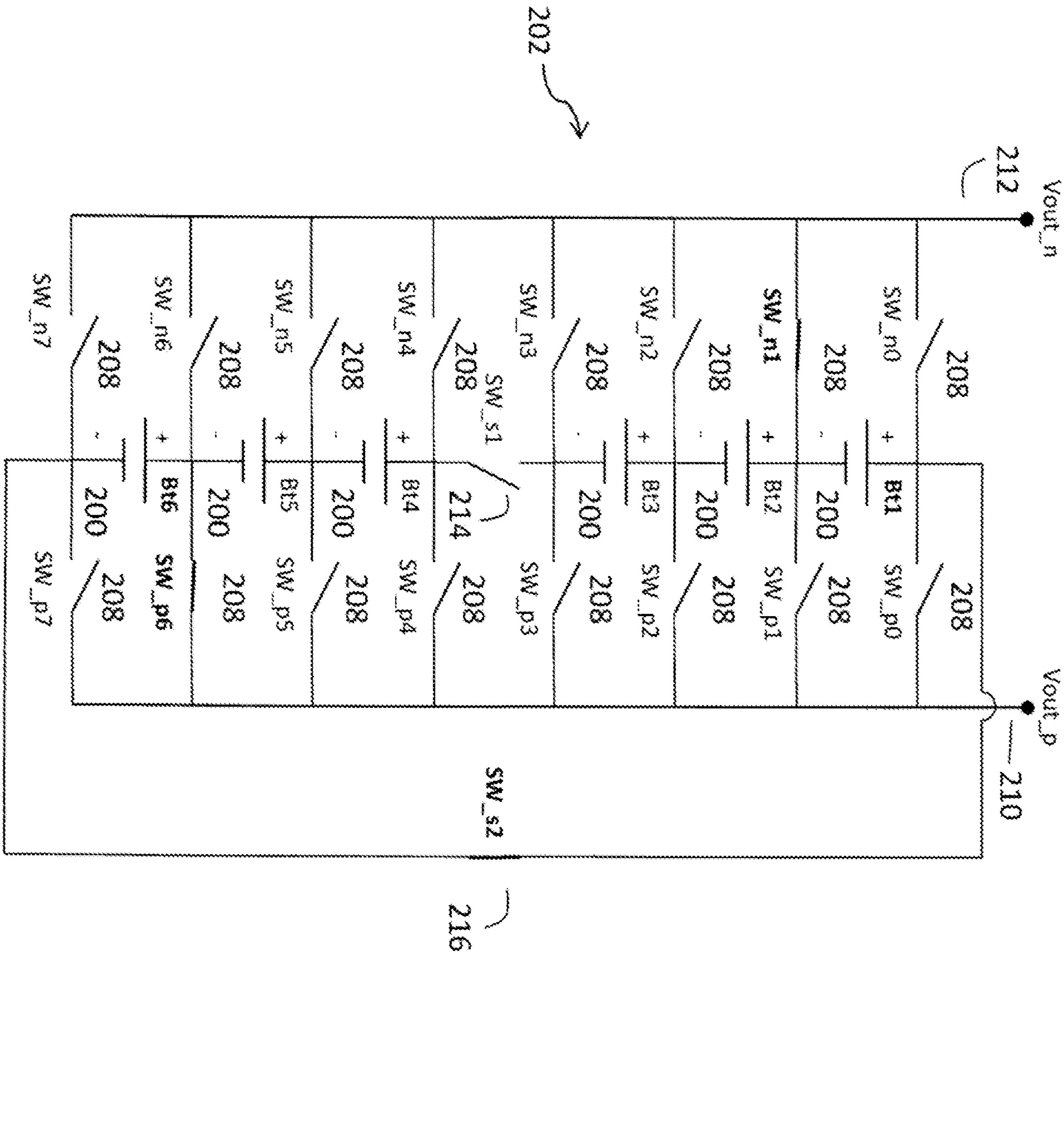
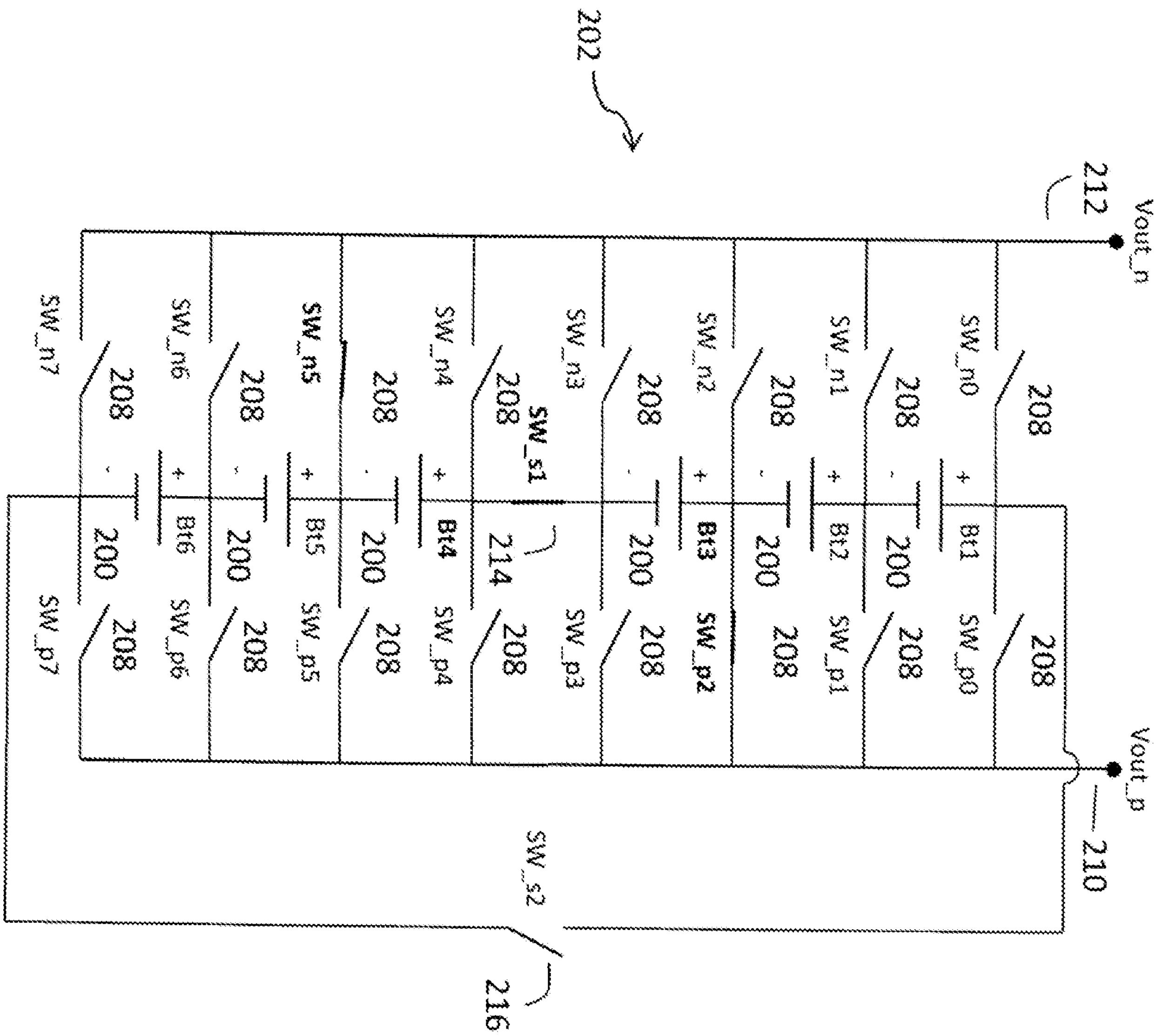

202
Vout_n
212
Vout_p
210
SW_n0
SW_n1
SW_n2
SW_n3
SW_n4
SW_n5
SW_n6
SW_n7
SW_p0
SW_p1
SW_p2
SW_p3
SW_p4
SW_p5
SW_p6
SW_p7
208
200
Bt1
Bt2
Bt3
Bt4
Bt5
Bt6
SW_s1
214
SW_s2
216

Figure 10c


202
212
Vout_n
Vout_p
210
SW_n0
SW_n1
SW_n2
SW_n3
SW_n4
SW_n5
SW_n6
SW_n7
SW_p0
SW_p1
SW_p2
SW_p3
SW_p4
SW_p5
SW_p6
SW_p7
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SW_s2
Bt1
Bt2
Bt3
Bt4
Bt5
Bt6
208
200
214
216

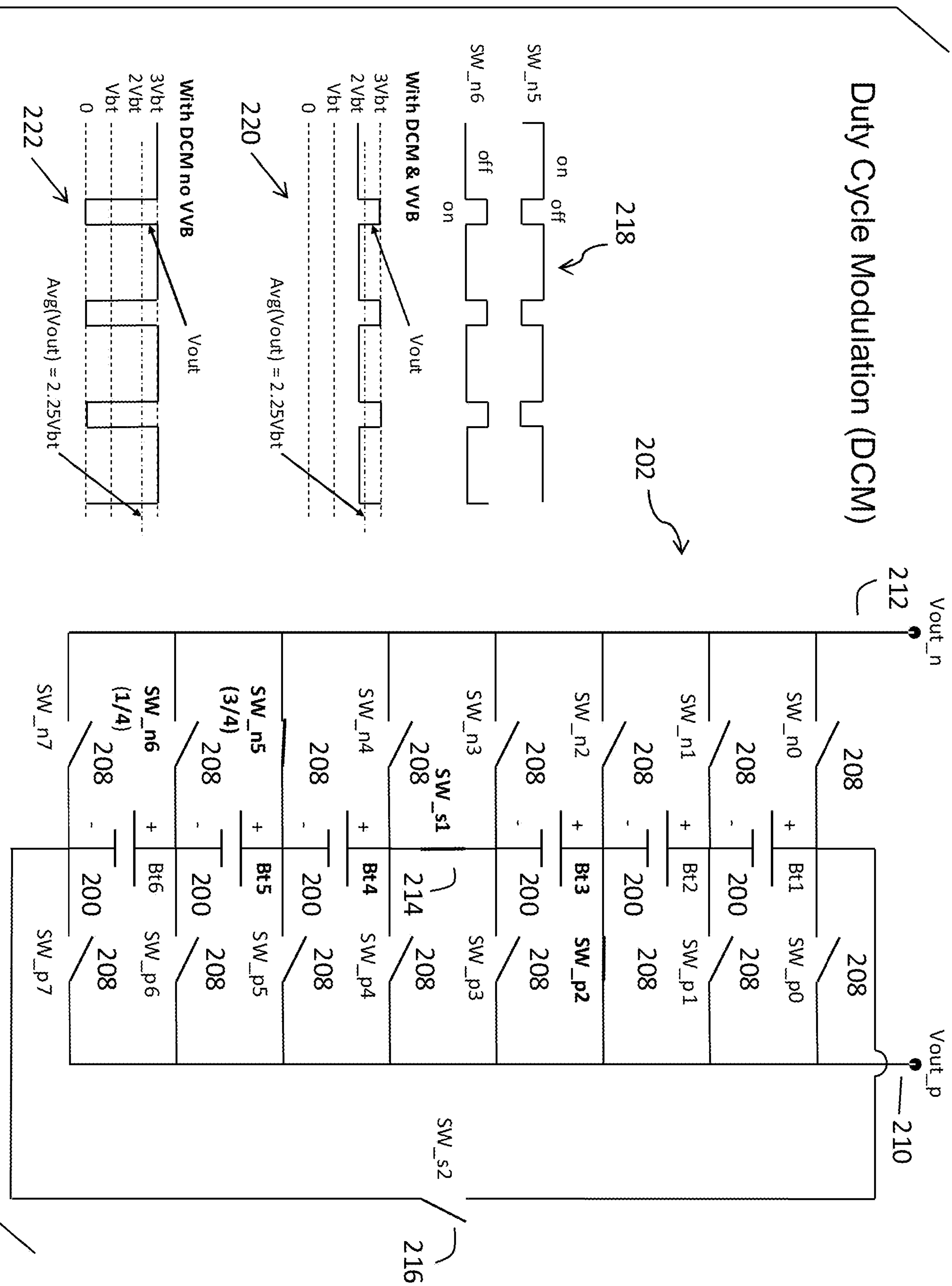

Duty Cycle Modulation (DCM)
202
218
SW_n5
SW_n6
on
off
off
on
With DCM & VVB
3Vbt
2Vbt
Vbt
0
Vout
Avg(Vout) = 2.25Vbt
220
With DCM no VVB
3Vbt
2Vbt
Vbt
0
Vout
Avg(Vout) = 2.25Vbt
222
Vout_n
212
Vout_p
210
SW_n0
SW_n1
SW_n2
SW_n3
SW_n4
SW_n5
(3/4)
SW_n6
(1/4)
SW_n7
SW_s1
214
Bt1
Bt2
Bt3
Bt4
Bt5
Bt6
200
208
SW_p0
SW_p1
SW_p2
SW_p3
SW_p4
SW_p5
SW_p6
SW_p7
SW_s2
216

Figure 11

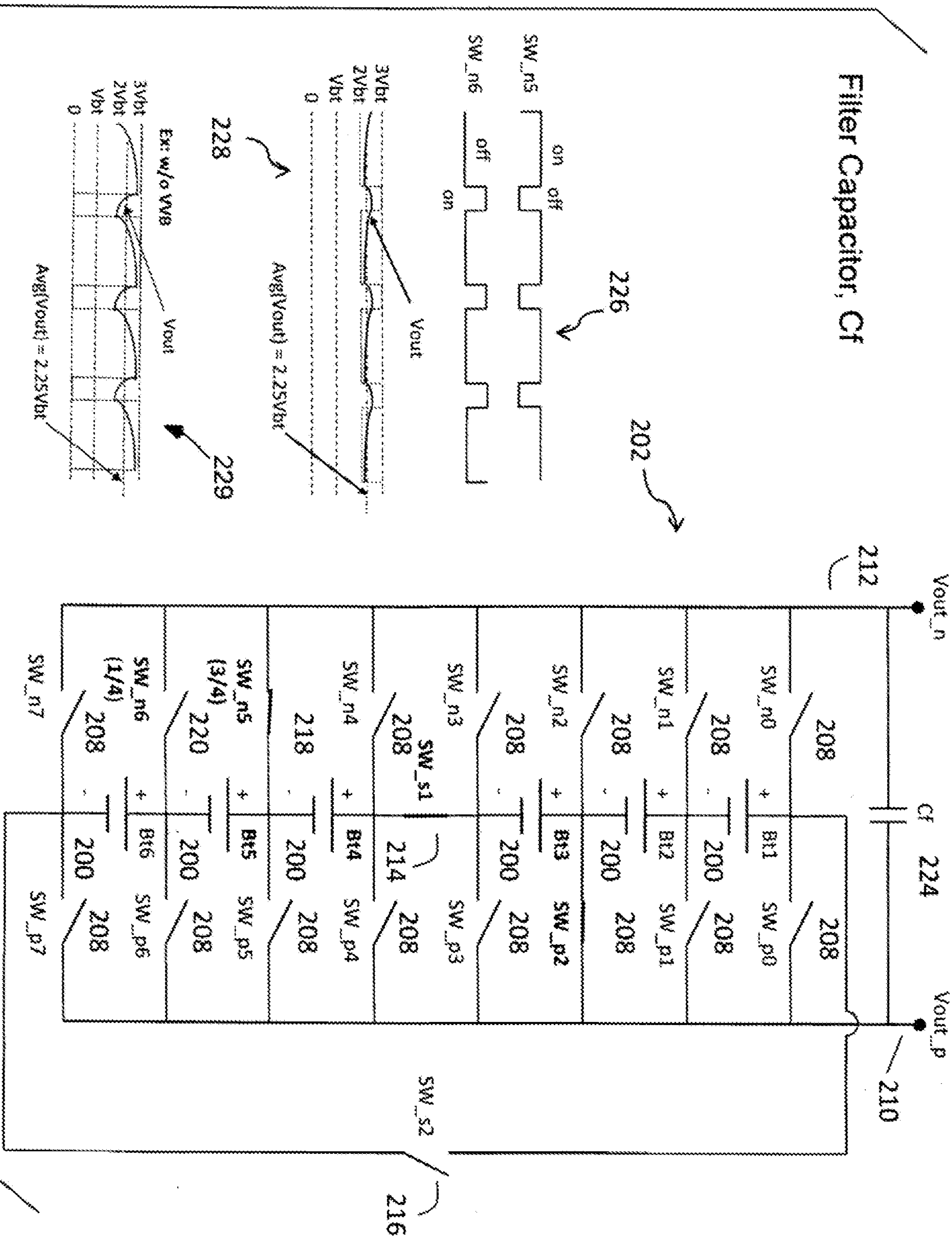
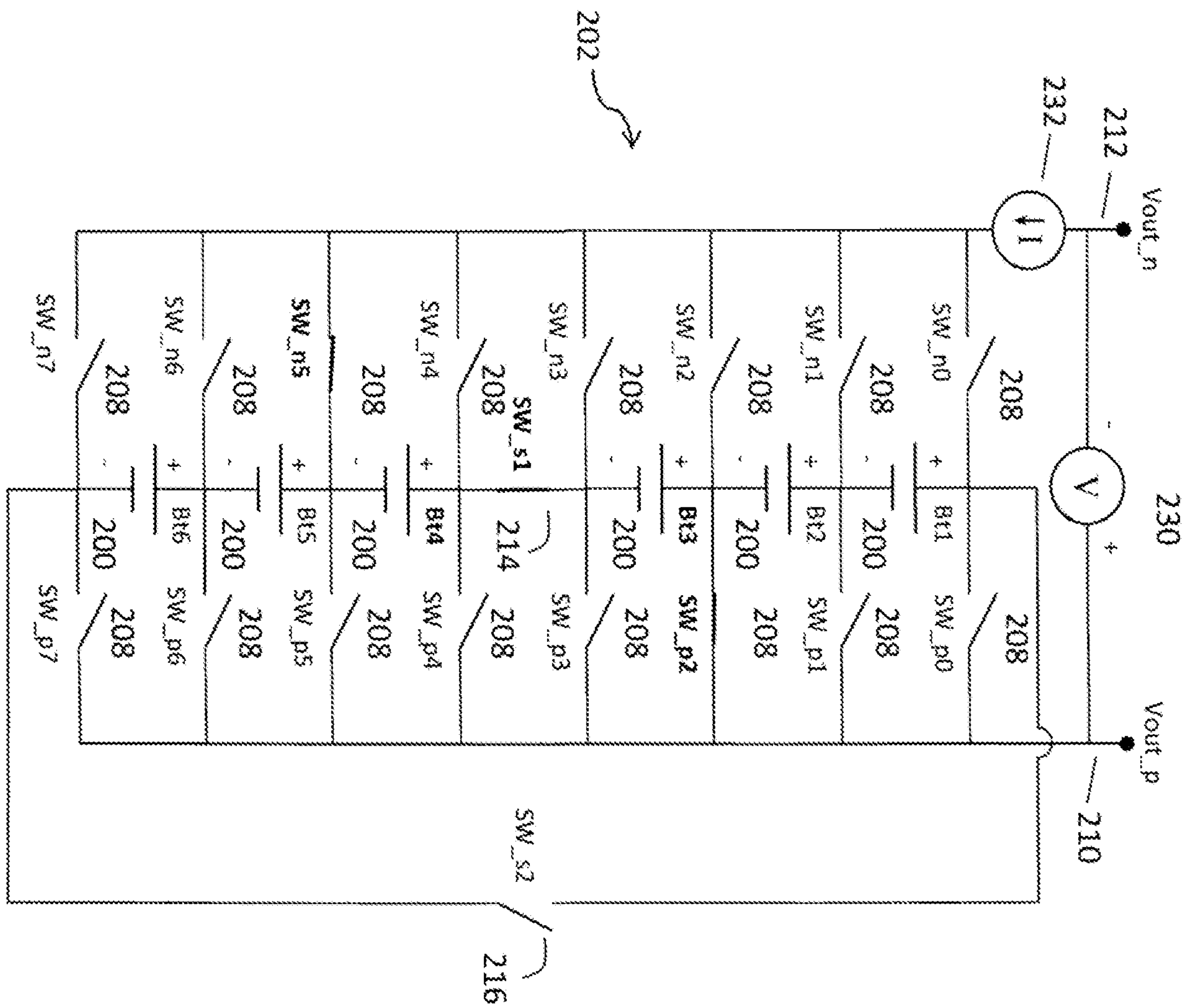

Filter Capacitor, Cf
SW_n5
SW_n6
on
off
off
on
226
202
3Vbt
2Vbt
Vbt
0
Vout
Avg(Vout) = 2.25Vbt
228
Ex: w/o VVB
229
Vout_n
212
Vout_p
210
Cf
224
SW_n0
SW_n1
SW_n2
SW_n3
SW_n4
SW_n5 (3/4)
SW_n6 (1/4)
SW_n7
SW_s1
214
218
220
208
Bt1
Bt2
Bt3
Bt4
Bt5
Bt6
200
SW_p0
SW_p1
SW_p2
SW_p3
SW_p4
SW_p5
SW_p6
SW_p7
SW_s2
216

Figure 12

Figure 13


202
232
212
230
Vout_n
Vout_p
210
SW_n0
SW_n1
SW_n2
SW_n3
SW_n4
SW_n5
SW_n6
SW_n7
SW_p0
SW_p1
SW_p2
SW_p3
SW_p4
SW_p5
SW_p6
SW_p7
SW_s1
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Bt6
208
200
214
216
V

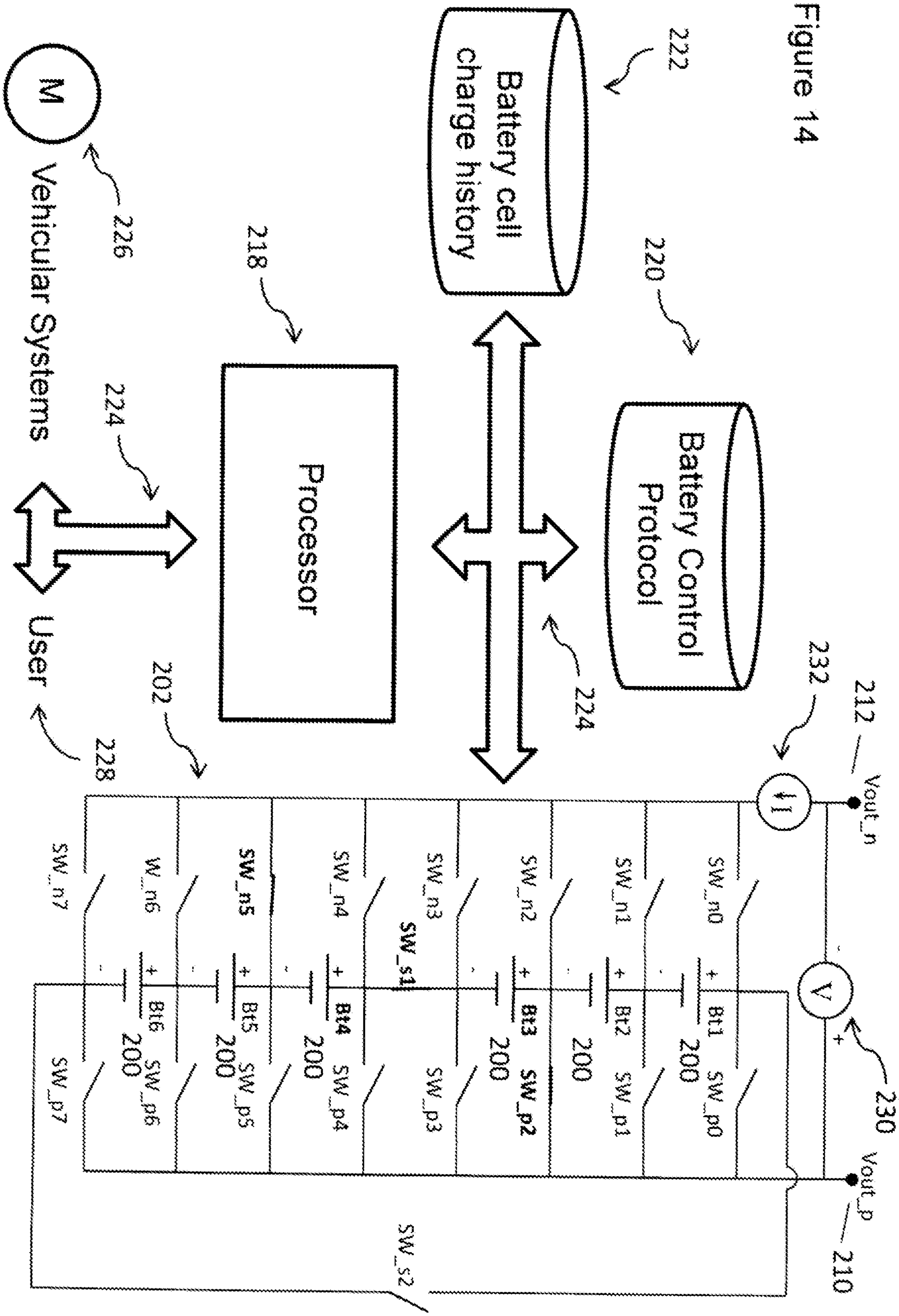
222
Battery cell charge history
220
Battery Control Protocol
218
Processor
224
224
226
M
Vehicular Systems
User
228
202
232
212
Vout_n
230
V
Vout_p
210
SW_n0
SW_n1
SW_n2
SW_n3
SW_n4
SW_n5
W_n6
SW_n7
SW_s1
SW_s2
Bt1
Bt2
Bt3
Bt4
Bt5
Bt6
200
SW_p0
SW_p1
SW_p2
SW_p3
SW_p4
SW_p5
SW_p6
SW_p7

Figure 14

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 13/21877

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - H02P 3/14, 5/00, 5/685, 7/18; H02J 7/00, 7/14 (2013.01)
USPC - 318/139; 307/71
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)
USPC: 318/139; 307/71

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
USPC: 318/139; 307/71; 320/116; 320/117; 318/376; 318/400.09

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
Patbase; Google Patents; Google Scholar
Search Terms Used: Reconfigurable, battery, cells, bank, rechargeable, vehicle, bicycle, auxiliary, switch, FET, MOSGET, stack, series, filter, motor, solid, state

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2007/0062744 A1 (Weidenheimer et al.) 22 March 2007 (22.03.2007) entire document	1-36
A	US 2011/0001442 A1 (Lee et al.) 06 January 2011 (06.01.2011) entire document	1-36
A	US 2011/0018352 A1 (Lai) 27 January 2011 (27.01.2011) entire document	1-36
A	US 6,430,692 B1 (Kimble et al.) 06 August 2002 (06.08.2002) entire document	1-36
A	US 2007/0052295 A1 (Frucht) 08 March 2007 (08.03.2007) entire document	1-36
A	US 2003/0071523 A1 (SILVERMAN) 17 April 2003 (17.04.2003) entire document	1-36
A	US 2001/0035696 A1 (KNOWLES et al.) 01 November 2001 (01.11.2001) entire document	1-36
A	US 2007/0080662 A1 (WU) 12 April 2007 (12.04.2007) entire document	1-36

☐ Further documents are listed in the continuation of Box C. ☐

* 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
08 March 2013 (08.03.2013)	08 APR 2013

Name and mailing address of the ISA/US	Authorized officer:
Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-3201	Lee W. Young PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774

(19)中华人民共和国国家知识产权局

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2014.07.16

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(74)专利代理机构 北京律盟知识产权代理有限责任公司 11287
代理人 王田

(51)Int.Cl.
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H02P 5/00(2006.01)
H02P 5/685(2006.01)
H02J 7/00(2006.01)
H02J 7/14(2006.01)

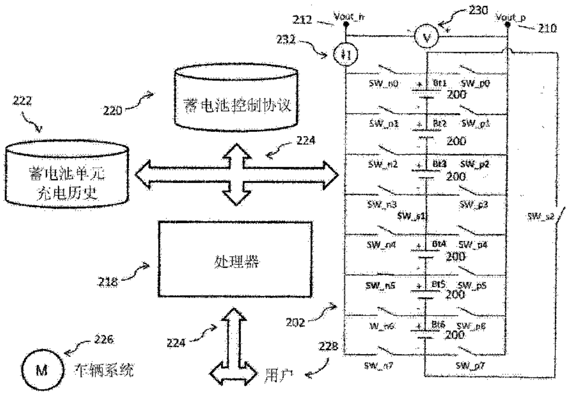
权利要求书4页　说明书15页　附图18页

(54)发明名称

可重配置蓄电池

(57)摘要

一种可重配置蓄电池具有至少一组静态接合的串联蓄电池单元，每一单元包含正极和负极。所述极通过开关连接到相应输出连接件。激活一组处理器控制的开关将所述蓄电池单元中的至少一些重新配置成横跨所述输出连接件提供电压的配置。所述输出蓄电池电压可在零伏特与串联的蓄电池单元所产生的最大电压之间变化。开关的替代配置将串联的蓄电池单元的群组划分成准许其它蓄电池单元配置的单独蓄电池组。所述开关的工作周期调制允许以减少的开关瞬变对输出电压进行中间控制。与电动机结合使用的可重配置蓄电池单元准许可选速度控制和与发动机输出匹配的蓄电池再生方案。



CN 104067507 A

1. 一种可重配置蓄电池，其包括至少一组：

静态接合的多个串联连接的蓄电池单元；

所述蓄电池单元中的每一者包括第一电压极和第二电压极；

电连接于所述蓄电池单元中的每一者的所述第一电压极与第一电输出连接件之间的至少一个处理器控制开关；

电连接于所述蓄电池单元中的每一者的第二电压极与第二电输出连接件之间的至少一个处理器控制开关；

其中所述处理器控制开关适合通过将所述蓄电池单元之一的第一电压极耦合到所述第一电输出连接件并将所述蓄电池单元之一的第二电压极耦合到所述第二电输出连接件而在电学上重新配置所述蓄电池单元，从而在所述第一和第二电输出连接件之间提供可重配置的蓄电池输出电压。

2. 根据权利要求 1 所述的可重配置蓄电池，其中所述可重配置蓄电池输出电压近似等于所述电性重新配置的蓄电池单元的电压和，且在零伏特与所述静态接合的多个串联蓄电池单元的最高绝对输出电压之间的范围内。

3. 根据权利要求 1 所述的可重配置蓄电池，其进一步包括：

至少一个开关，所述开关电连接于所述静态接合的多个串联蓄电池单元中的起始蓄电池单元的所述第一电压极与所述第二电输出连接件之间。

4. 根据权利要求 1 所述的可重配置蓄电池，其进一步包括：

至少一个开关，所述开关电连接于所述静态接合的多个串联蓄电池单元中的终止蓄电池单元的所述第二电压极与所述第一电输出连接件之间。

5. 根据权利要求 1 所述的可重配置蓄电池，其进一步包括以并联配置连接的多组所述静态接合的多个串联蓄电池单元。

6. 根据权利要求 1 所述的可重配置蓄电池，其中第一组所述静态接合的多个串联蓄电池单元到第二组所述静态接合的多个串联蓄电池单元的串联接合包括：

第一中间处理器控制开关，其连接于第一组中的末端放置蓄电池单元的第二电压极与第二组中的开端放置蓄电池单元的第一电压极之间；

第二中间处理器控制开关，其连接于第一组中的开端放置蓄电池单元的第一电压极与第二组中的末端放置蓄电池单元的第二电压极之间；

所述第一组的所述第一电输出连接件到所述第二组的所述第一电输出连接件的连接；以及

所述第一组的所述第二电输出连接件到所述第二组的所述第二电输出连接件的连接；

其中所述第一中间处理器控制开关和所述第二中间处理器控制开关不能同时处于闭合状态。

7. 根据权利要求 6 所述的可重配置蓄电池，其中包括静态接合的多个串联蓄电池单元的所述第二组由单个蓄电池单元代替。

8. 根据权利要求 1 所述的可重配置蓄电池，其进一步包括用于电压和 / 或电流波形滤波中至少一种操作的感应或电容元件中的至少一者。

9. 根据权利要求 1 所述的可重配置蓄电池，其进一步包括电压监测装置和电流监测装

置。

10. 根据权利要求 9 所述的可重配置蓄电池，其中所述电压和电流监测装置包括蓄电池单元状态控制系统。

11. 根据权利要求 10 所述的可重配置蓄电池，其中所述蓄电池单元状态控制系统包括至少一个电子处理器、至少一个数据存储装置、至少一个通信通道、至少一种可重配置蓄电池控制协议，以及一个用户接口协议。

12. 根据权利要求 6 所述的可重配置蓄电池，其中所述开关和所述中间开关包括固态开关和机械开关中的至少一者。

13. 根据权利要求 1 所述的可重配置蓄电池，其中所述第一电压极处于高于所述第二电压极的电压电位。

14. 根据权利要求 1 所述的可重配置蓄电池，其中所述蓄电池向包括具有至少一个电动机的车辆的电负载提供能量。

15. 根据权利要求 14 所述的可重配置蓄电池，其中所述车辆是电动自行车、电动小型摩托车、电动车辆、混合动力汽车、混合动力卡车、电动轮椅及电动高尔夫球车之一。

16. 根据权利要求 1 所述的可重配置蓄电池，其中 ：

所述蓄电池通过将至少一个电源连接到所述蓄电池而充电，以及

所述电源是适于再生充电的车辆电性系统。

17. 一种用于重新配置蓄电池的方法，其包括 ：

将静态接合的多个串联蓄电池单元的一部分布置成适于提供第一蓄电池电压的第一配置 ；以及

将所述静态接合的多个蓄电池单元的至少一部分重新配置成适于提供第二蓄电池电压的第二配置 ；

其中所述重新配置包括 ：

闭合第一处理器控制开关以将所述静态接合的多个串联蓄电池单元中的蓄电池单元的第一电压极电耦合到第一电输出连接件 ；以及

闭合第二处理器控制开关以将所述静态接合的多个串联蓄电池单元中的蓄电池单元的第二电压极电耦合到第二电输出连接件。

18. 根据权利要求 17 所述的方法，其中用于串联接合的所述静态接合的第一组多个串联蓄电池单元到第二组所述静态接合的多个串联蓄电池单元的所述重新配置包括交替地闭合 ：

a) 第一中间处理器控制开关，其连接于所述第一组中的末端放置蓄电池单元的第二电压极与所述第二组中的开端放置蓄电池单元的第一电压极之间，或

b) 第二中间处理器控制开关，其连接于所述第一组中的开端放置蓄电池单元的第一电压极与所述第二组中的末端放置蓄电池单元的第二电压极之间。

19. 根据权利要求 18 所述的方法，其中所述处理器控制开关包括脉冲宽度调制处理器控制开关或脉冲密度调制处理器控制开关之一。

20. 根据权利要求 18 所述的方法，其中所述第一电压极处于高于所述第二电压极的电压电位。

21. 根据权利要求 18 所述的方法，其中所述第二处理器控制开关包括通过在展现第一

电压的第一串联蓄电池单元配置与展现第二电压的第二串联蓄电池单元配置之间的脉冲宽度调制切换或脉冲密度调制切换而交替地切换，以产生中间输出电压。

22. 根据权利要求 18 所述的方法，其中所述可重配置蓄电池经交替地配置以向至少一个电负载提供能量或接收用于再充电的能量。

23. 根据权利要求 22 所述的方法，其中所述电负载包括具有至少一个电动机的车辆。

24. 根据权利要求 23 所述的方法，其中 ：

所述可重配置蓄电池通过将至少一个电源连接到所述蓄电池而再充电 ；以及

所述电源通过激活至少一个电动机的车辆制动动作而提供再生充电，从而诱发流向所述蓄电池的电流。

25. 根据权利要求 18 所述的方法，其进一步包括 ：

监测蓄电池电力放电的电压和电流 ；

监测蓄电池电力充电的电压和电流 ；以及

基于所述监测控制所述重新配置。

26. 根据权利要求 25 所述的方法，其进一步包括 ：

提供用于所述监测、用于所述控制和用于多个串联蓄电池单元的所述重新配置的辅助电源。

27. 根据权利要求 18 所述的方法，其进一步包括 ：

监测所述蓄电池单元的温度 ；以及

基于所述监测控制所述重新配置。

28. 根据权利要求 17 所述的方法，其中所述处理器控制开关包括脉冲宽度调制处理器控制开关或脉冲密度调制处理器控制开关之一。

29. 根据权利要求 17 所述的方法，其中所述第一电压极处于高于所述第二电压极的电压电位。

30. 根据权利要求 17 所述的方法，其中所述第二处理器控制开关包括通过在展现第一电压的第一串联蓄电池单元配置与展现第二电压的第二串联蓄电池单元配置之间的脉冲宽度调制切换或脉冲密度调制切换而交替地切换，以产生中间输出电压。

31. 根据权利要求 17 所述的方法，其中所述可重配置蓄电池经交替地配置以向至少一个电负载提供能量或接收用于再充电的能量。

32. 根据权利要求 31 所述的方法，其中所述电负载包括具有至少一个电动机的车辆。

33. 根据权利要求 32 所述的方法，其中 ：

所述可重配置蓄电池通过将至少一个电源连接到所述蓄电池而再充电 ；以及

所述电源通过激活至少一个电动机的车辆制动动作而提供再生充电，从而诱发流向所述蓄电池的电流。

34. 根据权利要求 17 所述的方法，其进一步包括 ：

监测蓄电池电力放电的电压和电流 ；

监测蓄电池电力充电的电压和电流 ；以及

根据所述监测控制所述重新配置。

35. 根据权利要求 34 所述的方法，其进一步包括 ：

提供用于所述监测、用于所述控制和用于多个串联蓄电池单元的所述重新配置的辅助

电源。

36. 根据权利要求 17 所述的方法，其进一步包括：

监测所述蓄电池单元的温度；以及

基于所述监测控制所述重新配置。

可重配置蓄电池

背景技术

[0001] 本发明涉及蓄电池领域，所述蓄电池经设计用于与可使用再生充电再充电的电动机一起使用，例如用于电动自行车的蓄电池。更特定来说，本发明涉及可重配置蓄电池、用于与所述可重配置蓄电池一起使用的可重配置电动机、重新配置用于驱动可变电负载的蓄电池的方法，和用于重新配置蓄电池以充电的方法与用于重新配置电动机以为蓄电池充电的方法。

[0002] 结合电动自行车（其中可充电蓄电池驱动电动机）而描述本发明。在现有技术电动自行车中，在某些情况下，来自蓄电池的电流由速度控制器调节，所述控制器控制向骑乘者提供协助的发动机。在其它情况下，其中下坡时骑乘者想要减速或制动，发动机像发电机一样工作并将电流供应回到蓄电池，从而实现恢复部分能量的再生制动，所述能量在单独使用机械制动时原本将失去。

[0003] 电动机通常使用一组磁体，例如，电磁铁和永磁体。在发动机转动时，这些磁体的吸引力和排斥力被电力地调节，从而使得所述发动机在所要方向上连续转动。此可由机电开关（例如整流器）实现，或可由固态开关（例如 FET- 场效应晶体管）实现。图 1 展示连接到蓄电池 10 的发动机 12。在电流 I_m 流入发动机 12 且发动机转动时，所述发动机产生与发动机 12 的速度大致成比例的反 EMF（电位）。电流 I_m 由 $(V_B-V_M)/(R_M+R_B)$ 定义，其中 R_M 是发动机 12 的内阻且 R_B 是蓄电池的内阻。给出固定的实施电压 V_B（例如来自蓄电池 10)，反电位减少流入发动机 12 的电流量，因为电流与发动机电压 V_M（反电位）与蓄电池电压 V_B 之差成比例。举例来说，如果发动机 12 以使反电位等于蓄电池电压 V_B 的速度旋转，那么将没有电流流动。如果发动机 12 以使反电位高于蓄电池电压 V_B 的速度旋转，那么电流反向流动，从而使蓄电池 10 再充电。一个极端的实例是停滞不前，此时发动机 12 静止。在这样的实例中，因为发动机静止，所以反电位为零，从蓄电池 10 流出的电流将是其最大值，且发动机 12 将产生其最大转矩。

[0004] 在自行车正移动且发动机 12 产生有限的反电位时，当达到所需的制动电平时，发动机 12 可像发电机一样使用以给蓄电池 10 充电。为了达到所述电平，从发动机 12 出来的电压使用被称作反相器的装置增加到高于蓄电池 10 电平的电平。

[0005] 没有再生制动的电动自行车系统的现有技术的框图在图 2 中展示。蓄电池 10 通过速度控制器 11 向发动机 12 提供电流。速度控制器 11 决定流到发动机 12 的电流，从而控制其速度。速度控制器 11 可由骑乘者使用控制旋钮 13 设定到所需速度。

[0006] 提供再生制动的电动自行车系统的另一现有技术的框图在图 3 中展示。图 3 类似于图 2，但还包括与控制器 11 并联的反相器 14。开关 15 经设计用于将发动机 12 耦合到控制器 11（在驾驶模式）或反相器 14（在制动模式）。在制动模式中，电流由发动机 12 产生且由反相器 14 传递到蓄电池 10，以便给蓄电池充电。

[0007] 应注意，实际系统涉及两个相异操作，一个是通过从蓄电池向发动机供应电流来驱动发动机和自行车车轮，另一个是使用来自发动机的电流来向蓄电池充电以获得再生制动，从而使自行车减速。从图 3 中进一步容易看出，为了给蓄电池再充电，需要增加来自发

动机的电压到高于蓄电池电压的值的反相器，以便使电流流回进蓄电池。

[0008] 对于典型可再充电蓄电池，充电电压必须高于蓄电池电压。充电电压相对于蓄电池电压越高，流入蓄电池的电流越多。控制充电电压是控制再充电速度以及制动速度的一种方式。控制再充电速度的另一种方法是脉冲宽度调制(PWM)，其中充电源与蓄电池之间的开关控制开－关工作周期。当然，充电电压仍然需要高于蓄电池电压以使此种装置工作。

[0009] 在大多数利用再生制动的电动车辆（例如电动自行车和电动汽车）中，电力系统通常由若干子系统组成，即发动机、速度控制器、反相器和蓄电池。有时，速度控制器通过脉冲宽度调制同时调节驱动电流和制动电流。潜在地，聪明的反相器设计可通过调节用于驾驶的发动机电压来调节驱动和制动两者，且调节用于再生制动的蓄电池电压，从而消除对单独的速度控制器的需要。

[0010] 然而，反相器不是容易设计或廉价生产的装置，因为其必须处置大量电流（特别是在快速制动时）且有时必须处置高输出电压（尽管其输入电压可在大的范围上波动）。输入电压在这种情况下是来自发动机的反电位，当自行车停止时通常接近于零，当自行车以其最大速度（通常蓄电池电压限制最大速度）在水平地面上滑行时接近于最大蓄电池电压。

[0011] 同样，反相器通常使用快速切换装置来实现其功能。一种反相器设计可首先将来自发动机的直流电流转变成交流电流，使用升压变压器增大电压，且将交流电转换回直流电以对蓄电池再充电。另一种反相器设计可使用电荷泵配置中的临时储能元件（例如电容器和电感器）以便增大电压。所涉及的切换频率通常大约为 1-100KHz。在大多数已知反相器设计中，能量损失是重要的，且由于除重量之外的高电流需求(100 安培或更大)，其成本是非常高的。因此，只有小部分电动自行车产品在其设计中并入再生制动。

[0012] 提供蓄电池和／或电动机配置（其在无需反相器的情况下在合理操作范围内提供驾驶和再生制动）是有利的，例如在电动自行车中。

[0013] 提供可重配置蓄电池和蓄电池控制系统也是有用的，所述控制系统提供蓄电池单元阵列的工作周期调制，从而在不引起大开关损耗的情况下控制中间输出电压，同时减少切换诱发的瞬变信号。

[0014] 本发明的方法和设备提供具有这些或其它优势的串联可重配置蓄电池。

发明内容

[0015] 本发明涉及可重配置的蓄电池，例如，用在电动车辆的驱动系统（例如自行车、汽车、卡车、火车头、实用工具车等）。明确地说，本发明涉及具有多个串联蓄电池单元的可重配置蓄电池和在电动车辆驱动系统中与所述可重配置蓄电池一起使用的可重配置电动机，以及重新配置蓄电池用于通过可变电负载充电和放电的方法。与本发明相一致，揭示具有至少一组由静态接合的多个串联蓄电池单元制成的蓄电池的可重配置蓄电池。每一蓄电池单元具有第一电压极和第二电压极。至少一个处理器控制的开关电连接于每一蓄电池单元的第一电压极和第一电输出连接件之间。处理器控制的开关适合通过将蓄电池单元的第一电压极耦合到第一电输出连接件并将蓄电池单元的第二电压极耦合到第二电输出连接件而重新配置蓄电池单元，从而在第一和第二电输出连接件之间提供可重配置的蓄电池输出电压。

[0016] 可重配置蓄电池输出电压近似等于电力重新配置蓄电池单元的电压和，且在零伏特与静态接合的多个串联蓄电池单元的最大绝对输出电压（例如正数和负数）之间的范围内。

[0017] 在另一实例实施例中，可重配置蓄电池进一步包含至少一种切换方法，所述方法为将在静态接合的多个串联蓄电池单元中的起始蓄电池单元的第一电压极与第二电输出连接件电连接。

[0018] 可重配置蓄电池还可包含至少一个开关，所述开关电连接于静态接合的多个串联蓄电池单元中的终止蓄电池单元的第二电压极与第一电输出连接件之间。

[0019] 在另一实例实施例中，可重配置蓄电池进一步包含以并联配置连接的多个组。

[0020] 在另一实例实施例中，可重配置蓄电池包含第一组蓄电池单元到第二组蓄电池单元的串联接合。第一中间处理器控制的开关连接于第一组中的末端放置蓄电池单元的第二电压极与第二组中的开端放置蓄电池单元的第一电压极之间。第二中间处理器控制的开关连接于第一组中的开端放置蓄电池单元的第一电压极与第二组中的末端放置蓄电池单元的第二电压极之间。第一组的第一电输出连接连接到第二组的第一电输出连接，且第一组的第二电输出连接连接到第二组的第二电输出连接。在操作中，第一中间处理器控制的开关和第二中间处理器控制的开关不能同时处于闭合状态。

[0021] 此外，在前述的实例实施例的可重配置的蓄电池中，第二组静态接合的串联蓄电池单元可被单个蓄电池单元代替。

[0022] 在另一实例实施例中，前述的实例实施例的可重配置的蓄电池可进一步包含用来于电压和／或电流波形滤波中至少一种操作的电容元件和／或感应元件。

[0023] 任一前述实例实施例可包含电压监测装置和电流监测装置，其中电压监测装置是跨接在第一电输出连接和第二电输出连接之间的电压表。替代地，电流监测装置是与第一电输出连接串联或与第二电输出连接串联的电流表。然而，另一个选择是电压和电流监测装置可以是蓄电池状态控制系统的一部分。更进一步，蓄电池单元的温度监测可经提供用于充电和放电控制，以及用于诊断故障和有故障的单元。

[0024] 蓄电池控制系统包含至少一个电子处理器、至少一个数据存储装置、至少一个通信通道、至少一种可重配置蓄电池控制协议，和允许用户通信和控制的用户接口协议。

[0025] 在实例实施例中，开关和中间开关可包含功率场效应晶体管和／或其它固态开关（例如半导体），其具有例如脉冲宽度调制或脉冲密度调制控制回路。机械开关还可单独使用或与其它固态开关一起使用。此外，第一电压极可被设定到高于第二电压极的电压电位。

[0026] 在实例实施例中，蓄电池向电负载提供能量，其中电负载可为具有至少一个电动机的车辆。车辆是电动自行车、电动小型摩托车、电动车辆、混合动力汽车、混合动力卡车、电动轮椅、电动高尔夫球车之一。

[0027] 在另一实例实施例中，可重配置蓄电池通过将至少一个电源连接到蓄电池而充电。例如，电源可以是适于再生充电的车辆电力系统，或整流的（或直接的）交流电源。

[0028] 在一实例实施例中，用于重新配置蓄电池的方法包含将静态接合的多个串联蓄电池单元的一部分布置成适于提供第一蓄电池电压的第一配置的步骤。另一个步骤包含将静态接合的多个串联蓄电池单元的一部分布置成适于提供第二蓄电池电压的第二配置的步骤。重新配置包括闭合第一处理器控制的开关，以将静态接合的多个串联蓄电池单元的蓄

电池单元的第一电压极电连接到第一电输出连接件。接下来,闭合第二处理器控制的开关,以将静态接合的多个串联蓄电池单元的蓄电池单元的第二电压极电连接到第二电输出连接件。

[0029] 在另一实例实施例中,揭示一种方法,其中重新配置串联接合的第一组到第二组进一步包含一个或两个步骤。闭合第一中间处理器控制的开关,其连接于第一组中的末端放置蓄电池单元的第二电压极与第二组中的开端放置蓄电池单元的第一电压极之间。交替地,闭合第二中间处理器控制的开关,其连接于第一组中的开端放置蓄电池单元的第一电压极与第二组中的末端放置蓄电池单元的第二电压极之间。

[0030] 在前述实例实施例的方法中,处理器控制的开关可包含脉冲宽度调制处理器控制的开关或脉冲密度调制处理器控制的开关之一。同样,第一电压极可处于比第二电压极高的电压电位。

[0031] 进一步的实例实施例包括一种方法,凭借所述方法第二处理器控制的开关通过在展现第一电压的第一蓄电池单元串联配置与展现第二电压的第二蓄电池单元串联配置之间的脉冲宽度调制切换或脉冲密度调制切换而被交替地切换,以产生在第一电压与第二电压之间的中间输出电压。

[0032] 另一实例实施例包括一种方法,其中可重配置蓄电池经交替地配置以向至少一种电负载提供能量或接收能量用于再充电。

[0033] 一种实例电负载是具有至少一个电动机的车辆,其中所述车辆是电动自行车、电动小型摩托车、电动车辆、混合动力汽车、混合动力卡车、电动轮椅、电动高尔夫球车之一。

[0034] 一种对可重配置蓄电池再充电的实例方法是通过将至少一个电源连接到蓄电池。一个此种电源是通过施加激活至少一个电动机的车辆制动动作的再生充电,从而诱发流向蓄电池的电流。另一种再充电方法是通过施加经整流的交流电源或直接的交流电源,其取决于蓄电池配置。举例来说,通过蓄电池的动态极性反转,直接的交流电源可不经整流而使用。

[0035] 进一步的实例实施例包含一种监测蓄电池电力放电的电压和电流的方法。所述方法包含监测蓄电池电力充电的电压和电流的步骤,且基于所述监测控制多个串联蓄电池单元的重新配置。还可应用用于监测、用于控制和用于多个串联蓄电池单元的重新配置的辅助电源。

[0036] 另一实例实施例描述了一种方法,其中可重配置蓄电池电压输出信号包含通过提供电容和/或电感元件的滤波步骤。

附图说明

[0037] 本发明将在下文中结合附图加以描述,其中同样的参考数字表示同样的元件,且:

[0038] 图1展示常规电动机和蓄电池配置;

[0039] 图2展示现有技术电动自行车系统的框图;

[0040] 图3展示另一现有技术电动自行车系统的框图;

[0041] 图4展示根据本发明的电动自行车的实例实施例;

[0042] 图5a展示根据本发明的第一蓄电池单元配置中的可重配置蓄电池的实例实施

例；

[0043] 图 5b 展示根据本发明的第二蓄电池单元配置中的可重配置蓄电池的实例实施例；

[0044] 图 5c 展示根据本发明的进一步蓄电池单元配置中的可重配置蓄电池的实例实施例；

[0045] 图 6 展示根据本发明的可重配置蓄电池的进一步实例实施例；

[0046] 图 7a 展示根据本发明的第一配置中的可重配置电动机装配的实例实施例；

[0047] 图 7b 展示根据本发明的第二配置中的可重配置电动机装配的实例实施例；

[0048] 图 8 展示根据本发明的具有不同负载分布的可重配置电动机装配的实例实施例；

[0049] 图 9a 展示根据本发明的可重配置蓄电池的实例实施例；

[0050] 图 9b 展示根据本发明的经配置的具有最大输出电压的可重配置蓄电池的实例实施例；

[0051] 图 9c 展示根据本发明的经配置的具有单个蓄电池单元输出电压的可重配置蓄电池的实例实施例；

[0052] 图 9d 展示根据本发明的经配置的具有单个蓄电池单元输出电压的可重配置蓄电池的替代实例实施例；

[0053] 图 9e 展示根据本发明的经配置的具有单个蓄电池单元输出电压的可重配置蓄电池的实例实施例；

[0054] 图 9f 展示根据本发明的经配置的具有两个蓄电池单元输出电压的可重配置蓄电池的实例实施例；

[0055] 图 9f 展示根据本发明的经配置的具有两个蓄电池单元输出电压的可重配置蓄电池的实例实施例；

[0056] 图 9g 展示根据本发明的经配置的具有两个蓄电池单元输出电压的可重配置蓄电池的替代实例实施例；

[0057] 图 9h 展示根据本发明的经配置的具有两个蓄电池单元输出电压的可重配置蓄电池的第二替代实例实施例；

[0058] 图 10a 展示根据本发明的具有两组蓄电池单元的可重配置蓄电池的实例实施例；

[0059] 图 10b 展示根据本发明的经配置的具有两组蓄电池单元的可重配置蓄电池的实例实施例；

[0060] 图 10c 展示根据本发明的经配置的具有两组蓄电池单元的可重配置蓄电池的替代实例实施例；

[0061] 图 11 展示根据本发明的经配置的具有两组蓄电池单元的可重配置蓄电池的工作周期调制的实例实施例；

[0062] 图 12 展示根据本发明的经配置的具有两组蓄电池单元的可重配置蓄电池的具有电容滤波的工作周期调制的实例实施例；

[0063] 图 13 展示根据本发明的经配置的具有两组蓄电池单元的可重配置蓄电池和电压及电流监测器的实例实施例；

[0064] 图 14 展示根据本发明的经配置的可重配置蓄电池和开关控制系统的实例实施例。

具体实施方式

[0065] 下列的详细描述只是提供了实例实施例，且不旨在限制本发明的范围、适用性或配置。确切的说，实例实施例的详细描述将给所属领域的技术人员提供实施本发明实施例的致能性描述。应理解，在不背离如由所附权利要求书阐述的本发明的精神和范围的条件下，可在元件的功能和布置中进行各种改变。

[0066] 尽管本发明是结合电动自行车（其中可再充电蓄电池驱动电动机）而描述，但所属领域的技术人员将明白其同样适用于其它类型的电动车辆和蓄电池充电系统。

[0067] 在许多机电系统设计中（例如电动自行车），设计问题的复杂性由将系统分成单独的子系统来决定，每一子系统提供特定的功能以使整个系统顺利运行。只要其满足给定的设计要求，每一子系统可被设计得或多或少地独立于另一子系统。典型的现有技术电动车辆设计（例如电动自行车）可被分为下列子系统：具有电动机的驱动机构、速度控制器、反相器、蓄电池且或许具有协调其它子系统的智能中心控制器。举例来说，蓄电池子系统通常由蓄电池制造商提供，其具有包含电压及电流额定值的规格；反相器设计者可按照从发动机输出电压可能的范围可升的足够高以给蓄电池再充电的说明书工作；机械设计人员将为其它子系统设计驱动机构和发动机的接口等。通过所述方法，当每次注意力集中在一个子系统，容易漏掉系统级简化或子系统间的协同效应。

[0068] 当从发动机对蓄电池再充电时需要解决的基本问题是保持充电电压高于蓄电池电压。本发明通过在充电阶段有效地降低蓄电池电压解决了所述问题。其根据本发明通过可重配置蓄电池的方法解决。只要蓄电池电压低于发动机产生的电压，再充电就完成。相应地，根据本发明，无需使用反相器增大发动机的输出电压。

[0069] 典型电动自行车所需的蓄电池必须产生 10 伏特电压，需要半打到多打蓄电池单元。举例来说，典型现有技术电动车辆使用 36V、13 安培小时 NiMH 蓄电池。每一蓄电池单元通常将产生 1.2V（例如 NiCd 或 NiMH 单元）到 3.6V（LiIo 或 LiPo 单元）之间的电压。许多这些单元必须串联以产生发动机所需的电压。

[0070] 根据本发明，提供可重配置的蓄电池，其适于根据系统变化（例如从为驱动发动机提供电流到接收给蓄电池再充电的电流，且反之亦然）的需要动态地重连接或重新配置蓄电池单元。图 4 展示根据本发明的电动自行车 40 的简化实施例。具有多个单元的可配置蓄电池 42 安装到自行车框架 44。至少一个发动机 46 安装到框架 44 且适于驱动自行车 40 的车轮 48。蓄电池 42 和发动机 46 都和控制器 50 通信。控制器 50 可适于控制从蓄电池 42 施加到发动机 46 的电流以驱动车轮 48，适于控制从发动机 46 施加到蓄电池 42 的电流以给蓄电池 42 再充电，且适于像下文详细描述那样重新配置蓄电池 42（或重新配置多个发动机 46）。

[0071] 图 5a 和 5b 说明根据本发明的可重配置蓄电池的一个实例实施例。图 5a 展示以第一配置布置的蓄电池 42 的多个蓄电池单元 52，其适于向电动机 46 提供第一蓄电池电压。图 5b 展示配置到第二配置的蓄电池单元 52，其适于提供第二蓄电池电压。应理解，多个蓄电池单元的仅一部分可重配置以提供第二配置。第二蓄电池电压可低于第一蓄电池电压。当多个蓄电池单元 52 以第二配置布置时，蓄电池 42 可接着被充电。

[0072] 在如图 5a 展示的第一配置中，多个蓄电池单元 52 可以串联方式布置。在如图 5b

展示的第二配置中，多个蓄电池单元 52 可以并联方式布置。

[0073] 替代地，在第二配置中，多个蓄电池单元 52 中的仅一部分可以串联方式布置且蓄电池单元 52 的第二部分可以并联方式布置。此外，如图 5c 所示在第二配置的变化中，多个蓄电池单元 52 可经布置而使得蓄电池单元的至少第一部分串联且蓄电池单元的第二部分串联，蓄电池单元的第一部分与第二部分并联。举例来说，注意，在具有四个蓄电池单元 52 所展示的实例中，蓄电池 42 可被配置到至少三个可能电压（其中 Vb 穿过每一单元 52）：4xVb（如图 5a 中的所有 4 个串联单元）、1xVb（如图 5b 中所示的所有 4 个并联单元）和 2xVb（如图 5c 中所示两对串联单元，其中所得两对并联地布置）。

[0074] 充电可包括在车辆制动动作中由电动机 46 提供的再生充电。在此种实例实施例中，发动机 46 的发动机电压和电流中的至少一者可被监测。多个蓄电池单元 52 的重新配置可基于监测被控制。举例来说，电流传感器 49 可用于监测流过发动机的电流和 / 或电压传感器 58 可用于监测发动机电压，且传感器 49 和 58 可将所需的电压和 / 或电流信息中继到控制器（例如图 4 中的控制器 50）以决定如何将蓄电池 42 重新配置到所需的电压。替代地，传感器可监测发动机速度以向控制器 50 提供等效信息。此外，可提供辅助电源（例如后备蓄电池 56）以给控制器 50 和传感器 49 与 58 供电。

[0075] 此外，制动动作所需的制动电能量可被监测且向控制器 50 提供，且多个蓄电池单元 52 的重新配置可基于监测而被控制。施加的制动力可被电流传感器 49（或被在电动机 46 本身内部提供的电路）监测并传递到控制器 50。

[0076] 可提供开关装置 57，使得多个蓄电池单元可被重新配置。开关装置 57 可连接到蓄电池单元中的至少一者。举例来说，开关装置 57 可包括由控制器 50 控制的脉冲宽度调制开关装置或脉冲密度调制开关装置之一。

[0077] 还可提供速度控制开关 59。开关 59 可以是脉冲宽度调制开关机构，且控制器 50 可以是 PWM 控制系统，所述控制系统适于调节发动机 46 与蓄电池 42 之间的 PWM 开关 59 的开关工作周期。电流传感器 49 可用于计算电流流动的平均量。举例来说，如果因为发动机 46 与蓄电池 42 之间的电压差太小以致不能维持所需电流量，那么蓄电池 42 可被重新配置以在再生充电过程中提供较低电压，或为了驱动或加速而提供较高电压。对于典型的直流发动机，发动机的转矩（或发动机的制动力）与流入（或流出）发动机的电流成比例。

[0078] 备用蓄电池 56 可能需要或可能不需要，且可用于运行控制电路和传感器 49 与 58。备用蓄电池 56 可每当发动机电压较高时保持充电，其使用额外的开关 55 来控制充电量。

[0079] 在一个实例实施例中，蓄电池 42 可提供于电动车辆中且适于再生充电。举例来说，蓄电池 42 可提供于电动自行车中（如图 4 所示）。所属领域的技术人员将明白，可重配置蓄电池 42 可用于其它类型的电动车辆中，例如电动小型摩托车、电动汽车、混合动力车辆、电动轮椅、电动高尔夫球车等。还应明白，本发明的可重配置蓄电池可适于在事实上需要使用可再充电蓄电池的任何类型的装置中使用，从而减少给所述蓄电池充电所需的时间。

[0080] 因此，根据本发明，可在系统的操作期间动态地重新配置蓄电池 42（例如经过控制器 50）。举例来说，如图 5a 所示，当电动车辆在驾驶模式时，控制器 50 可将蓄电池单元 52 串联配置，如图 5b 所示当电动车辆在重新充电或再生制动过程中，控制器 50 可将蓄电池单元 52 并联配置。

[0081] 图 6 展示替代实施例，其中主要 PWM 开关（图 5a 和 5b 的开关 59）是不需要的。在此实例实施例中，重新配置开关 57 在 PWM 模式（或替代地 PDM- 脉冲密度调制）中控制。

[0082] 在一些电动自行车设计中，使用一个以上电动机是有利的。举例来说，一个发动机可针对前轮而提供，而一个发动机可针对后轮而提供，从而使驱动扭矩加倍并可在两个轮子提供再生制动。其它可能的配置可能需要更多发动机，也许每一车轮两个。根据本发明，许多电动机可重配置以获得某些优势，类似于上文论述的蓄电池的重新配置。特别在低速时（其中每一个别发动机电压可能太低甚至于不能给单个蓄电池单元充电），重新配置电动机的布置的一个动机将为增加或减少整个发动机电压以帮助再生制动。

[0083] 另一个动机是通过将发动机排成并联来增加发动机的扭矩。当在并联布置中时，更多的电流可流到集合的发动机，就好像车辆在“低速档”。如果蓄电池也重新配置成并联配置，可提供发动机所需的更高电流。因此，通过重新配置并联电动机的配置和并联蓄电池单元的配置，将可以找到发动机的串联 / 并联配置的最佳组合和蓄电池单元的串联 / 并联配置以实现电动车辆的不同情况（不管在驱动模式中还是在再生制动模式中）。

[0084] 因此，本发明还包含重新配置电动车辆的方法和装置，其如下文描述可与可重配置蓄电池的方法和装置结合。

[0085] 在如图 7a 所示的一个实例实施例中，两个或两个以上发动机 46 以第一配置被布置，所述配置适于在驱动过程中提供第一扭矩输出和 / 或在制动过程中提供第一再生电压输出。如图 7b 所示，两个或两个以上电动机 46 可被配置成第二配置，其适于在驱动过程中提供第二扭矩输出和 / 或在制动过程中提供第二再生电压输出。

[0086] 如图 7a 所示的第一配置可包括两个或两个以上并联布置的电动机。如图 7b 所示的第二配置可包括两个或两个以上串联布置的电动机。

[0087] 在一个实例实施例中，可提供用于操作两个或两个以上电动机 46 的蓄电池 42(例如如图 5a、5b、5c 或图 6 所示的蓄电池 42)。蓄电池 42 可包括多个蓄电池单元，且两个或两个以上电动机 46 的第一或第二配置之一可为蓄电池 42 的再生充电而选择。

[0088] 蓄电池 42 可包括多个蓄电池单元 52，其可按第一蓄电池配置（例如，如图 5a 所示）布置，其适于在驱动过程中提供第一蓄电池电压以操作两个或两个以上电动机 46。多个蓄电池单元 52 的至少一部分可被重新配置成第二蓄电池配置（例如，如图 5b 所示），其适于在制动过程中提供第二蓄电池电压，其中第二蓄电池电压低于第一蓄电池电压。当两个或两个以上电动机 46 以第二配置布置且多个蓄电池单元 52 以第二蓄电池配置布置时，蓄电池 42 可接着被充电。

[0089] 在第一蓄电池配置中，多个蓄电池单元 52 可如图 5a 所示串联布置。在第二蓄电池配置中，多个蓄电池单元可如图 5b 所示并联布置。

[0090] 替代地，在第二蓄电池配置中，多个蓄电池单元 52 中的第一部分可并联布置且多个蓄电池单元 52 中的第二部分可串联布置。此外，在第二蓄电池配置中，多个蓄电池单元 52 可与蓄电池单元 52 中的至少第一部分串联布置，蓄电池单元 52 中的第一部分与第二部分并联布置（如图 5c 所示）。

[0091] 发动机 46 的电压（或电流）可被监测（例如通过上文所论述的关于图 5a 和图 5b 的传感器 58 和 49)。根据监测控制所述多个蓄电池单元 52 的配置和两个或两个以上电动机 46 的重新配置中的至少一者（例如通过控制器 50)。可提供用于给控制器 50 和传感器

49 及 58 充电的辅助电源(例如备用蓄电池 56)。

[0092] 此外,制动过程所需的许多制动力和驱动过程所需的许多驱动力中的至少一者可被监测。举例来说,施加的制动力可被电流传感器 49(或被在电动机 46 本身内部提供的电路)监测,并传递到控制器 50。多个蓄电池单元 52 的重新配置和两个或两个以上电动机 46 的重新配置中的至少一者可基于监测而被控制。

[0093] 可提供开关装置 57,使得多个蓄电池单元 52(如上文所论述)可被重新配置。可提供发动机开关装置 62(图 7a、7b 和 8),其使得两个或两个以上电动机 46 可被重新配置。发动机开关装置 62 可连接到电动机 46 中的至少一者。发动机开关装置 62 可包括(例如)脉冲宽度调制开关装置或脉冲密度调制开关装置之一。

[0094] 在一个实例实施例中,两个或两个以上电动机 46 可在电动车辆中提供,其适于再生制动。举例来说,两个或两个以上电动机 46 可在电动自行车、电动小型摩托车、电动汽车、混合动力车辆、电动轮椅、电动高尔夫球车等中提供。

[0095] 在可重配置蓄电池的实施例中,可重配置电动机组合件或其组合(其中单个 PWM 开关(例如开关 59)被使用),控制器 50 可以是 PWM 控制系统,其适于在发动机和蓄电池之间调整 PWM 开关的开 - 关工作周期。电流传感器 49 可用于计算电流流动的平均量。如果发动机 46 和蓄电池 42 之间的电压差太小以致不能维持所需电流量,那么蓄电池 42 或发动机 46 被重新配置以增大在正确方向上的电压差(用于再生制动的更高发动机电压,或用于驱动或加速的更高蓄电池电压)。

[0096] 如上文中所述,还可提供速度控制开关 59,其将包括脉冲宽度调制开关装置。所属领域的技术人员将明白,需要有效开关来实现电动机重新配置,且同样可使用并联 FET 开关代替单个 PWM 开关 59,特别是当需要并联发动机和并联蓄电池组合时。还将明白,只要电流流动被控制,单个 PWM 开关 59 可被可变电阻系统代替。真正的可变电阻器将比 PWM 开关浪费更多的热量,但应提供切实可行的选择。

[0097] 图 8 展示向发动机 46 提供不同驱动扭矩和再生制动的进一步实例实施例,其使用两个 PWM 开关 59 和三个发动机开关装置 62。举例来说,根据图 8 的实施例,在加速过程中可从发动机 46 向电动自行车 40 的后轮施加比向电动自行车 40 的前轮施加的扭矩更大的扭矩,并在制动过程中可从发动机 46 从电动自行车 40 的前轮比从电动自行车 40 的后轮获得更大的再生充电。

[0098] 图 9a 到 9h 说明根据本发明的可变电压可重配置的蓄电池和方法的替代实例实施例。所述图展示蓄电池 202 的单组静态接合的多个串联蓄电池单元 200。静态接合的多个串联蓄电池单元 200 没有额外的电路元件,例如开关,其可断开相邻蓄电池单元的电连接。每一这样一组静态接合的多个串联蓄电池单元 200 被指定为"组"。多组蓄电池单元 200 可以串联或并联连接配置到一起。

[0099] 在图 9a 到 9h 中,展示蓄电池 202 的一组七 (7) 个蓄电池单元 200 以串联配置布置。蓄电池单元被指定为 Bt1 到 Bt7。每一蓄电池单元 200 具有第一电压极 204 和第二电压极 206。图示的每一蓄电池单元 200 的第一电压极 204 具有高于第二电压极 206 的直流 (DC) 电压电位,因此第一电压极 204 被指定为"+"而第二电压极 206 被指定为"-"。第一电压输出连接 210 被指定为 Vout_p,且第二电压输出连接 212 被指定为 Vout_n。第一电压输出连接 210 可用作蓄电池 202 的正极端子,而第二电压输出连接 210 可用作蓄电池 202

的负极端子。至少一个开关装置 208 提供串联的每一蓄电池单元 200 的第一电压极 204 与第一电输出连接 210(被指定为 Vout_p) 之间的电连接。

[0100] 在图中,循序地指定为 SW_p0 到 SW_p6 的开关装置 208 连接每一蓄电池单元的正极到 Vout_p。同样,至少一个开关装置 208 提供串联的每一蓄电池单元 200 的第二电压极 206 到第二电压输出连接 212(被指定为 Vout_n) 的电连接。循序地指定为 SW_n1 到 SW_n7 的开关装置 208 连接每一蓄电池的负极到 Vout_n。此外,至少一个开关装置 208 可将多个串联蓄电池单元 200 的开始处的蓄电池单元 200 的第一电压极 204 电连接到第二电压输出连接 212。

[0101] 指定为 SW_n0 的开关装置 208 连接 BT1 的正极到 Vout_n。至少一个开关装置 208 可将静态接合的多个串联蓄电池单元 200 的末端蓄电池单元 200 的第二电压极 206 电连接到第一电输出连接 210。在图中,指定为 SW_p7 的开关装置 208 将 BT7 的负极连接到 Vout_p。开关装置 208 可例如包含场效应晶体管。在一些实施例中,脉冲宽度调制或脉冲密度调制作为开关装置的部分包括于其中。在其它实施例中,场效应晶体管可在没有脉冲宽度调制或脉冲密度调制的条件下配置。

[0102] 闭合第一电压极 204 与第一电输出连接件 210 之间的开关装置 208,并闭合第二电压极 206 与第二电输出连接件 212 之间的开关装置 208 提供了在电输出连接件处的电压差,并在蓄电池 202 连接到负载(或到蓄电池充电回路)时允许电流流动。在图中,在被指定为 Vout_p 的第一电输出连接 210 和被指定为 Vout_n 的第二电压输出连接 212 之间,输出电压 Vout 的电位是不同的。

[0103] 蓄电池单元 200 经重新配置以向多个串联蓄电池单元 200 提供大约等于电重新配置蓄电池单元的电压总和的输出电压,其在零伏特与最大输出电压之间的范围内。所述电压由所提供单元的数目和技术决定。

[0104] 任何众所周知的蓄电池类型可与发明的结构一起使用。一个此种特别适于和本发明一起使用的蓄电池技术是基于纳米磷酸的锂离子蓄电池技术。所述蓄电池可在不变得不稳定的条件下处置超过现有蓄电池技术一个数量级的电流。可预期在未来开发的其它蓄电池技术也将适于和本文揭示的串联蓄电池实施例一起使用。

[0105] 图 9a 展示所有开关 208 在断开状态以致没有电流流动发生且 Vout = 0 伏特的配置。图 9b 展示一种配置,其中最大电压由一组静态接合的多个串联蓄电池单元 200 实现,其是通过闭合连接第一蓄电池单元 Bt1 的正极与 Vout_p 的开关装置 208(特别是 SW_p0) 且闭合连接最后蓄电池单元 Bt7 的负极与 Vout_n 的开关装置 208(特别是 SW_n7)。Vout 等于在串联 Bt1 到 Bt7 中连接的蓄电池单元的电压和。举例来说,如果每一蓄电池单元 200 是具有 3.6V 额定电压的锂离子技术,对于这个具有七个蓄电池单元的配置,Vout = 25.2 福特减去开关和其它损耗。

[0106] 图 9c 展示一实例配置,其中单个单元电压在静态接合的多个串联蓄电池单元 200 中的输出处实现。单元 Bt1 的电压在输出连接件 Vout_p 和 Vout_n 之间通过闭合开关 SW_p0 和 SW_n1 而实现。

[0107] 图 9d 展示替代实例配置,其中通过将蓄电池单元 Bt2 连接到第一电输出连接件 210 与第二电输出连接件 212,输出电压也大约等于单个单元的电压。单元 Bt2 的电压在输出连接件 Vout_p 与 Vout_n 之间通过闭合开关 SW_p1 和 SW_n2 而实现。

[0108] 图 9e 展示另一替代实例配置，其中输出电压大约等于单个蓄电池单元 Bt7 的电压。蓄电池单元 Bt7 的电压在输出连接件 Vout_p 与 Vout_n 之间通过闭合开关 SW_p6 和 SW_n7 而实现。

[0109] 在如本实施例中描述的任何多个蓄电池单元的串联配置中，存在 N 种实现单个单元电压的方法，其中 N 是蓄电池中单元的数量。

[0110] 图 9f 展示一配置，其中中间电压在串联配置的多个蓄电池单元 200 中的电压输出处实现。在所述实例中，两个蓄电池单元 200 的电压和被实现。明确地说，单元 Bt1 和 Bt2 的电压和在输出连接件 Vout_p 和 Vout_n 之间通过闭合开关 SW_p0 和 SW_n2 而实现。图 9g 和图 9h 展示两个另外的将两个串联蓄电池单元连接到电压输出的替代配置。

[0111] 在串联配置的多个蓄电池单元 200 中，如该典型实施例所描述，有 N-1 种方法实现两个单元电压，其中 N 是蓄电池中单元 200 的数量。

[0112] 在不包含电压极性反转的配置的情况下，对于在所述示范性实施例中描述的任何数目的 N 个静态接合的多个串联蓄电池单元 200，对于具有 P 个电连续蓄电池单元 200 的切换组，有 (N-P)+1 种方法重新配置它们。

[0113] 电压极可通过激活开关装置 208 交替地反转，所述开关装置将连接蓄电池单元 200 的第一电压极 204 到第二电输出连接件 212（而不是将其连接到第一电输出连接件 210），并将第二电压极 206 连接到第一电输出连接件 210。举例来说，在图 9c 所示的实例配置中，闭合开关装置 SW_n0（而不是 SW_p0）和闭合开关装置 SW_p1（而不是 SW_n1）将在电输出连接件 210 和 212 引起极性反转。所述极性反转可有助于发动机激活的制动。

[0114] 有 (N-P)+1 种方法来配置 P 个单元的一个有用结果是允许单元以时间序列的方式保持负载平衡，从而通过改变 P 个电连接单元的组的消耗而维持正常电压。

[0115] 以串联配置连接蓄电池单元 200（在单元之间没有开关装置 208）的一个有用结果是允许开关引起的电压损失保持最低，因为应用电负载时只需激活两个开关装置 208。

[0116] 根据本发明的可重配置蓄电池的另一替代实例实施例和方法在图 10a 到 10c 中展示。这些图展示第一组静态接合的多个串联蓄电池单元 200（指定为 Bt1 到 Bt3），其以串联连接接合到第二组静态接合的多个串联蓄电池单元 200（指定为 Bt4 到 Bt6）。循序指定为 SW_p0 到 SW_p7 的开关装置 208 将蓄电池 Bt1 到 Bt6 连接到 Vout_p。循序指定为 SW_n1 到 SW_n7 的开关装置 208 将蓄电池 Bt1 到 Bt6 连接到 Vout_n。第一中间开关装置 214（指定为 SW_s1）连接于第一组中的末端放置的蓄电池单元（指定为 Bt3）的第二（“-”）电压极 206 与第二组中的开端放置的蓄电池单元（指定为 Bt4）的第一（“+”）电压极 204 之间。第二中间开关装置 216 连接于第一组中的开端放置的蓄电池单元（指定为 Bt1）的第一（“+”）电压极 204 与第二组中的末端放置的蓄电池单元（指定为 Bt6）的第二（“-”）电压极 206 之间。本质上三 (3) 个蓄电池单元 200 的两 (2) 组（被称为组）在实例配置中被配置。两组的第一电输出连接件（被指定为 Vout_p）被共同地连接。同样，两组的第二电输出连接件（被指定为 Vout_n）被共同地连接。需要理解，可以类似配置提供额外的组。

[0117] 在蓄电池单元组之间的开关装置的放置在开关断开时有效地分开两个相邻单元之间的连接性。导致两组蓄电池单元可被独立配置。每一静态接合的多个串联蓄电池单元 200 独立组以在图 9a 到 9h 的实例实施例中描述的方式运行。在开关装置 208 中，第一中间开关装置 214 和第一中间开关装置 216 可以是具有例如脉冲宽度调制或脉冲密度调制的场

效应晶体管。

[0118] 在蓄电池单元将被配置在单个组中的条件下，在第一电压极 204 与第一电输出连接件 210 之间闭合开关装置 208，并在第二电压极 206 与第二电输出连接件 212 之间闭合开关装置 208 显示输出电压。然而，如果连接件需要在处于一组的蓄电池单元 200 与处于另一组的蓄电池单元 200 之间，无论第一中间开关装置 214 还是第二中间开关装置 216 必须闭合以获得在输出连接器 210 与 212 之间的电压。为了防止在串联配置蓄电池 202 中的短路，第一和第二中间开关 214 和 216 不可同时闭合。当第一和第二中间开关 214 和 216 都处在断开状态时，所述两组并联连接。

[0119] 图 10a 展示串联可重配置蓄电池 202 的实例配置，其所有开关装置处于断开状态以使没有电压在输出处出现。中间开关 SW_s1 和 SW_s2 是断开的，以使两组单元处于并联连接。组中的所有开关 208 同样断开以使 Vout 等于零伏特。

[0120] 图 10b 展示一种实例配置，其中两个蓄电池单元 200 在两个组的相反末端，蓄电池单元 Bt1 和 Bt6 通过开关装置 SW_s2 电串联。闭合的开关装置 SW_n1 将蓄电池单元 Bt1 连接到 Vout_n，且闭合的开关装置 SW_p6 将 Bt6 连接到 Vout_p。同时，闭合的第二中间开关装置 SW_s2 配置蓄电池单元 Bt1 和 Bt6 的电压和。

[0121] 图 10c 展示一种配置，其中两个相邻的蓄电池单元 Bt3 和 Bt4（其在每一组中）通过第一中间开关装置 214 而配置。闭合的开关装置 SW_p2 将蓄电池单元 Bt3 连接到 Vout_p，闭合的开关装置 SW_n5 将蓄电池单元 Bt4 连接到 Vout_n，且闭合的第一中间开关装置 SW_s1 配置蓄电池单元 Bt3 和 Bt4 的电压和。

[0122] 本实施例是有用的，因为其准许蓄电池单元 200 之间的串联，其在多个蓄电池单元 200 的相对端而无需电连接，其中单元占据蓄电池单元 200 中间部分。这有助于蓄电池放电负载分布和单元的选择性充电。本实例实施例提供了增加的配置灵活性，而只通过图 9a 到 9h 的实施例的两个开关装置 214 和 216 增加有效开关开销。

[0123] 根据本发明的为串联蓄电池单元 200 重新配置蓄电池 202 的方法的另一替代实例实施例在图 11 中展示。开关装置 208 进一步包含工作周期调制（“DCM”），其是通过在展现第一电压的第一串联蓄电池单元 200 配置与展现第二电压的第二串联蓄电池单元 200 配置之间交替地切换。工作周期调制在第一电压和第二电压之间产生中间输出电压。图 11 中说明的实例配置展示连接到蓄电池 Bt4 的开关装置 SW_n5 的调制，其在断开和闭合状态交替地切换。连接到蓄电池 Bt5 的开关装置 SW_n6 通过在闭合和断开状态之间交替地切换相反地反映开关装置 SW_n5 的周期。因此，输出电压是两个串联的单元 200 与三个串联的单元 200 之间的平均。这在开关循环中导致相对小的电压差。小的电压改变与将在三个串联蓄电池在闭合和断开的状态下切换的条件下发生的显著更大的电压改变形成对比。工作周期调制的结果是对于电压、电流和产生的发动机转矩具有减少的开关瞬变的输出电压的中间控制。

[0124] 模拟数字脉冲迹线 218 和模拟电压迹线 220 在图 11 中展示。模拟数字脉冲迹线 218 演示开关 SW_n5 和 SW_n6 的交替的开和关状态的时序。模拟电压迹线 220 展示相应的作为时间的函数的输出电压 Vout。对于此实例实施例，开关装置 SW_n6 的开状态工作周期是开关装置 SW_n5 的四分之一。因此，在所有蓄电池单元 200 电压相等的条件下，所述实例实施例的平均输出电压等于 3/4（伏特 (BT3)+ 伏特 (BT5)）+1/4（伏特 (BT3)+ 伏特 (BT5)+

伏特(BT6))＝2.25伏特(BT)。为了对比而展示使用全电压开－关脉冲宽度调制222的说明性电压迹线。注意在没有可变电压蓄电池的条件下在开关状态之间的更大电压摆动,如在模拟迹线222中所展示。

[0125] 至少一个电容滤波器224(如在图12中所展示)可添加到上述实施例以使输出电压平滑。在本发明的实例实施例中,单个电容器224横跨输出电压连接件210和212而被放置。电容器使用如前述实施例所描述的工作周期调制连接到电路中。模拟数字脉冲迹线226和模拟电压迹线228演示通过将滤波器添加到本发明的可变电压蓄电池(“VVB”)而产生的平滑波形。根据本实施例使用的开关类型、开关方法、波形滤波器,切换速度可被减少,从而可能导致能量节省。感应滤波可代替(或一起使用)电容滤波,例如通过在蓄电池和负载间提供串联电感。一个说明性电压迹线229说明(用于对比)其中本发明的可变电压蓄电池未被使用的实例。注意,在没有可变电压蓄电池的条件下在开关状态之间的更大的电压摆动,如在模拟迹线229中所展示。

[0126] 前述实施例可包含电压监测器230和电流检测器232,其如在图13中的可重配置串联的多个蓄电池单元的实例实施例中展示。电压和电流监测系统和本文中描述的结合开关装置208的方法,允许蓄电池单元200充放电状态的识别和状态监测。

[0127] 至少和一个电动机226一起使用的在前述实施例中描述的可重配置蓄电池202允许根据串联配置的单元数量通过调节蓄电池输出电压控制发动机速度。同样,蓄电池单元200再充电方案可通过替代地配置串联蓄电池单元200的数量和相对位置而定制,其在再生制动或充电过程中与发动机226输出电压匹配。

[0128] 图14展示蓄电池重新配置控制系统,其可与车辆系统(例如发动机226)交互且可与用户228沟通以控制开关208的重新配置,从而(如果必须重新获得电流处理能力)绕开差的或废的蓄电池单元200、短路将废的单元并平衡蓄电池单元200的使用。电子处理器218(例如具有相关主要和次要存储器220和222的微处理器、电压230和电流232传感器,和相关软件)可保持充电/放电历史以帮助调节蓄电池单元寿命并在充电和放电状态中提供负载平衡。还可包含蓄电池单元200温度监测,因为蓄电池工作周期以温度的函数变化。所述温度监测特别适用于充电和放电控制,同样适用于有故障单元的诊断。控制信号可在传感器230和232、蓄电池202、发动机226和处理器218之间交换,其使用专用的通讯路径224或通过电源连接件210和212。

[0129] 给蓄电池重新配置控制系统断电和重新加电需要遵循预定的协议。例如,断电在可重配置蓄电池202变得放电,且需要所有开关装置208和214和216在图9a和10a中的不活动状态(断开)中被放置时发生。给系统重新充电随着处理器218(也许是微处理器)的激活开始,接着获得配置设定、蓄电池单元状态、来自存储器220和222的过去的历史和异常状态。如果充电周期开始了,那么控制逻辑分析从存储器220和222接收的信息,并配置开关装置208以最有效地完成任务。

[0130] 注意,测量平均电流流动可能花费时间,其可能导致不良的延迟量。一个可代替的选择是计算预期的电流流动,从而阻力或脉冲宽度调制工作周期可与蓄电池、发动机或两者的重新配置同步而调整。

[0131] 现应理解,本发明提供用于重新配置具有多个蓄电池单元的蓄电池、重新配置电动机组合件,或其组合的有利方法和设备。

[0132] 根据本发明,当完整的电流输出需要在串联路径内部没有中间开关的条件下保持蓄电池单元串联时,可避免电位损失。通过分接串联蓄电池的不同点,电压输出可在只引起两个开关损失的情况下变化。蓄电池的输出电压甚至可被设定为零,且如果需要(例如紧急制动),蓄电池的电压极性可被反转。如果所有的串联蓄电池单元被使用(例如一侧的底部开关和另一侧的顶部开关闭合),那么达到最大电压。如果少于整个单元数量的单元被使用,电压将会更低。根据本发明的蓄电池结构,具有针对同样(更低的)电压输出的许多开关闭合的不同组合。当保持恒定的电压输出时,这些组合可以时序的方式被选择以使单元的消耗均等而不使任何一个单元消耗太多。

[0133] 本发明的可变电压蓄电池的一个关键益处是允许蓄电池驱动车辆的速度控制和再生制动易于实现。这是由于当驾驶和达到再生制动的电压输出时蓄电池电压适应发动机需要的事实。举例来说,用于设定蓄电池电压的两个开关之一可被调整(例如使用脉冲宽度调制)以提供发动机速度控制。替代地,可在两个电压输出值之间调整,从而实现发动机平均蓄电池电压输出的更好控制。在全或无式脉冲宽度调制速度控制中,当开关断开时,发动机的电压立即从其最大值变为零。在此种情形中,当发动机和蓄电池分离时将有一个大的电压尖锋,这是因为发动机中的磁场必须塌缩。根据两个电压之间揭示的更好电压控制,因为电路仍然与蓄电池在一起闭合,因此有更少的瞬变。

[0134] 蓄电池的配置和开关调整的切换可以很高的频率发生,例如以 KHz 甚至 MHz 的频率(在开关(例如功率场效应管)迅速断开和闭合时)。然而,较低的切换频率可能节省一点电力,这是因为随着切换频率增加,场效应晶体管需要更多的电流。因此,在切换速度和能量需求之间存在折衷。

[0135] 此外,根据本发明,在切换操作过程中的电压波动可以像一个蓄电池单元电压那么小(例如相较于在常规小型电动车辆(例如自行车)中使用的蓄电池组的 48V 的锂离子蓄电池单元的 3.6V),切换瞬变可同时在电压、电流和转矩中更小。如果由普通蓄电池驱动的发动机使用脉冲宽度调制控制,那么由于发动机的感应性质,每当脉冲宽度调制开关断开,通常将有大的电压尖峰。事实上,当开关断开时,因为电感试图保持电流流动,大的电压可在其间形成,从而引起火花。根据本发明,可变电压蓄电池的提供防止电路完全断开。蓄电池仅仅从一个电压变到另一个,且蓄电池的一部分始终连接到发动机。除了当电压必须缓降到零时,这始终提供了连续的电流路径。根据本发明的可变电压蓄电池,即使当电压斜变到零,电流路径仍可通过适当地重新配置蓄电池而提供。因此,同时对于驱动和再生制动,本发明的基于可变电压蓄电池的操作更加温和。如上文所述,在没有使用可变电压蓄电池的情况下添加滤波电容器在某种程度上是有用的,但是针对给定尺寸的电容器使用本发明的可变电压蓄电池导致更好的性能。

[0136] 本发明还使用反相器(例如直流到直流转换器)在设计上提供重要的优势,因为在再生制动模式中,当试图对蓄电池再充电时,此些反相器遭受显著切换损耗且引起复杂性。

[0137] 本发明的配置还可以“绕开”(例如绕过)废的或弱的蓄电池单元以使整个蓄电池不由于单个坏单元而遭受故障。并联坏单元也可被绕过且蓄电池组仍将正常运作,只是最大电压减小。可使用算法寻找出弱的或坏的单元,其在再放电时不保持合理的电压或电流或在再充电时出现不良情况。如所属领域的技术人员将明白,此种特征将需要电流和电压

传感器和适当的控制器。可根据本发明而提供另一算法，其提供负载平衡以保持所有的蓄电池单元在再充电或再生制动过程中被均匀地充电。

[0138] 应进一步理解，描述包含多个蓄电池单元的实例实施例同样可在不背离本发明范围的条件下解释成多个蓄电池组或多个蓄电池。举例来说，本文中描述的每一蓄电池单元可由串联或并联连接的两个或两个以上蓄电池单元组成。

[0139] 尽管已结合各种所说明的实施例而描述本发明，但可对其进行许多修改或改变而不背离如在权利要求书中阐述的本发明的精神和范围。

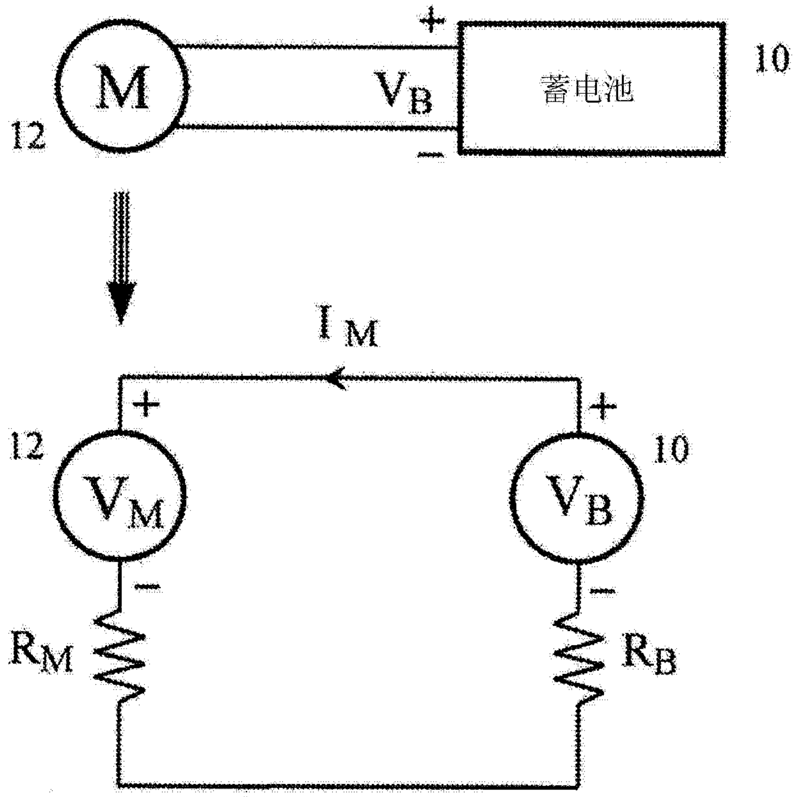


图 1（现有技术）

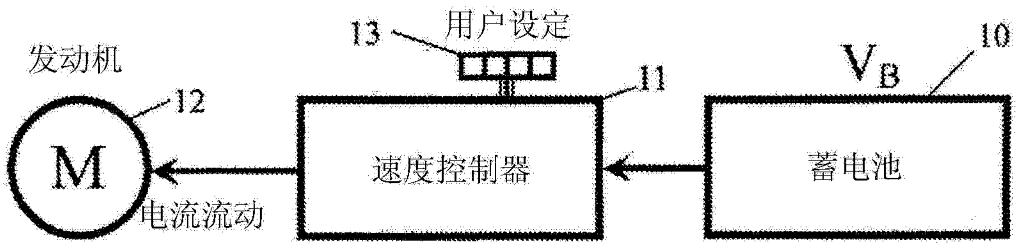


图 2（现有技术）

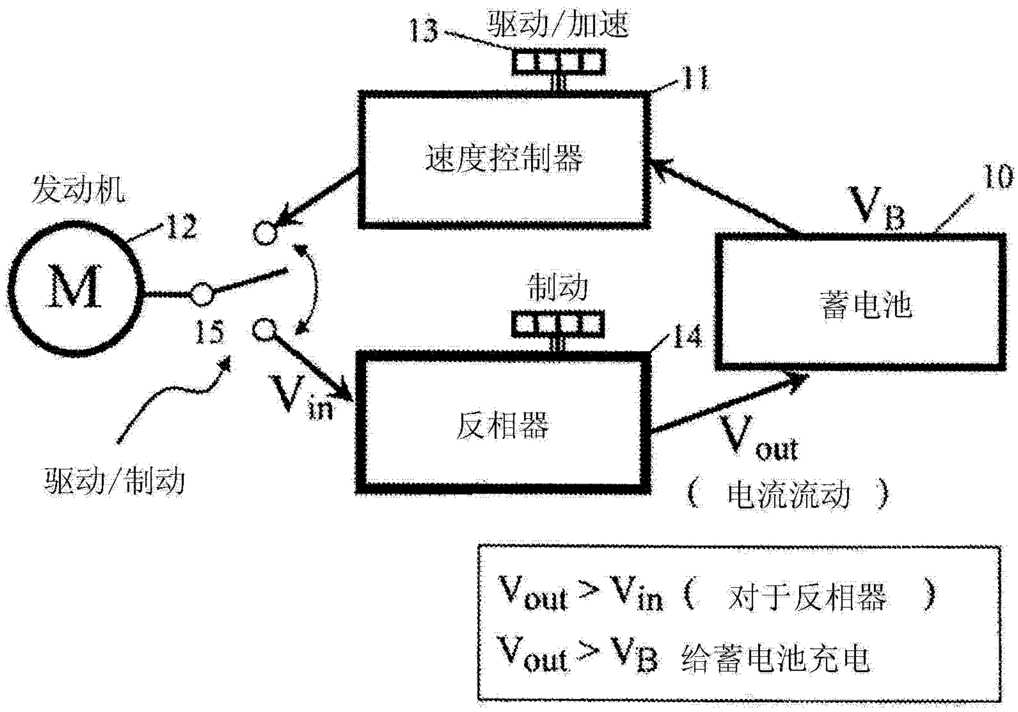

13
驱动/加速
11
速度控制器
发动机
12
M
10
V_B
蓄电池
制动
14
15
V_{in}
反相器
V_{out}
（ 电流流动 ）
驱动/制动
$V_{out} > V_{in}$ （ 对于反相器 ）
$V_{out} > V_B$ 给蓄电池充电

图 3（现有技术）

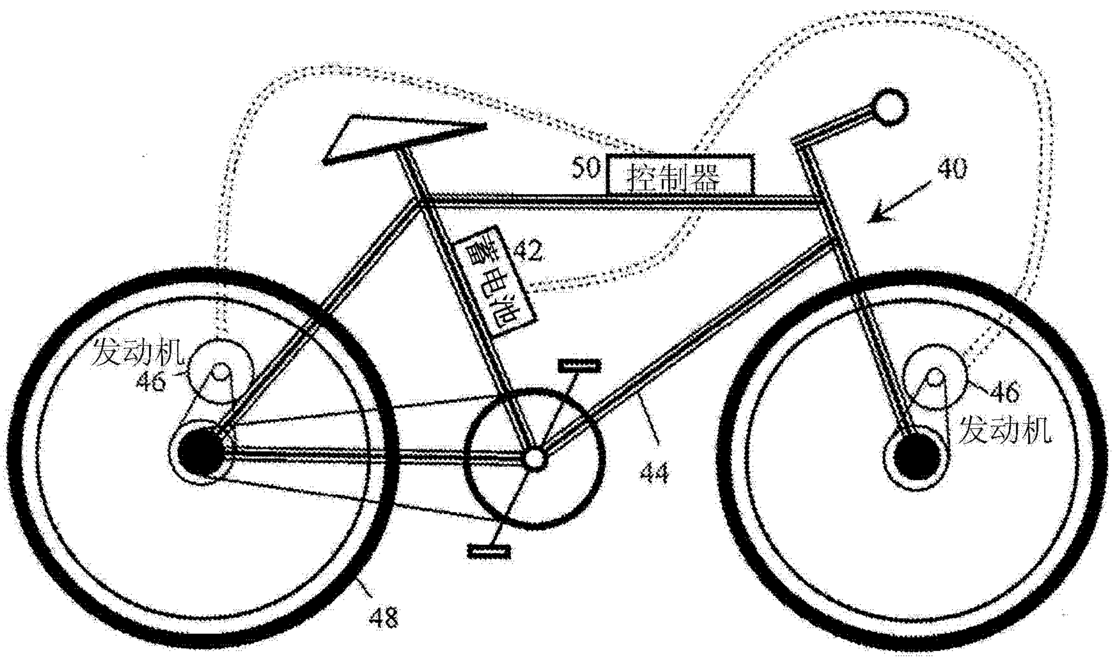

50
控制器
40
蓄电池
42
发动机
46
46
发动机
44
48

图 4

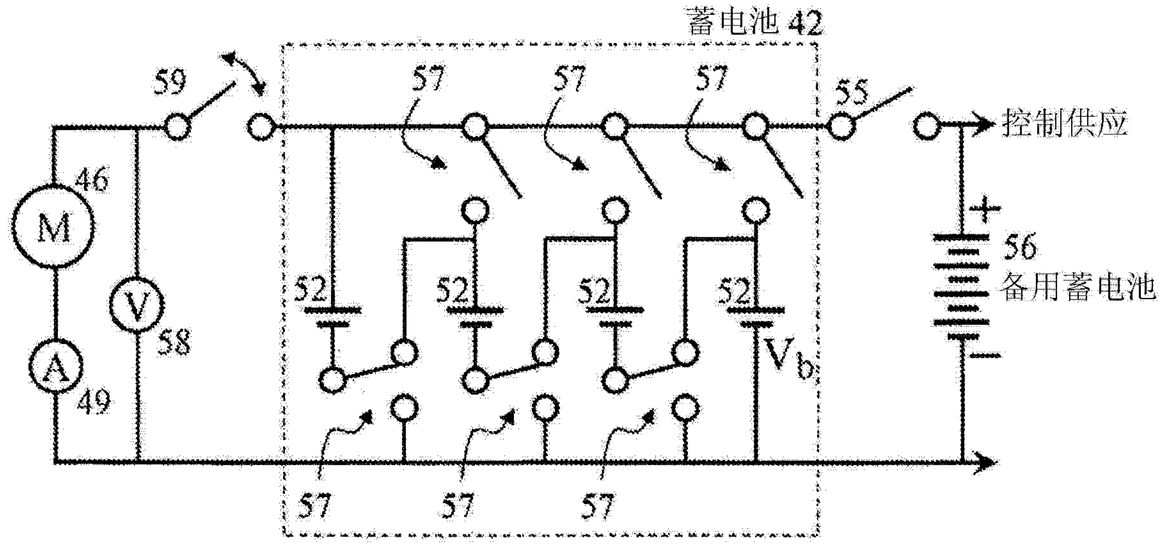


图 5a 驱动模式（串联单元）

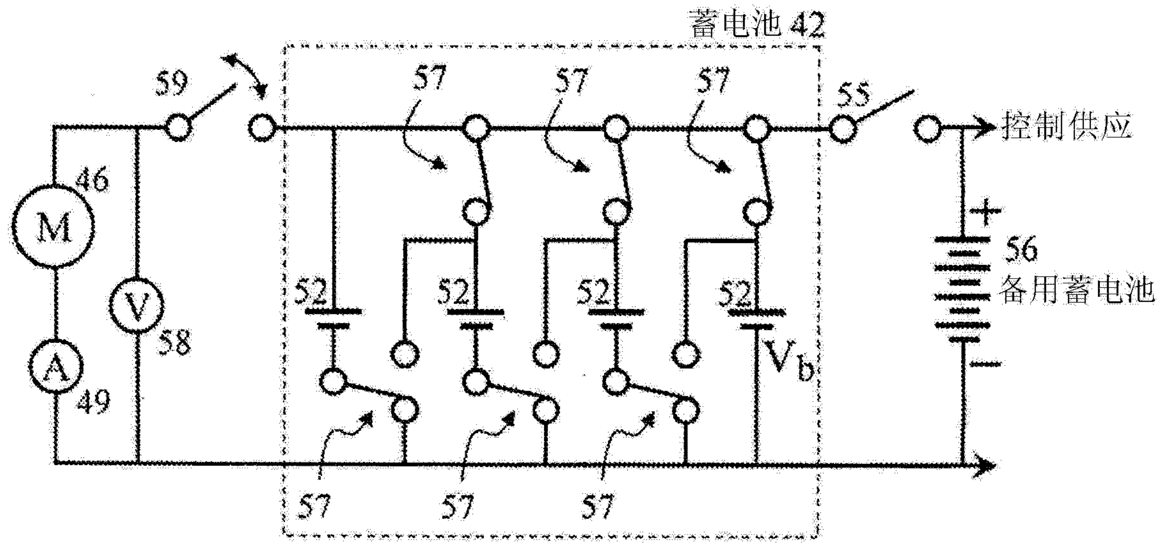


图 5b 再生模式（并联单元）

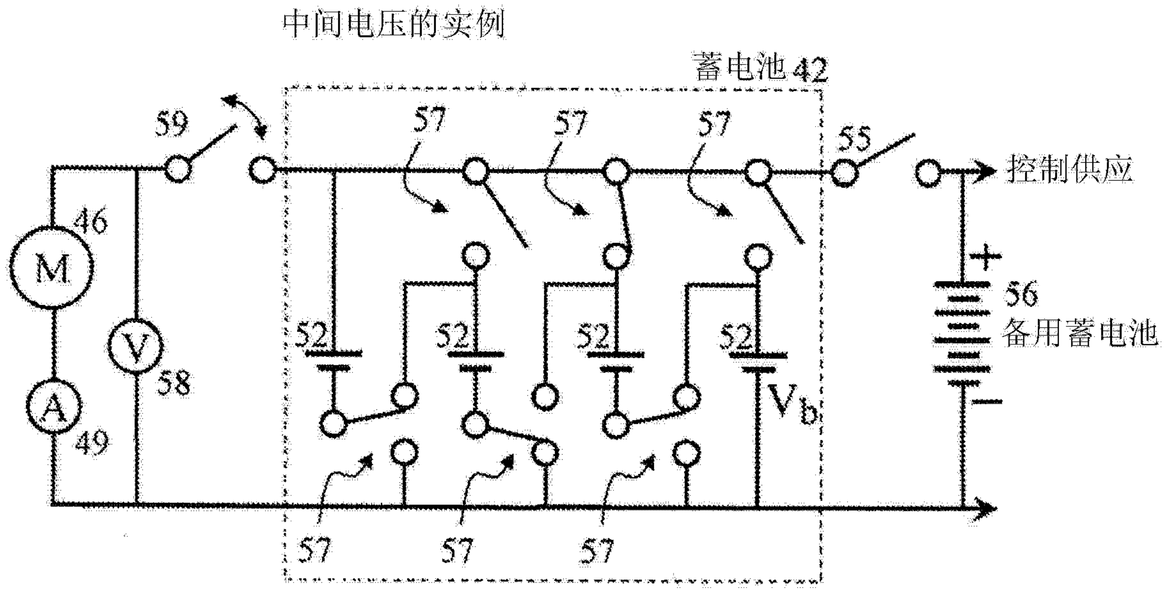

中间电压的实例
蓄电池 42
59
57
57
57
55
控制供应
46
M
V
58
A
49
52
52
52
52
Vb
+
56
备用蓄电池
−
57
57
57

图 5c

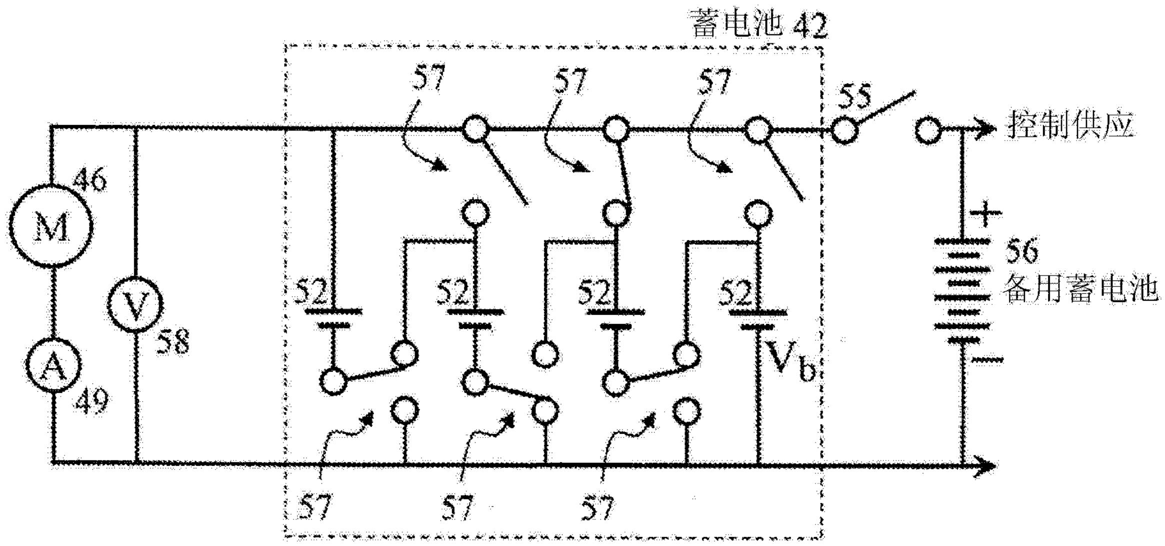

蓄电池 42
57
57
57
55
控制供应
46
M
V
58
A
49
52
52
52
52
Vb
+
56
备用蓄电池
−
57
57
57

图 6

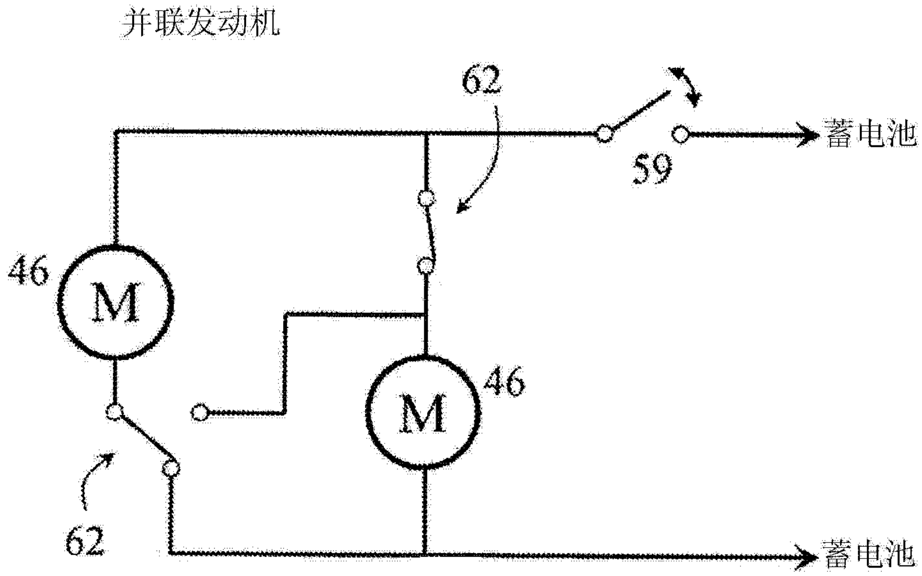


图 7a

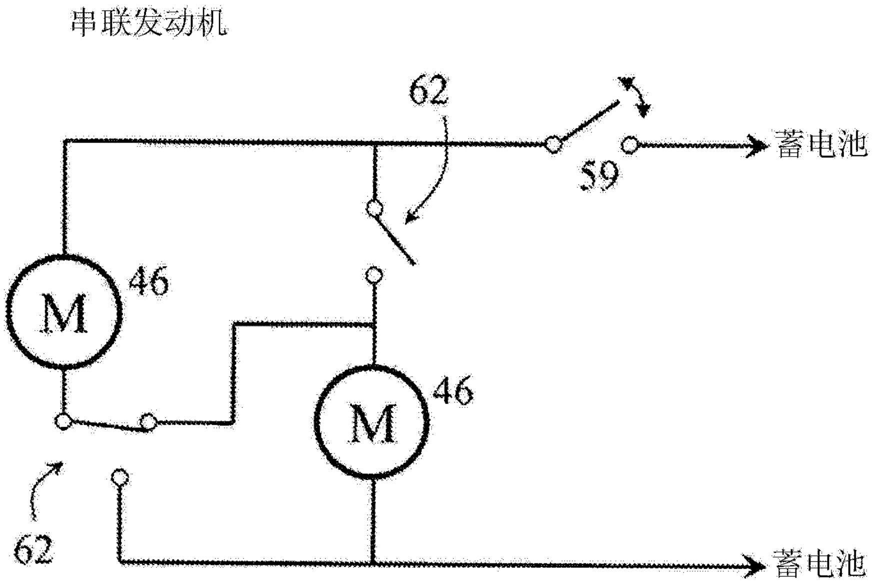


图 7b

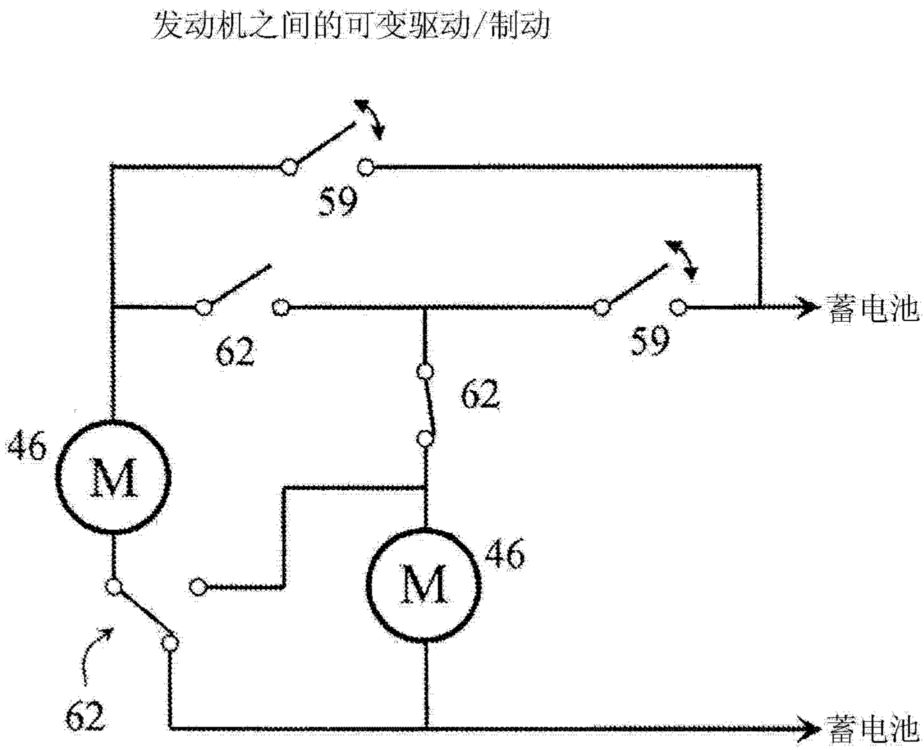


图 8

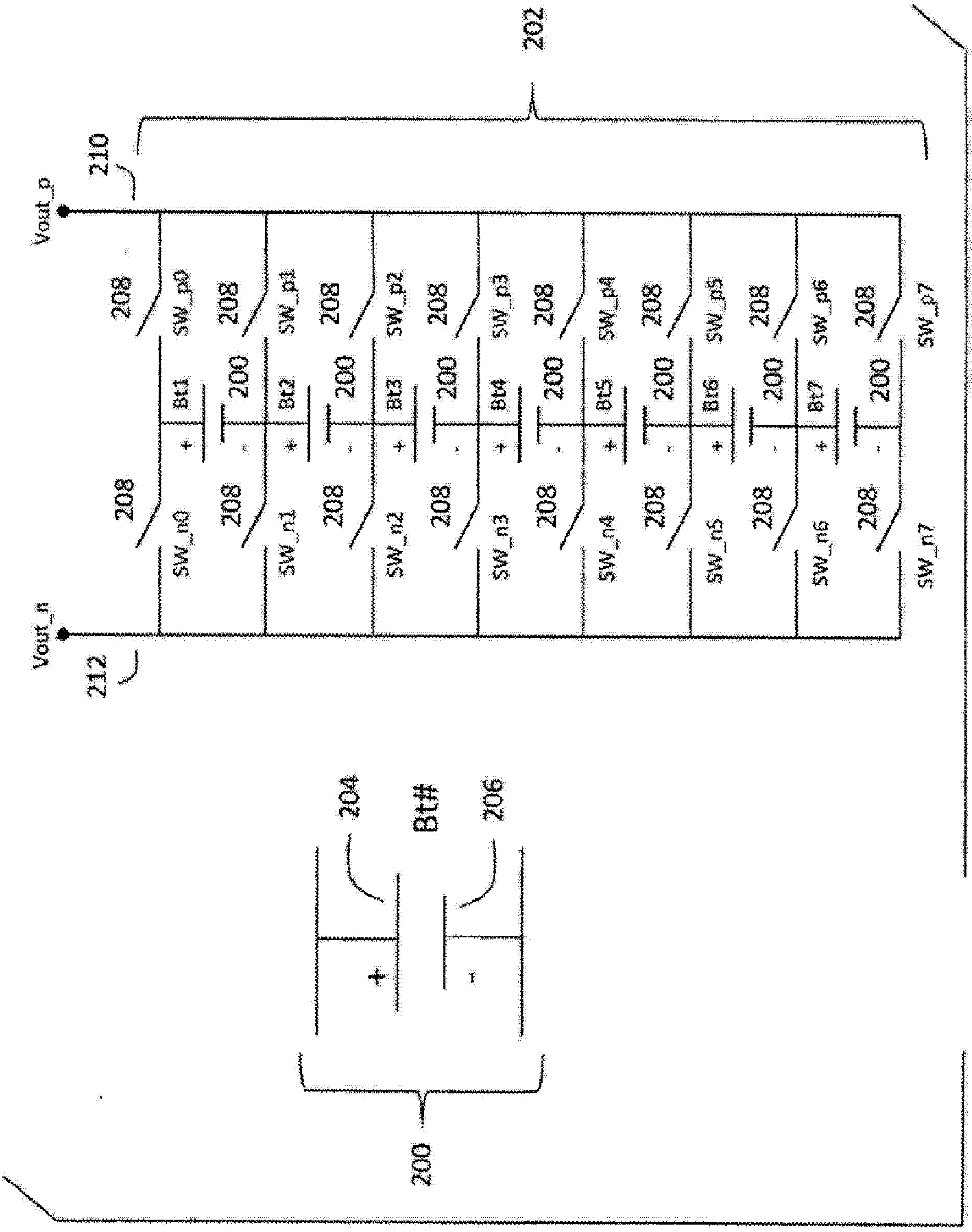

202
210
Vout_p
Vout_n
212
208
SW_p0
SW_p1
SW_p2
SW_p3
SW_p4
SW_p5
SW_p6
SW_p7
Bt1
Bt2
Bt3
Bt4
Bt5
Bt6
Bt7
200
SW_n0
SW_n1
SW_n2
SW_n3
SW_n4
SW_n5
SW_n6
SW_n7
204
Bt#
206
+
-
200

图 9a

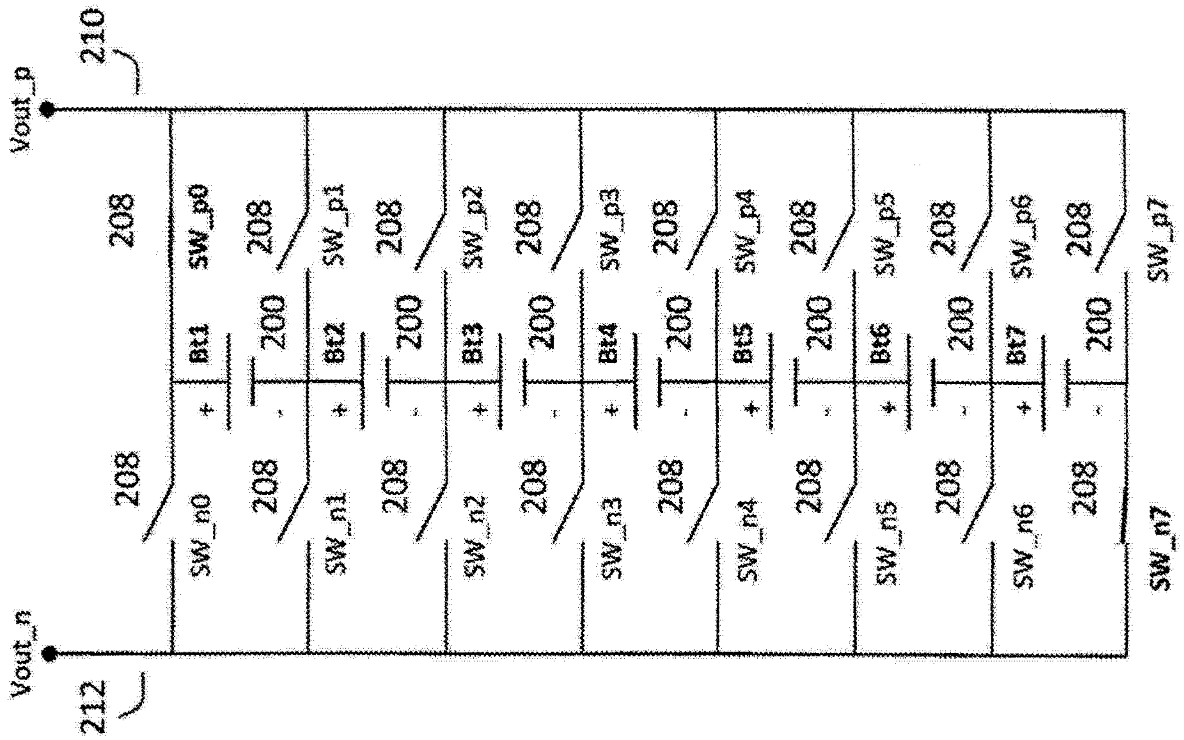

Vout_p
210
Vout_n
212
208
SW_p0
SW_p1
SW_p2
SW_p3
SW_p4
SW_p5
SW_p6
SW_p7
Bt1
Bt2
Bt3
Bt4
Bt5
Bt6
Bt7
200
SW_n0
SW_n1
SW_n2
SW_n3
SW_n4
SW_n5
SW_n6
SW_n7

图 9b

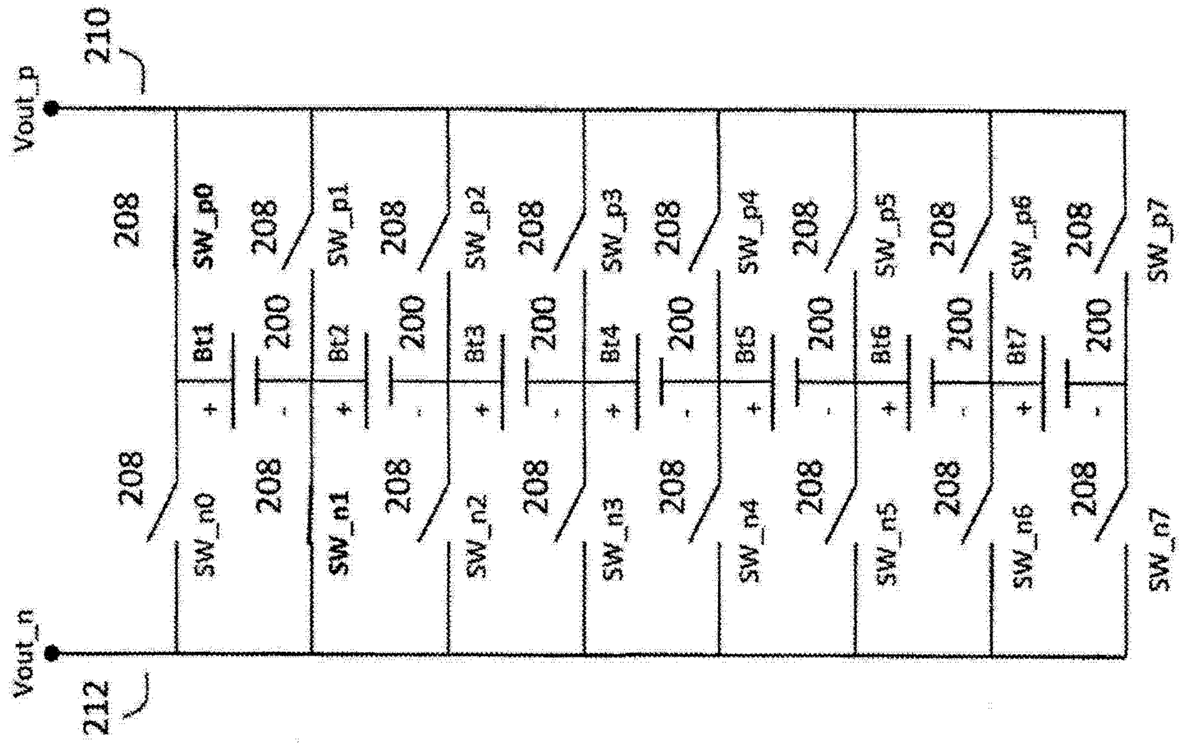

Vout_p
210
Vout_n
212
208
SW_p0
SW_p1
SW_p2
SW_p3
SW_p4
SW_p5
SW_p6
SW_p7
Bt1
Bt2
Bt3
Bt4
Bt5
Bt6
Bt7
200
SW_n0
SW_n1
SW_n2
SW_n3
SW_n4
SW_n5
SW_n6
SW_n7

图 9c

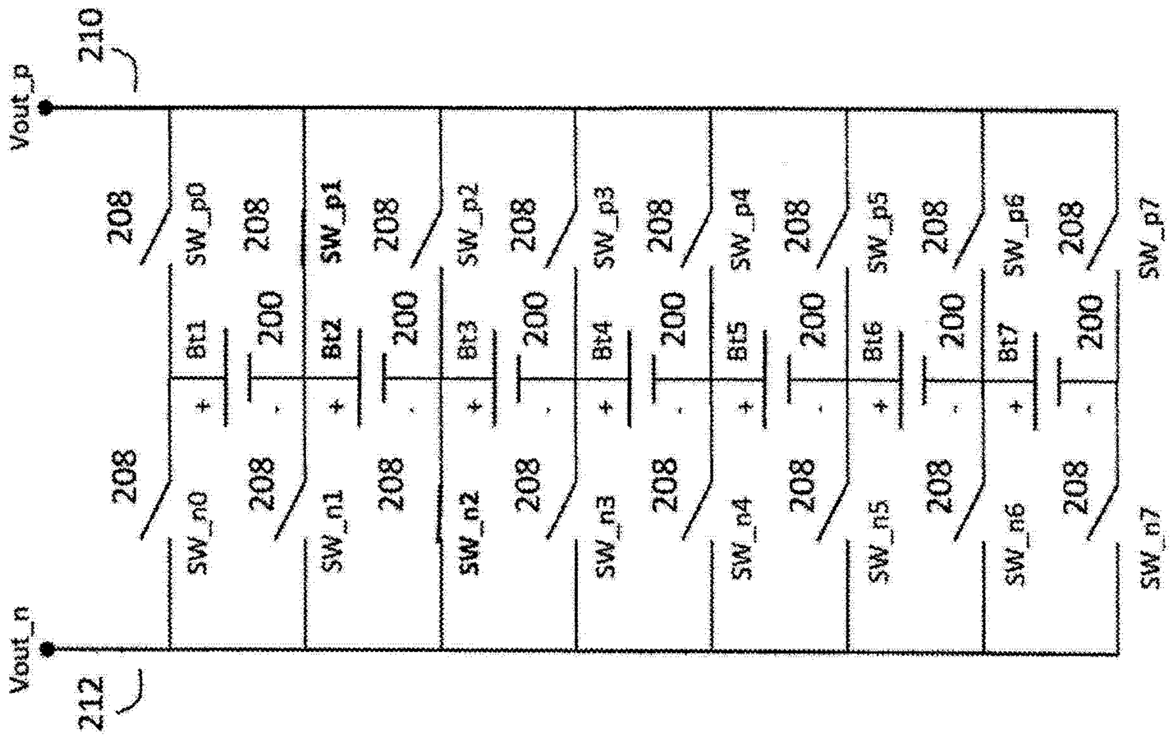

210
Vout_p
Vout_n
212
208
SW_p0
SW_p1
SW_p2
SW_p3
SW_p4
SW_p5
SW_p6
SW_p7
SW_n0
SW_n1
SW_n2
SW_n3
SW_n4
SW_n5
SW_n6
SW_n7
Bt1
Bt2
Bt3
Bt4
Bt5
Bt6
Bt7
200
+
-

图 9d

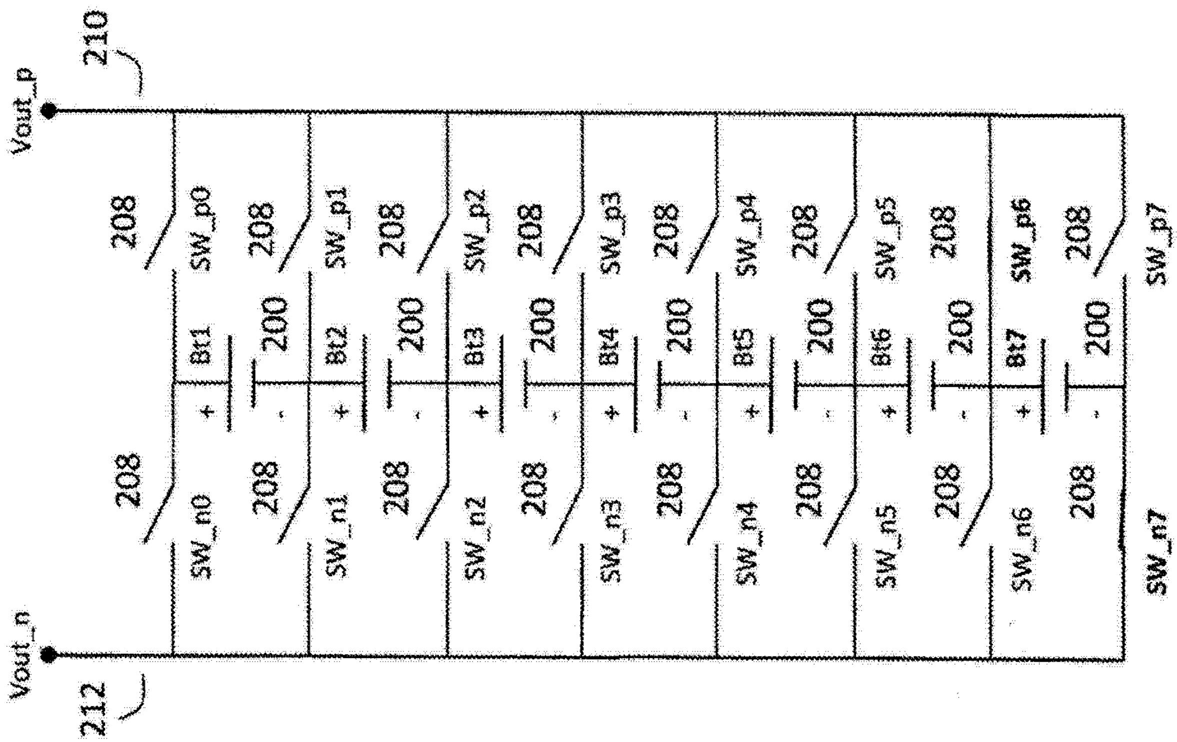

210
Vout_p
Vout_n
212
208
SW_p0
SW_p1
SW_p2
SW_p3
SW_p4
SW_p5
SW_p6
SW_p7
SW_n0
SW_n1
SW_n2
SW_n3
SW_n4
SW_n5
SW_n6
SW_n7
Bt1
Bt2
Bt3
Bt4
Bt5
Bt6
Bt7
200
+
-

图 9e

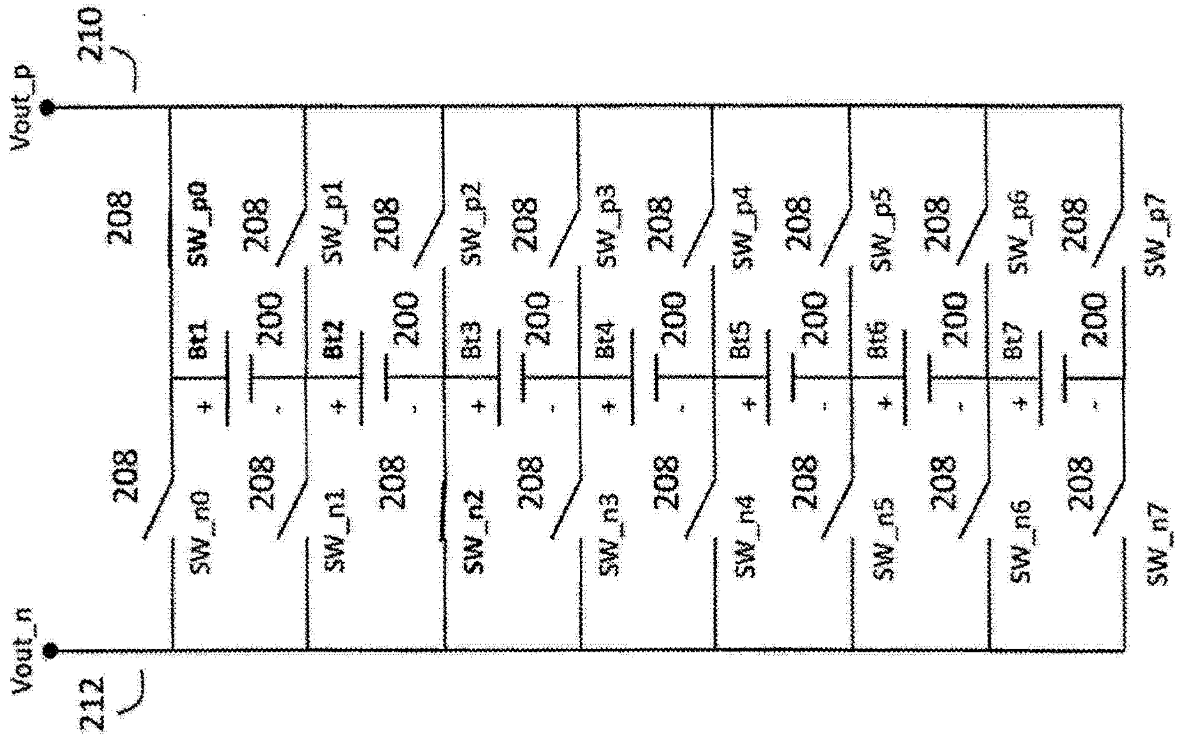

210
Vout_p
Vout_n
212
208
200
SW_p0
SW_p1
SW_p2
SW_p3
SW_p4
SW_p5
SW_p6
SW_p7
Bt1
Bt2
Bt3
Bt4
Bt5
Bt6
Bt7
SW_n0
SW_n1
SW_n2
SW_n3
SW_n4
SW_n5
SW_n6
SW_n7

图 9f

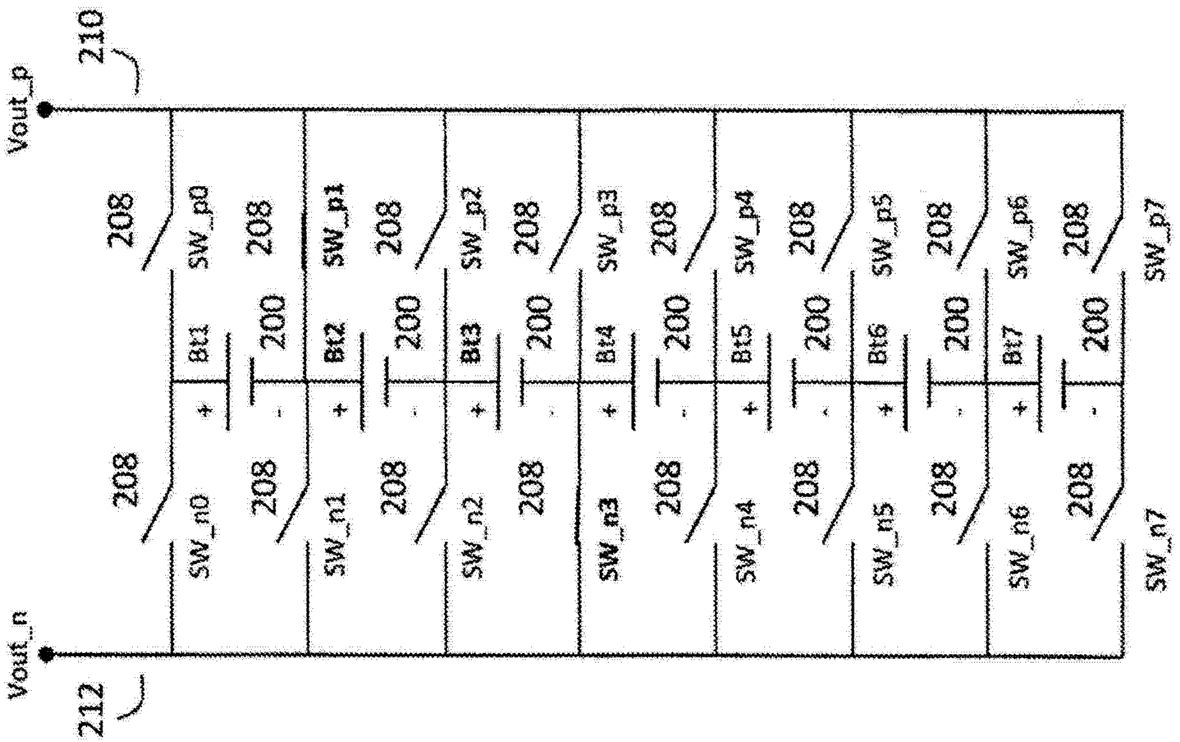

210
Vout_p
Vout_n
212
208
200
SW_p0
SW_p1
SW_p2
SW_p3
SW_p4
SW_p5
SW_p6
SW_p7
Bt1
Bt2
Bt3
Bt4
Bt5
Bt6
Bt7
SW_n0
SW_n1
SW_n2
SW_n3
SW_n4
SW_n5
SW_n6
SW_n7

图 9g

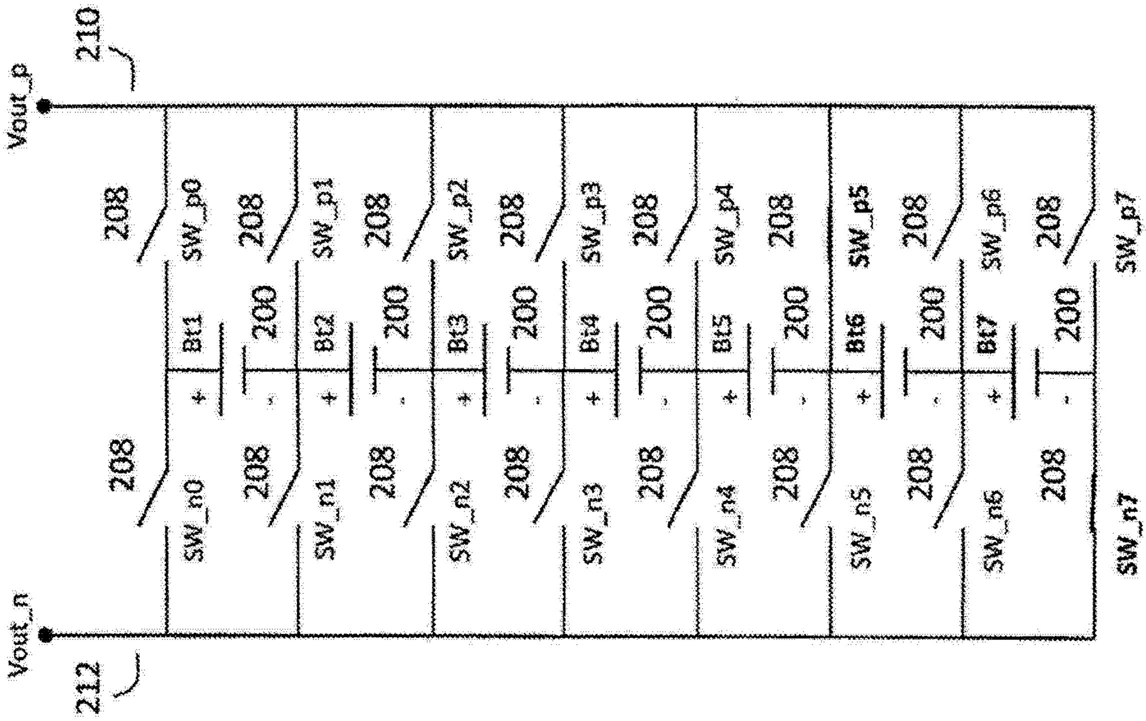

210
Vout_p
208
SW_p0
SW_p1
SW_p2
SW_p3
SW_p4
SW_p5
SW_p6
SW_p7
200
Bt1
Bt2
Bt3
Bt4
Bt5
Bt6
Bt7
SW_n0
SW_n1
SW_n2
SW_n3
SW_n4
SW_n5
SW_n6
SW_n7
Vout_n
212

图 9h

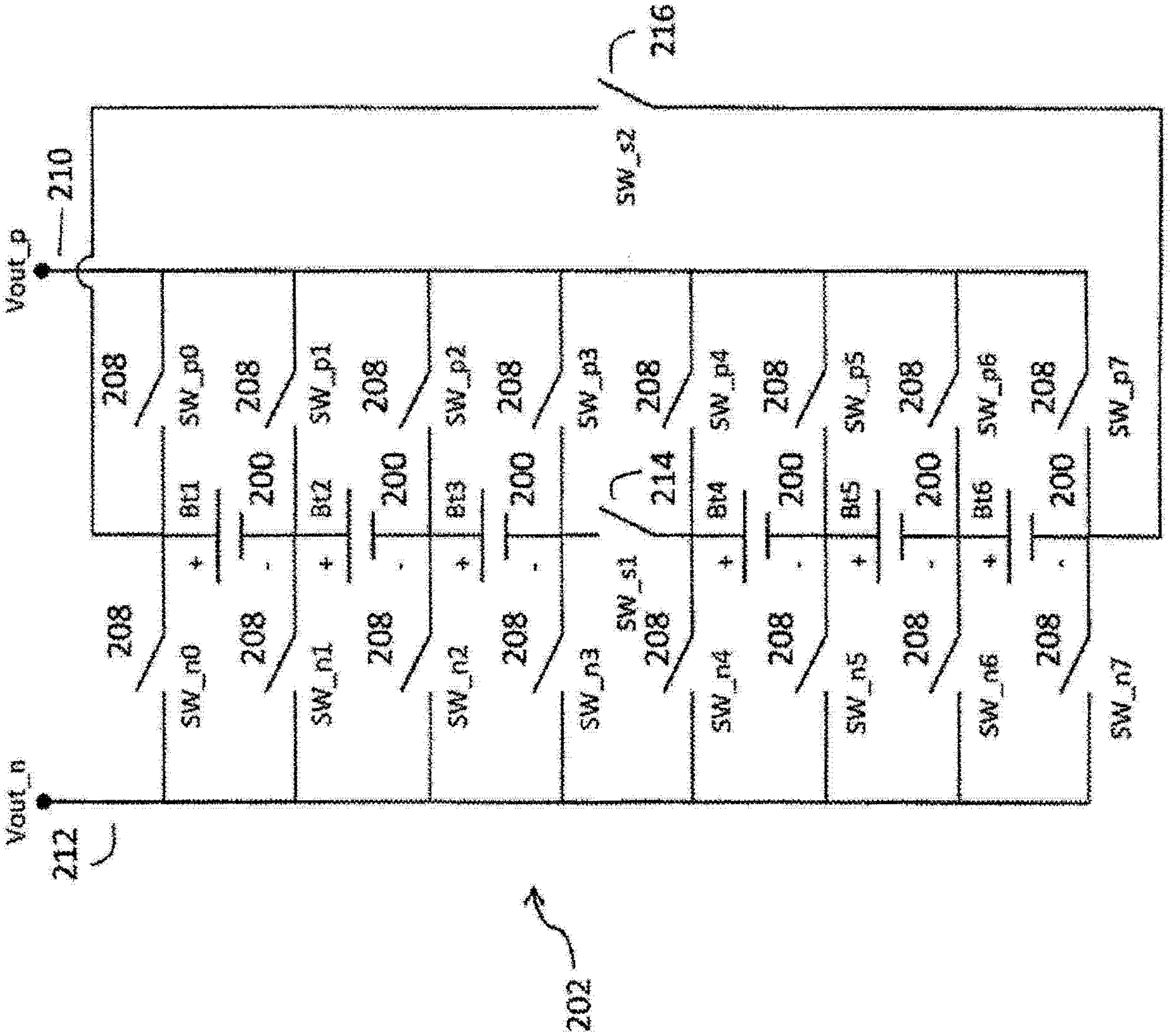

216
SW_s2
210
Vout_p
208
SW_p0
SW_p1
SW_p2
SW_p3
SW_p4
SW_p5
SW_p6
SW_p7
Bt1
Bt2
Bt3
Bt4
Bt5
Bt6
200
214
SW_s1
+
-
SW_n0
SW_n1
SW_n2
SW_n3
SW_n4
SW_n5
SW_n6
SW_n7
Vout_n
212
202

图 10a

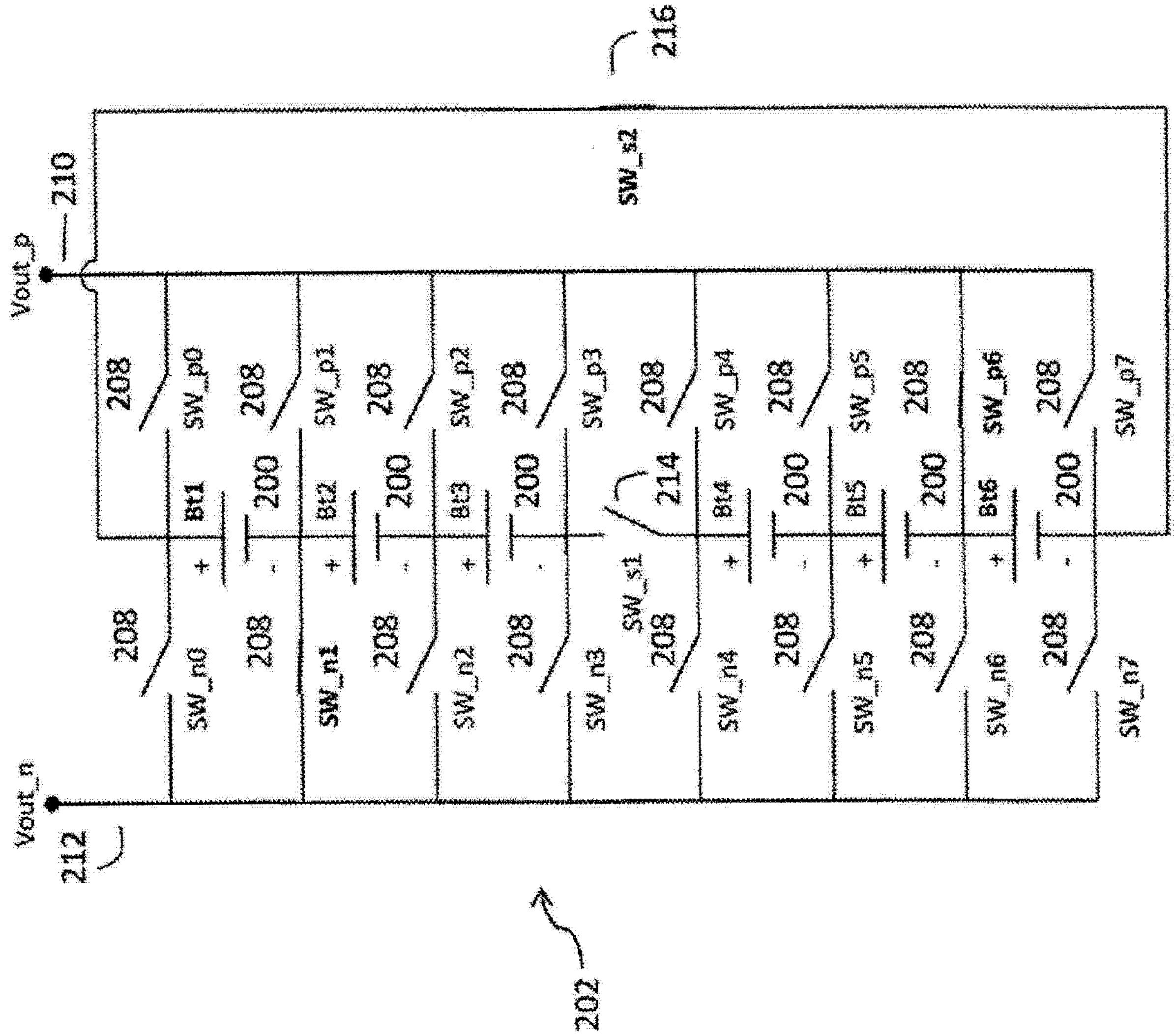

216
SW_s2
210
Vout_p
208
SW_p0
SW_p1
SW_p2
SW_p3
SW_p4
SW_p5
SW_p6
SW_p7
Bt1
Bt2
Bt3
Bt4
Bt5
Bt6
200
214
SW_s1
SW_n0
SW_n1
SW_n2
SW_n3
SW_n4
SW_n5
SW_n6
SW_n7
Vout_n
212
202

图 10b

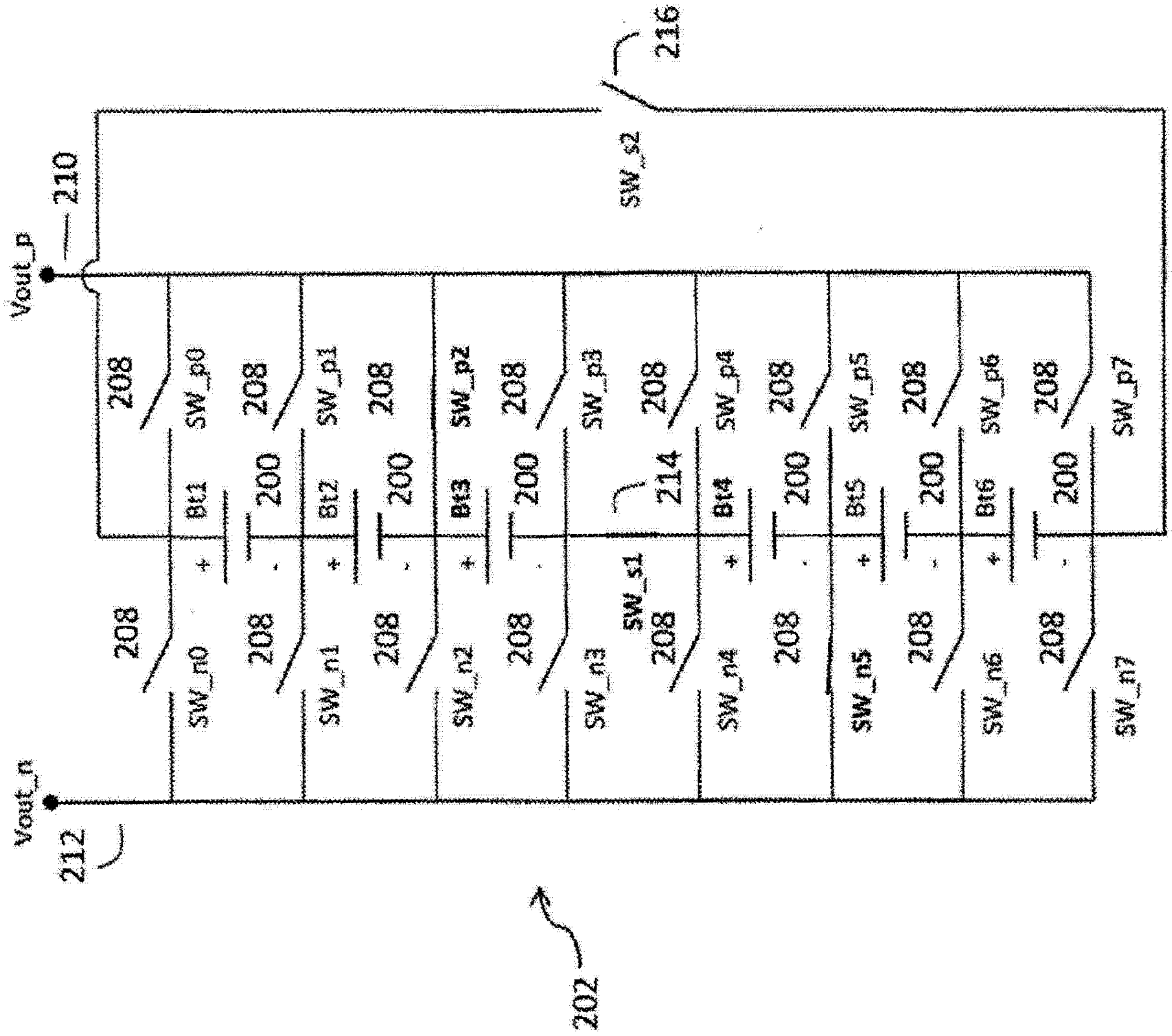

216
SW_s2
210
Vout_p
208
SW_p0
SW_p1
SW_p2
SW_p3
SW_p4
SW_p5
SW_p6
SW_p7
Bt1
Bt2
Bt3
Bt4
Bt5
Bt6
200
214
SW_s1
SW_n0
SW_n1
SW_n2
SW_n3
SW_n4
SW_n5
SW_n6
SW_n7
Vout_n
212
202

图 10c

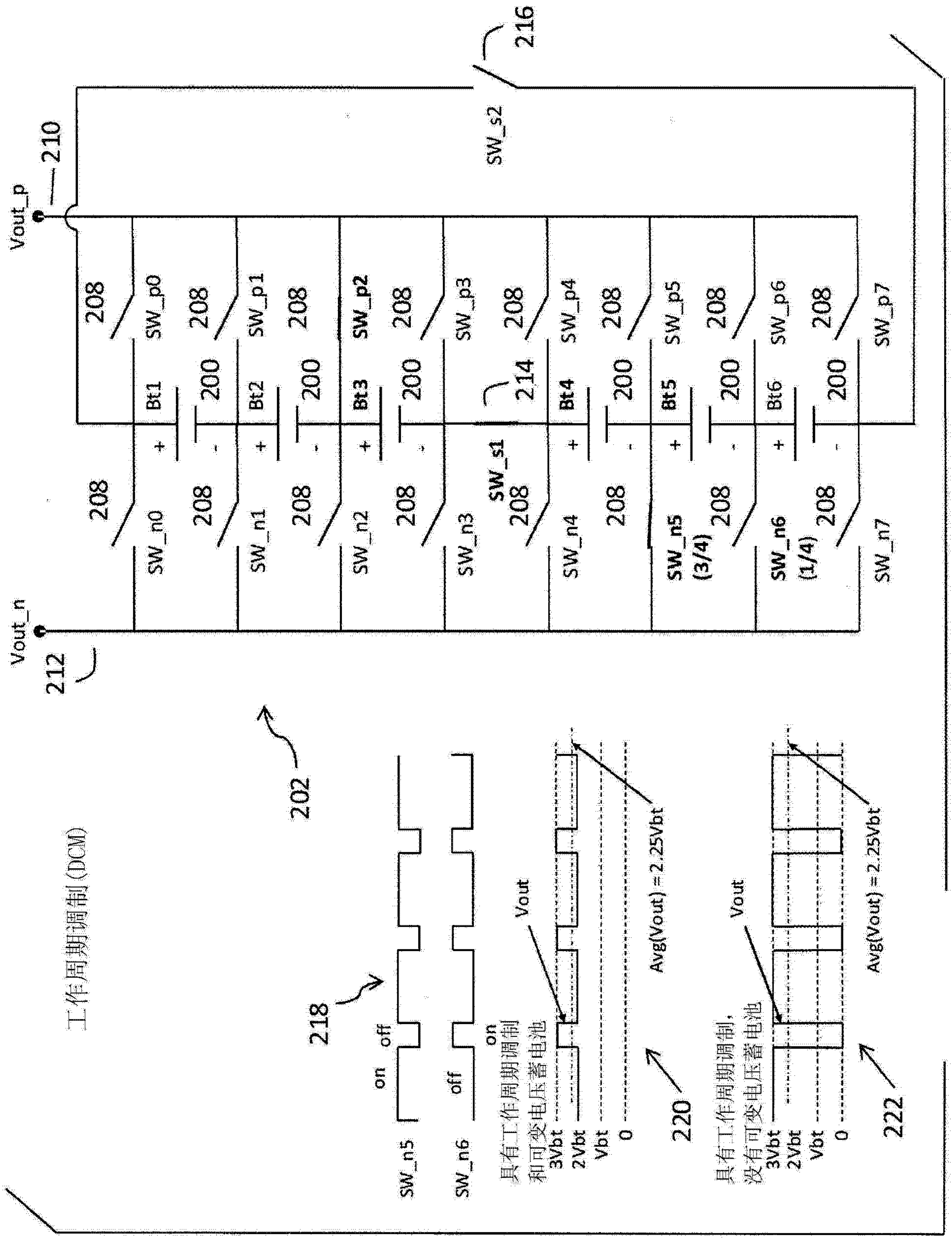

216
SW_s2
210
Vout_p
Vout_n
212
208
SW_p0
SW_p1
SW_p2
SW_p3
SW_p4
SW_p5
SW_p6
SW_p7
Bt1
Bt2
Bt3
Bt4
Bt5
Bt6
200
214
SW_s1
SW_n0
SW_n1
SW_n2
SW_n3
SW_n4
SW_n5 (3/4)
SW_n6 (1/4)
SW_n7
202
工作周期调制(DCM)
218
SW_n5
SW_n6
on
off
具有工作周期调制和可变电压蓄电池
3Vbt
2Vbt
Vbt
0
Vout
Avg(Vout) = 2.25Vbt
220
具有工作周期调制，没有可变电压蓄电池
222

图 11

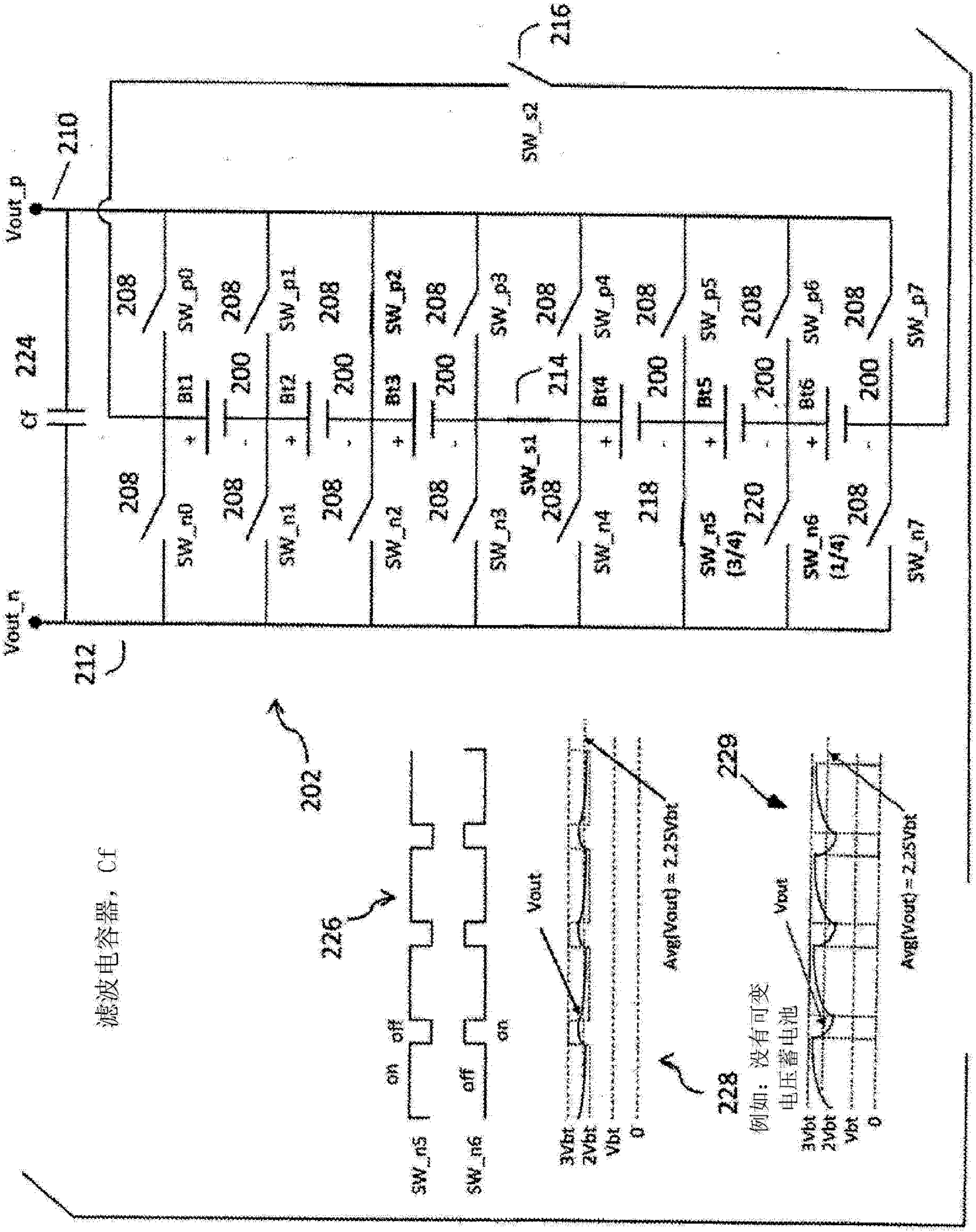

Vout_p
210
216
SW_s2
224
Cf
Vout_n
212
208
SW_p0
SW_p1
SW_p2
SW_p3
SW_p4
SW_p5
SW_p6
SW_p7
Bt1
Bt2
Bt3
Bt4
Bt5
Bt6
200
214
SW_s1
218
220
SW_n0
SW_n1
SW_n2
SW_n3
SW_n4
SW_n5 (3/4)
SW_n6 (1/4)
SW_n7
202
滤波电容器，Cf
226
on
off
SW_n5
SW_n6
Vout
Avg(Vout) = 2.25Vbt
3Vbt
2Vbt
Vbt
0
228
例如：没有可变电压蓄电池
229

图 12

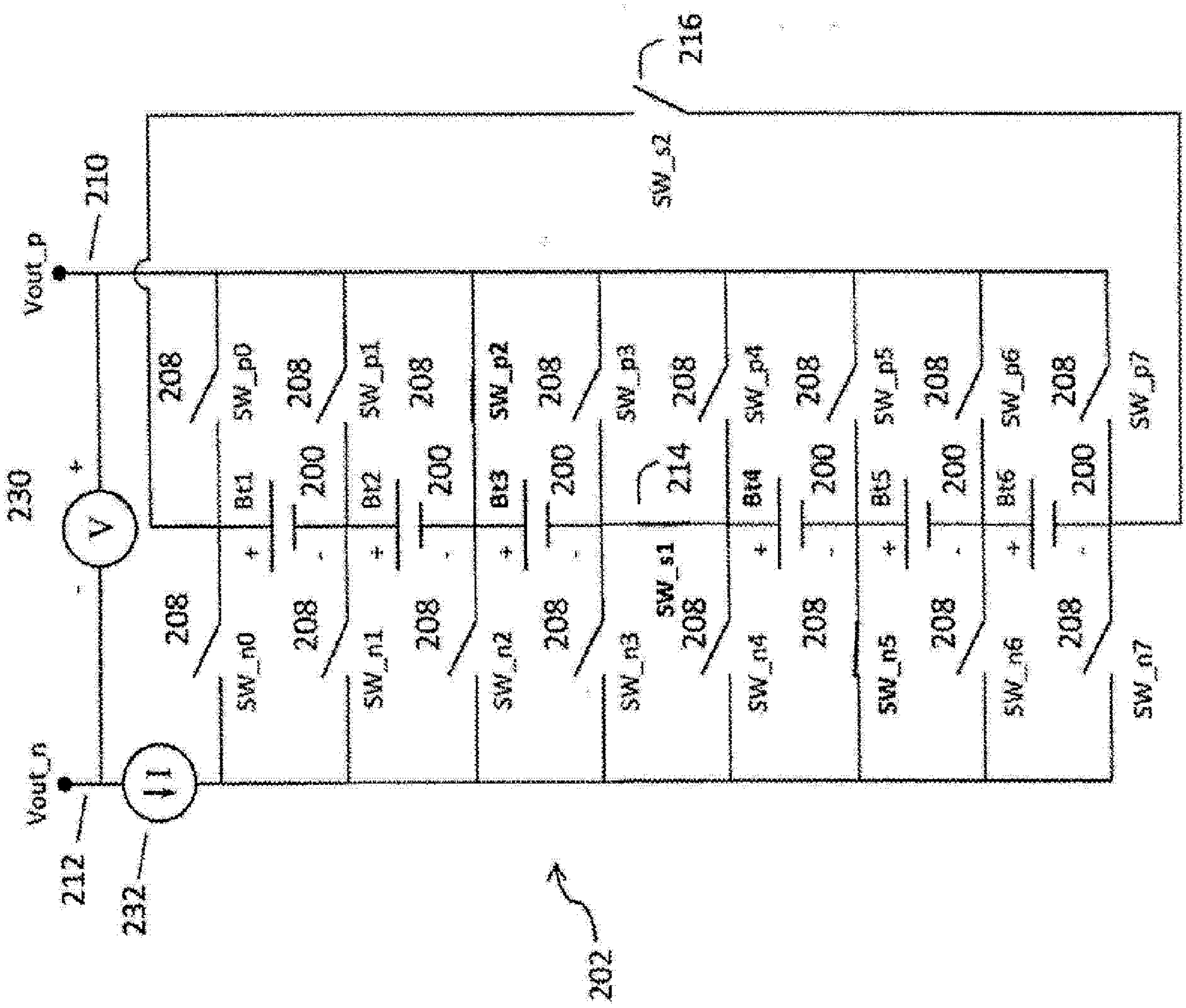

Vout_p
210
Vout_n
212
230
V
232
202
216
SW_s2
SW_s1
214
Bt1
Bt2
Bt3
Bt4
Bt5
Bt6
200
208
SW_p0
SW_p1
SW_p2
SW_p3
SW_p4
SW_p5
SW_p6
SW_p7
SW_n0
SW_n1
SW_n2
SW_n3
SW_n4
SW_n5
SW_n6
SW_n7

图 13

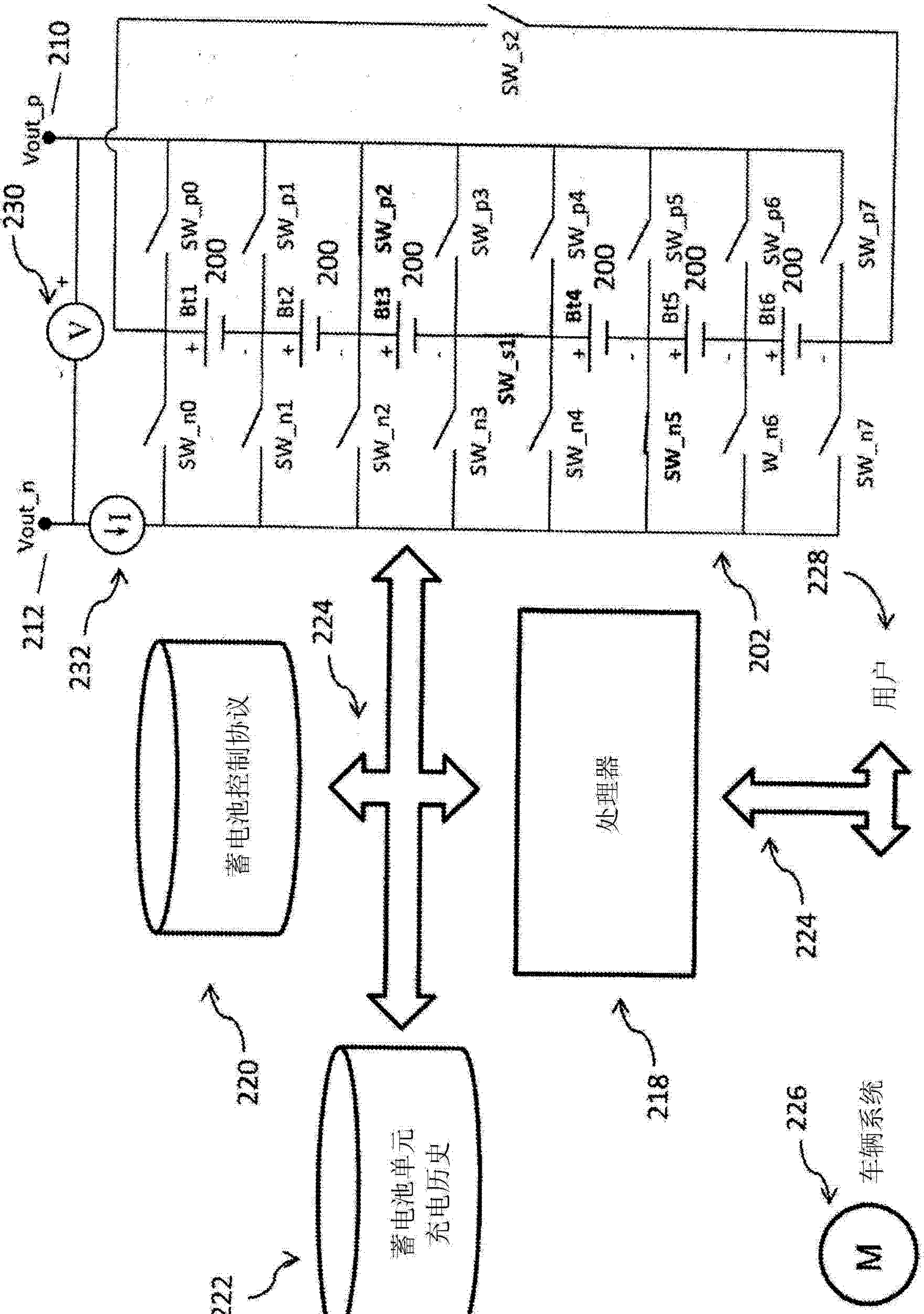

Vout_p
210
Vout_n
212
230
232
V
I
SW_s2
SW_s1
SW_p0
SW_p1
SW_p2
SW_p3
SW_p4
SW_p5
SW_p6
SW_p7
Bt1
Bt2
Bt3
Bt4
Bt5
Bt6
200
SW_n0
SW_n1
SW_n2
SW_n3
SW_n4
SW_n5
W_n6
SW_n7
202
228
224
蓄电池控制协议
220
蓄电池单元
充电历史
222
处理器
218
用户
车辆系统
226
M

图 14