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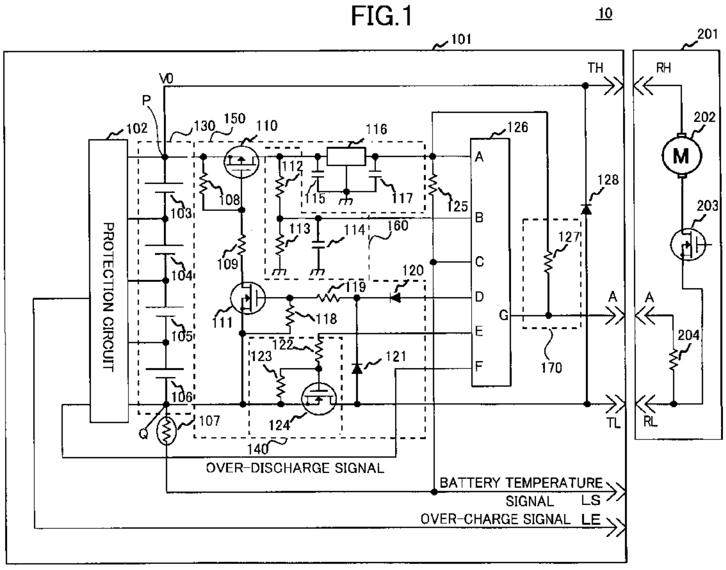
[Continued on next page]

(54) **Title**: BATTERY PACK AND POWER TOOL USING THE SAME

FIG.1



(57) **Abstract**: The present invention features a battery pack and a power tool using the same. The battery pack includes a battery, a switching element, and a control section. The battery has a plurality of rechargeable battery cells and configured to supply power to an electric power tool. The switching element is connected to the battery in series. The control section controls a switching operation of the switching element. The control section receives voltage specification information from the electric power tool, the voltage specification information including an available voltage for the electric power tool. The control section controls the switching operation of the switching element in accordance with the available voltage. Preferably, the voltage specification information has a rated voltage of the power tool.

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DESCRIPTION

Title of Invention

BATTERY PACK AND POWER TOOL USING THE SAME

Technical Field

This invention relates to a battery pack including a plurality of secondary battery cells and a power tool which is supplied power from the battery pack.

Background Art

A nickel hydride battery, a nickel-cadmium (nicad) battery, or a high-capacity or lightweight nickel-lithium battery is well-known as a power source to drive a cordless power tool. The nicad battery cell and nickel hydride battery cell have a nominal voltage of 1.2 V, and the lithium battery cell has a nominal voltage of 3.6 V. In other words, the nominal voltage of the lithium battery cell is three times higher than that of the nickel-lithium battery cell or the nicad battery cell. The lithium battery cell has three times higher energy density than that of the nicad battery cell. The lithium battery cell is compact and lightweight, compared with the nickel-lithium battery cell or the nicad battery cell. The lithium battery cell has good discharge efficiency, can discharge at a relatively lower temperature, and produces a stable battery voltage within a wide temperature range.

On the other hand, a conventional cordless power tool having a rated voltage of 12V often uses a battery in which ten nicad battery cells or nickel hydride battery cells, each having a nominal cell voltage of 1.2 V, are connected in series. If the battery is configured from only lithium battery cells, the voltage produced by connecting merely lithium battery cells, each battery producing a nominal voltage of 3.6 V, in series is merely an integral multiple of 3.6 V, and not equal to 12 V. That is, only lithium battery cells cannot compose a battery pack for the above cordless power tool. Japanese Patent Application Publication No. 2005-160233 discloses a method to combine the lithium battery cell and the nicad battery cell to provide a battery pack for producing a voltage of 12 V.

In order to change the output voltage of the lithium battery cell, Japanese Patent Application Publication No. Hei 11-185824 discloses a method for connecting a voltage converter to the lithium battery cell to reduce an output voltage produced by the battery pack to one-third of a cell nominal voltage, which leads to maintain the compatibility between the lithium battery cell and the primary battery cell.

Citation List

Patent Literature

PLT1: Japanese Patent Application Publication No. 2005-160233

PLT2: Japanese Patent Application Publication No. Hei 11-185824

Summary of Invention

Technical Problem

The lithium battery cell has different characteristics from those of the nicad battery cell and the nickel-hydride battery cell in terms of a method for controlling charging the battery cell, a charging capacity, and self-discharge rate. Therefore, if the lithium battery cell, nicad battery cell, and nickel-hydride battery cell compose the battery, a complicated charging control and/or a self-discharge control is necessary to pay attention to different characteristics between the lithium battery cell, nicad battery cell, and nickel-hydride battery cell.

The power tool generally has a rated voltage of 12 V which is higher than the voltage of a general-purpose primary battery cell. Accordingly, the battery pack including the voltage converter disclosed in Japanese Patent Application Publication No. Hei 11-185824 produces a lower output voltage so that it is hard to drive the power tool by the battery pack.

An object of the present invention is to provide a battery pack which applies a voltage which is available for a power tool and to provide a power tool using the same.

Solution to Problem

The present invention features a battery pack and a power tool using the same. The battery pack includes a battery, a switching element, and a control section. The battery has a plurality of rechargeable battery cells and configured to supply power to an electric power tool. The switching element is connected to the battery in series. The control section controls a switching operation of the switching element. The control section receives voltage specification information from the electric power tool, the voltage specification information including an available voltage for the electric power tool. The control section controls the switching operation of the switching element in accordance with the available voltage. Preferably, the voltage specification information has a rated voltage of the power tool.

According to the above structure, when the control section receives the voltage specification information form the main unit of the power tool, the control section performs the switching operations of the switching element in accordance with the available voltage of the power tool included in the voltage specification information and the battery voltage of the battery. The battery voltage of the battery is averaged by the switching operations of the switching element, so that the average output voltage of the battery pack becomes lower than the battery voltage from the battery. Accordingly, the average output voltage of the battery pack is rendered suitable for driving the power tool, and the power tool can be driven by the power supply from the battery pack.

Preferably, the battery pack further includes a battery voltage detecting section that detects a battery voltage across the battery. The control section turns off the switching element to interrupt the power supply from the battery when the battery voltage detecting section detects a battery voltage which is equal or less than a predetermined voltage. When the battery voltage detected by the battery voltage detecting section lowers than the predetermined voltage, it is considered that the battery may occur over-discharge. Accordingly, the control section turns off the switching element to interrupt the power supply from the battery, thereby protecting the battery from over-discharge.

Preferably, the control section turns off the switching element to interrupt the power supply from the battery when a predetermined time period has elapsed since a start of the switching operation. This structure prevents power consumption of the battery when the power tool is not used.

Preferably, the battery pack as claimed as claim 1 further includes a battery voltage detecting section that detects a battery voltage across the battery. The control section sets a condition of the switching operation in accordance with the battery voltage detected by battery voltage detecting section. This structure maintains the average output voltage from the battery pack constant by setting the condition of the switching operation of the switching element in accordance with any change in the output voltage from the battery, when the battery voltage from the battery changes because of the reduction of the capacitance by discharge.

Preferably, the control section detects a battery temperature of the battery. The control section turns off the switching element to interrupt the power supply from the battery when the detected battery temperature is more than or equal to a predetermined temperature. This structure prevents unusual rise in the temperature of the battery, thereby preventing any deterioration and/or damage of the battery.

Preferably, the control section outputs a pulse-width modulation (PWM) control signal for the switching operation of the switching element, and sets a duty cycle of the switching element. With this structure, the switching element performs the switching operation with the set duty cycle, so that the battery voltage of the battery is averaged depending on the duty cycle. That is, a PWM control is performed for an output voltage from the battery pack. As a result, the average output voltage of the battery pack becomes lower than the battery voltage of the battery. By selecting a proper duty cycle, the average output voltage of the battery pack becomes to match the available voltage for the power tool. Thus, the power tool can be driven by the power supply from the battery pack.

Advantageous Effects of Invention

According to the present invention, an average output voltage from a battery pack can be adjusted to an output voltage which is not produced by just connecting several battery cells in series. Therefore, an optimal voltage for an intended purpose of the power tool can be applied from the battery pack to the power tool. And, switching operations are performed in accordance with the voltage specification information related to the power tool, so that a single battery pack can be used for different types of power tools, each of which having the respective voltage specification.

Brief Description of Drawings

[Fig. 1] Fig. 1 is a circuit diagram showing a battery pack and a power tool according to the present invention.

[Fig. 2] Fig. 2 is a flowchart showing a discharge of a battery pack and control therefor.

[Fig. 3] Fig. 3 is a table showing the relationship between a voltage indicated by voltage discriminating signal and rated voltage of the power tool.

[Fig. 4] Fig. 4 is a circuit diagram showing a charger to charge the battery pack shown in Fig. 1.

[Fig. 5] Fig. 5 is an alternative circuit diagram of the battery pack and the power tool shown in Fig. 1.

Description of Embodiments

An embodiment of the invention will be described with reference to the accompanying drawings. As shown in Fig. 1, a battery-driven power tool 10 is made up of a battery pack 101 and a power tool body 201 configured to be operable with voltage Vs.

The battery pack 101 includes a rechargeable (secondary) battery 130, a protection circuit 102, a switching section 140, a power supply section 150, a battery voltage detecting section 160, a thermistor 107, a power tool rated voltage detecting section (hereinafter referred to as "rated voltage detecting section") 170, and a microcomputer 126 serving as a control unit.

The battery 130 consists of four lithium-ion battery cells 103, 104, 105 and 106 connected in series. The battery 130 has a positive terminal P connected to the positive output terminal TH in the connection port of the battery pack 101, and a negative terminal Q connected to a negative output terminal TL in the connection port thereof.

The protection circuit 102 functions to monitor the voltage across each cell 103, 104, 105, 106 of the battery 130. When the monitored voltages indicate that at least one battery cell falls below a predetermined voltage to be over-discharged, the protection circuit 102 outputs an over-discharge signal to an input port F of the microcomputer 126. Also, the protection circuit 102 outputs an over-charge signal LE to a battery charger 301 (see Fig. 4). The over-charge signal is indicative of an over-charged condition in at least one battery cell of the battery 130 and outputted during charging the battery 130 with the battery charger 301.

The switching section 140 is configured from an N-channel FET 124 serving as a switching element, and resistors 122, 123. The FET 124 has a drain connected to the negative output terminal TL in the connection port of the battery pack 101 and a source connected to the negative terminal Q of the battery 130. The FET 124 performs switching or ON/OFF actions in response to a switching signal outputted from the output port E of the microcomputer 126. The switching signal is a pulse-width modulation (PWM) control signal and applied to the gate of the FET 124 through the resistor 122. When the FET 124 is rendered ON, the power tool body 201 is electrically connected to and powered by the battery 130 whereas when the FET 124 is rendered OFF, the power tool body 201 is electrically disconnected from and unpowered by the battery 130.

The power supply section 150 is configured from a P-channel FET 110, an N-channel FET 111, a three-terminal regulator 116, diodes 120, 121, resistors 108, 109, 118, 119, and capacitors 115, 117. Both the FET 110 and 111 operate as switching elements. The FET 110 has a source connected to the positive terminal P of the battery 130 and a drain connected to a power port A of the microcomputer 126 through the regulator 116. The resistor 108 is connected across the source and gate of the FET 110.

The capacitor 115 is connected between the first (input) terminal of the regulator 116 and ground. Another capacitor 117 is connected between the second (output) terminal of the regulator 116 and ground. The third terminal is connected to ground.

The FET 111 has a drain connected to the resistor 109 which in turn is connected to both the gate of the FET 110 and the resistor 108. The source of the FET 111 is connected to the negative terminal Q of the battery 130. Between the gate of the FET 111 and the negative terminal of the battery 130 are connected the diode 121 and the resistor 119. The resistor 118 is connected across the gate and the source of the FET 111. Also, the diode 120 and the resistor 119 are connected between the output port D of the microcomputer 126 and the gate of the FET 111.

When the FET 124 of the switching section 140 is held OFF, current flows through the diode 121, resistor 119 and resistor 118 in the stated order. The voltage developed across the resistor 118 renders the FET 111 ON, and the FET 110 is also rendered ON due to the voltage developed across the resistor 108. When the FET 110 is rendered ON, the regulator 116 supplies a constant voltage to the microcomputer 126 for placing the same in operative condition. Once the microcomputer 126 is powered by the regulator 116, the high level signal outputted from the output port D of the microcomputer 126 maintains the FET 111 ON regardless of whether the FET 124 is ON or OFF.

The battery voltage detecting section 160 is configured from resistors 112, 113 connected in series between the drain of FET 110 and ground. A capacitor 114 is connected in parallel to the resistor 113. The battery voltage detecting section 160 is provided for detecting the battery voltage V_0, i.e., the voltage across the positive terminal P and negative terminal Q, and supplying the detected battery voltage to the input port B of the microcomputer 126.

A thermistor 107 and a resistor 125 are connected in series between the output of the regulator 116 and the negative terminal Q of the battery 130. The thermistor 107 is disposed in contact with or in proximity with any of the battery cells 103, 104, 105, and 106 to sense the temperature of the battery 130. The resistance of the thermistor 107 changes depending upon the temperature of the battery 130. Thus, the voltage developed across the thermistor 107 indicates the temperature of the battery 130 and is applied to both an input port C of the microcomputer 126 and a battery charger 301 shown in Fig. 4 as a battery temperature signal LS. When the battery pack 101 is connected to the battery charger 301 as shown in Fig. 4, the battery temperature signal LS is applied to a control circuit 303 provided within the battery charger 301.

The rated voltage detecting section 170 is configured from a resistor 127 and produces a voltage discriminating signal A corresponding to a voltage Vs relevant to the power tool body 201 to be used in conjunction with the battery pack 101.

Although not shown, the microcomputer 126 includes a CPU, a ROM, a RAM, an analog-to-digital converter connected to the input ports, as is well known in the art. The ROM stores a program for executing a process as shown in Fig. 2.

The microcomputer 126 determines a duty cycle R for the FET 124 to perform the switching actions. The switching actions of the FET 124 lower the battery voltage V_0 and the duty cycle R is so determined that the average output voltage is in coincidence with the rated voltage Vs of the power tool body 201 to be used. A switching signal corresponding to the duty cycle R thus determined is outputted from an output port E of the microcomputer 126 and applied to the gate of the FET 124 through the resistor 122. The duty cycle is changed when the battery voltage V_0 is lowered due to continuous use of the battery 130 so that the predetermined average voltage can be supplied from the battery pack 101.

When any of the battery cells 103, 104, 105, and 106 is over-discharged, the microcomputer 126 changes the switching signal applied to the gate of the FET 124 of the switching section 140 from a high level to a low level, causing the FET 124 to be switched to OFF. As a consequence, the battery 130 is no longer discharged. Concurrently with rendering the FET 124 OFF, the FETs 111 and 110 are also rendered OFF. To this effect, the microcomputer 126 applies a low level signal to the gate of the FET 111, so that the FET 111 is rendered OFF, and the FET 110 is in turn rendered OFF. As the FET 110 is OFF, the microcomputer 126 is not powered and thus placed in an inactive condition.

A diode 128 is connected between the positive and negative output terminals TH and TL in such a manner that the anode of the diode 128 is connected to the negative output terminal TL and the cathode thereof to the positive output terminal TH.

The power tool body 201 has a positive input terminal RH and a negative input terminal RL which are adapted to be connectable to the corresponding terminals of the battery pack 101. The power tool body 201 is configured from a motor 202, an N-channel FET 203, and a resistor 204 having a resistance specific to the power tool body

201. The resistance of the resistor 204 identifies the rated voltage Vs of the power tool body 201. The motor 202 is connected between the positive and negative input terminals RH and RL of its own connection port. Connection of the battery pack 101 to the power tool body 201 applies the relevant voltage to the motor 202. The FET 203 is interposed between the motor 202 and the negative input terminal RL in such a manner that the drain is connected to the motor 202, and a source connected to the negative input terminal RL. Although not shown in Fig. 1, the power tool body 201 has a trigger switch to be operated by the user. The trigger switch is connected to a control circuit (not shown). When the trigger switch is operated, the control circuit outputs a PWM control signal to the gate of the FET 203. Depending upon how much degree the trigger switch is operated by the user, the duty cycle of the PWM control signal is changed so that the rotational speed of the motor 202 is changed in conjunction with the operation degree of the trigger switch. The control circuit is configured to receive the over-discharge signal from the battery pack 101, and the control circuit renders the FET 203 OFF to thereby stop rotations of the motor 202 in response to the over-discharge signal.

As shown in Fig. 4, the battery charger 301 has a connection port for connection of the battery pack 101. The connection port of the battery pack 101 has not only the positive and negative output terminals but also a battery temperature signal receiving terminal for receiving the battery temperature signal LS from the battery pack 101, and an over-charge signal receiving terminal for receiving the over-charge signal LE from the battery pack 101.

The battery charger 301 is configured from a charging circuit 302 connected between the positive and negative terminals of its own connection port, and a control circuit 303. The charging circuit 302 supplies a charging current to the battery 130 for recharging the same. The control circuit 303 is connected to the charging circuit 302 for controlling the same during charging. The control circuit 303 controls the charging circuit 302 to halt charging the battery 130 in response to the over-charge signal LE received from the protection circuit 102 provided in the battery pack 101. The control circuit 303 also monitors the charging status of the battery pack 101 and halt charging when a fully charged condition is detected.

Discharge from the battery pack 101 to the power tool body 201 will be explained, referring to Fig. 2.

The battery pack 101 is fitted to the power tool body 201 and the FET 203 of the power tool body 201 is then turned on, so that a current flow passes from the battery 130 through the T_H, the positive input terminal RH, the motor 202, and the FET 203 in turn to the negative output terminal TL which is on a lower potential side of the battery pack 101 (S401). At this time, the FET 124 is OFF, and the current flow passes through the diode 121 and the resistor 119 to the gate of the FET 111. The current flow induces a voltage, which turns on the FET 111.

When the FET 111 is turned on, the FET 110 is then turned on, and the battery voltage V_0 is applied to the regulator 116. The regulator 116 is a constant-voltage source that applies a constant voltage to the microcomputer 126 (S402). The microcomputer 126 is activated by the start of supplying power thereto and produces a high level signal from the output port D through the diode 120 to the gate of the FET 111, which maintains the turning on the FET 111 (S403). Because the turning on the FET 111 is maintained, the turning on the FET 110 is maintained. Accordingly, the microcomputer 126 continuously controls charge and discharge of the battery 130.

When the battery pack 101 is fitted to the power tool body 201, the resistor 127 of the rated voltage detecting section is connected with the resistor 204 of the power tool body 201 in series. The microcomputer 126 receives a voltage value of the battery voltage V_0 divided by the series-connected resistors 127 and 204 through the input port G as the voltage discriminating signal A (S404). Fig. 3 shows one example of the relationship between the voltage value of the voltage discriminating signal A and a rated voltage of the power tool body 201. For example, if the voltage value of the voltage discriminating signal A is any value from 0 to 0.5 V, the microcomputer 126 determines that the power tool body 201 with the rated voltage of 3.6 V is fitted. If the voltage discriminating signal A has a voltage of 2.5-3.0 V, the microcomputer 126 determines that a power tool body 201 with the rated voltage of 14.4 V is fitted.

Next, the microcomputer 126 determines the battery voltage V_0 of the battery 130 (S405). The microcomputer 126 uses the rated voltage Vs of the power tool body 201 detected in S404 and the battery voltage V_0 of the battery 130 detected in S405 to calculate a duty cycle of the switching operation of the FET 124 (S406).

Duty cycle

= (rated voltage of the power tool unit/actual battery voltage of battery) × 100%

Next, the microcomputer 126 supplies the switching signal having the duty cycle determined in S406 to the gate of the FET 124 through the resistor 122. The FET 124 starts the switching operation in response to the switching signal. When the switching signal has a high level, the FET 124 is turned on. When the switching signal is a low level, the FET 124 is turned off. Due to the switching operations, the output voltage from the battery 130 is averaged depending on the duty cycle and applied to the power tool body 201 (S407). That is, a PWM control is performed for the output voltage from the battery pack 101. At this time, the average voltage outputted from the battery pack 101 is not battery voltage V_0. This average voltage matches the rated voltage of the power tool body 201.

Next, the microcomputer 126 detects whether an over-discharge signal occurs from the protection circuit 102 (S408). If the over-discharge signal is detected (S408: YES), the process goes to S411. If the over-discharge signal is not detected (S408: NO), the process goes to S409.

In S409, the microcomputer 126 determines the temperature of the battery pack 101. If the temperature of the battery pack 101 is more than or equal to a predetermined temperature (S409: YES), the process goes to S411. If the temperature of the battery pack 101 is less than a predetermined temperature (S409: NO), the process goes to S410.

In S410, the microcomputer 126 determines whether one hour has passed since the start of the switching operations of the FET 124. If one hour has passed since the start of the switching operations (S410: YES), the process goes to S411. If one hour has not passed since the start of the switching operations (S410: NO), the process returns to S403. And then the microcomputer 126 continues the control of the battery pack 101 and the monitoring the conditions of the battery pack 101.

If the process advances to S411 due to the determination of the microcomputer 126, the FET 124 is turned off and the discharge from the battery pack 101 to the power tool body 201 is stopped (S411). Further, the microcomputer 126 switches the high level signal supplied to the FET 111 to the low level signal, to turn off the FET 111 (S412). Because the FET 111 is turned off, the FET 110 is turned to stop the power supply to the microcomputer 126.

It should be noted that each of the steps from S403 to S412 in the flowchart of Fig. 2 are performed by the microcomputer 126.

The next description will be explained how to charge the battery pack 101.

When the battery pack 101 is connected to the battery charger 301 and the charging of the battery pack 101 is started, the battery pack 101 is turned on and the microcomputer 126 is then activated, similarly to just after the discharge of the battery pack 101 is started. The microcomputer 126 senses that the battery pack 101 is in a process to charge, because the microcomputer 126 does not receives the voltage discriminating signal A. The microcomputer 126 produces a high level signal to the gate of the FET 124 to turn on the FET 124 and maintain the FET 124 ON. The battery 130 and the charging circuit 302 are electrically connected to charge the battery pack 101. Alternatively, the charger 301 may include an identifying resistor indicative of the charger. When the battery pack 101 is connected to the charger, the microcomputer 126 may read the identifying resistor through the terminal A to determine that the battery pack 101 is connected to the charger. And then the microcomputer 126 may turn on the FET 124.

As described above, the microcomputer 126 of the battery pack 101 receives the rated voltage from the power tool body 201 which has been connected to the battery pack 101, and performs the switching operations of the FET 124 connected to the battery 130 in series with the duty cycle calculated from the rated voltage and the actual battery voltage of the battery. Thus, an average output voltage from the battery pack is rendered identical to the rated voltage of the power tool body 201. Accordingly, the power tool body 201 can be driven by supplying power from the battery pack 101. Even if the battery voltage V_0 across the battery 130 does not match the rated voltage of the power tool body 201, the battery pack 101 can be connected to the power tool body 201, and the power tool body 201 can be driven by power from the battery pack 101.

During the discharge of the battery pack 101, the microcomputer 126 detects the battery voltage V_0 intermittently, and calculates the duty cycle every time the battery voltage is detected. When the battery voltage V_0 drops due to the continuation of the discharge, the microcomputer 126 changes the duty cycle to maintain the output voltage fixed. Accordingly, the application of a constant voltage to the power tool body 201 can be maintained.

When the discharge from the battery pack 101 to the power tool body 201 is suspended by turning off the FET 124, the power supply from the battery 130 to the microcomputer 126 is also suspended. Accordingly, internal power consumption in the battery pack 101 can be prevented when the battery pack 101 is not in use.

When at least one of the cells 103, 104, 105, and 106 over-discharges, or the temperature of the battery pack 101 becomes very high, the discharge of the battery pack 101 is suspended and the internal power consumption of the battery pack 101 is prevented.

In the above embodiment, the battery pack 101 includes the battery 130, protection circuit 102, switching section 140, power supply section 150, battery voltage detecting section 160, thermistor 107, rated voltage detecting section 170, and microcomputer 126. In another embodiment, the battery pack 101 may have the configuration as shown in Fig. 5. Referring to Fig. 5, the battery pack 101 includes the battery 130, protection circuit 102, and thermistor 107. On the other hand, the power tool body 201 includes the power supply section 150, battery voltage detecting section 160, rated voltage detecting section 170, and microcomputer 126. When the battery pack 101 includes a plurality of cells connected in series, the microcomputer 126 of the battery pack 101 can adjust an average output voltage from the battery pack 101 to the rated voltage of the power tool body 201 by switching operations of the FET 124. Accordingly, the configuration of Fig. 5 can exhibit the same advantages and effects as those of the configuration of Fig. 1.

In the above embodiment, the battery 130 consists of four cells connected in series. However, the structure of the cell 103 is not limited to the above embodiment. In this case, the relationship between the voltage value of the voltage discriminating signal A and the rated voltage of the power tool body is changed depending on the number of cells connected in series in the battery pack. The type of battery cell is not limited to a lithium-ion battery cell. Any other type of secondary battery cell can be used.

Additionally, the elapsed time in S410 in Fig. 2 can be changed, depending on the application of the power tool 10.

It is understood that the foregoing description and accompanying drawings set forth the embodiments of the invention at the present time. Various modifications, additions and alternative designs will, of course, become apparent to those skilled in the art in light of the foregoing teachings without departing from the spirit and scope of the disclosed invention. Thus, it should be appreciated that the invention is not limited to the disclosed embodiments but may be practiced within the full scope of the appended claims.

Industrial Applicability

This invention can be applied to any type of battery pack and/or a power tool which is supplied power from the battery pack.

Reference Signs List

10, 201 power tool

101 battery pack

103, 104, 105, 106 battery cells

124 switching element

130 battery

CLAIMS

[Claim 1]

A battery pack comprising:

a battery having a plurality of rechargeable battery cells and configured to supply power to an electric power tool;

a switching element connected to the battery in series; and

a control section that controls a switching operation of the switching element, the control section receiving voltage specification information from the electric power tool, the voltage specification information including an available voltage for the electric power tool, and the control section controlling the switching operation of the switching element in accordance with the available voltage.

[Claim 2]

The battery pack as claimed as claim 1, further comprising a battery voltage detecting section that detects a battery voltage across the battery; wherein the control section turns off the switching element to interrupt the power supply from the battery when the battery voltage detecting section detects a battery voltage which is equal or less than a predetermined voltage.

[Claim 3]

The battery pack as claimed as claim 1, the control section turns off the switching element to interrupt the power supply from the battery when a predetermined time period has elapsed since a start of the switching operation.

[Claim 4]

The battery pack as claimed as claim 1, further comprising a battery voltage detecting section that detects a battery voltage across the battery, the control section sets a condition of the switching operation in accordance with the battery voltage detected by battery voltage detecting section.

[Claim 5]

The battery pack as claimed as claim 1, wherein the control section detects a battery temperature of the battery, the control section turns off the switching element to interrupt the power supply from the battery when the detected battery temperature is more than or equal to a predetermined temperature.

[Claim 6]

The battery pack as claimed as any one of claims 1 to 5, wherein the control section outputs a pulse-width modulation (PWM) control signal for the switching operation of the switching element, and sets a duty cycle of the PWM control signal.

[Claim 7]

A power tool comprising:

a main unit; and

a battery pack that supplies power to the main unit, wherein the main unit comprises a voltage specification information providing section that provides voltage specification information indicating an available voltage for the main unit, and

the battery pack comprises:

a battery including a plurality of rechargeable battery cells and supplying power to the main unit;

a switching element connected to the battery in series; and

a control section that controls a switching operation of the switching element, and wherein the control section receives the voltage specification information from the voltage specification information providing section to control the switching operation in accordance with the received voltage specification information.

[Claim 8]

The power tool as claimed as claim 7, further comprises a battery voltage detecting section that detects a battery voltage of the battery, wherein the control section turns off the switching element to interrupt power supply from the battery when the battery voltage detecting section detects a battery voltage which is equal or less than a predetermined voltage.

[Claim 9]

The power tool as claimed as claim 7, wherein the control section turns off the switching element to interrupt power supply from the battery when a predetermined time period has elapsed since a start of the switching operation.

[Claim 10]

The power tool as claimed as claim 7, further comprises a battery voltage detecting section that detects a battery voltage across the battery, wherein the control section sets a condition of the switching operation in accordance with the battery voltage detected by battery voltage detecting section.

[Claim 11]

The power tool as claimed as claim 7, wherein the control section detects a battery temperature of the battery, the control section turns off the switching element to interrupt the power supply from the battery when the detected battery temperature is more than or equal to a predetermined temperature.

[Claim 12]

The power tool as claimed as any one of claims 7 to 11, wherein the control section outputs a PWM control signal for the switching operation of the switching element, and sets a duty cycle of the PWM control signal.

FIG.1

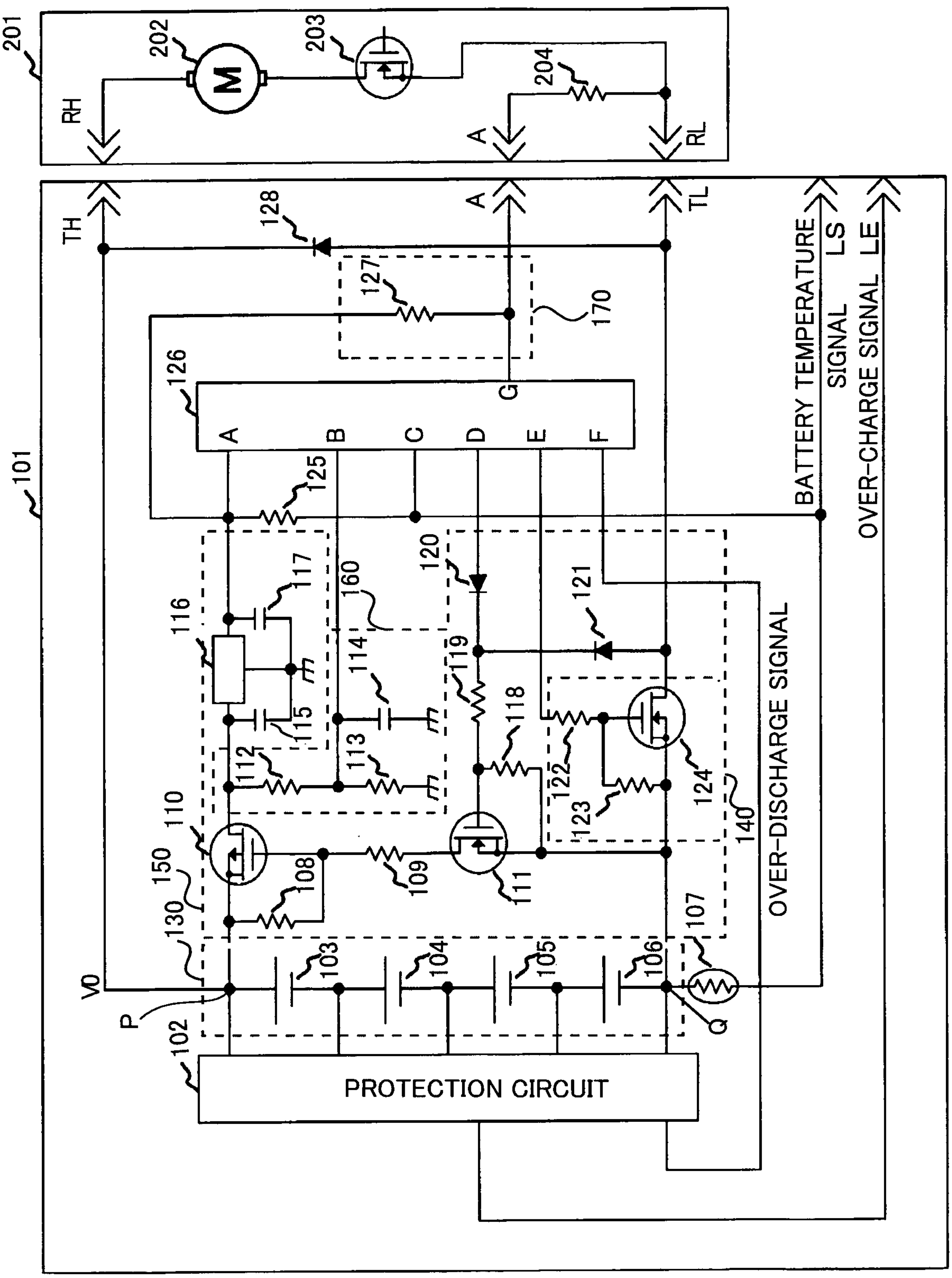

10
101
102
PROTECTION CIRCUIT
201
202
M
203
204
RH
RL
TH
TL
A
V0
P
Q
103
104
105
106
107
108
109
110
111
112
113
114
115
116
117
118
119
120
121
122
123
124
125
126
127
128
130
140
150
160
170
A
B
C
D
E
F
G
BATTERY TEMPERATURE SIGNAL
LS
OVER-CHARGE SIGNAL
LE
OVER-DISCHARGE SIGNAL

FIG.2

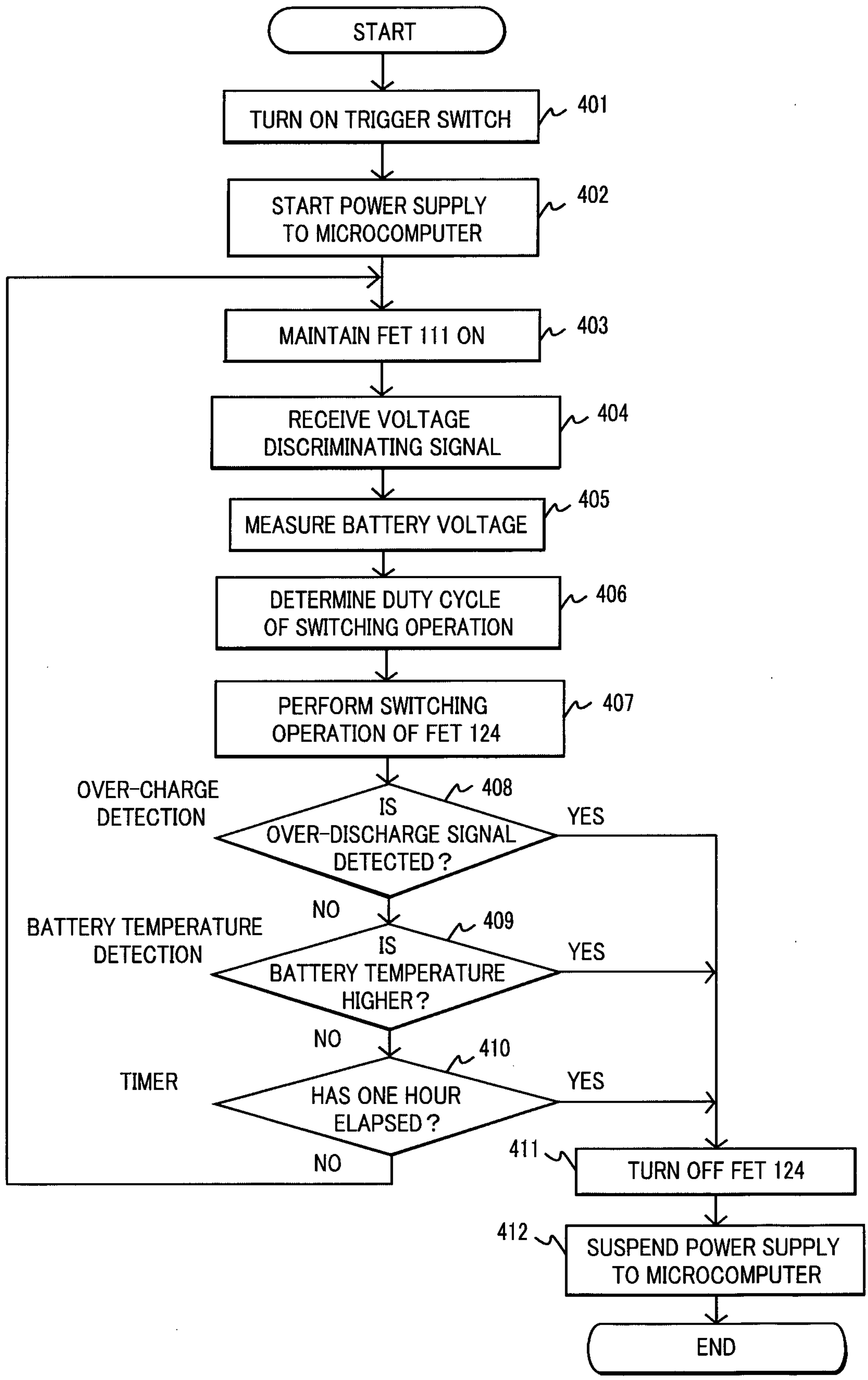

START
TURN ON TRIGGER SWITCH
401
START POWER SUPPLY
TO MICROCOMPUTER
402
MAINTAIN FET 111 ON
403
RECEIVE VOLTAGE
DISCRIMINATING SIGNAL
404
MEASURE BATTERY VOLTAGE
405
DETERMINE DUTY CYCLE
OF SWITCHING OPERATION
406
PERFORM SWITCHING
OPERATION OF FET 124
407
OVER-CHARGE
DETECTION
IS
OVER-DISCHARGE SIGNAL
DETECTED?
408
YES
NO
BATTERY TEMPERATURE
DETECTION
IS
BATTERY TEMPERATURE
HIGHER?
409
YES
NO
TIMER
HAS ONE HOUR
ELAPSED?
410
YES
NO
411
TURN OFF FET 124
412
SUSPEND POWER SUPPLY
TO MICROCOMPUTER
END

FIG.3

VOLTAGE DISCRIMINATING SIGNAL	RATED VOLTAGE FOR POWER TOOL
0 ～ 0. 5V	3. 6V
0. 5 ～ 1. 0V	7. 2V
1. 0 ～ 1. 5V	9. 6V
1. 5 ～ 2. 0V	10. 8V
2. 0 ～ 2. 5V	12. 0V
2. 5 ～ 3. 0V	14. 4V

FIG.4

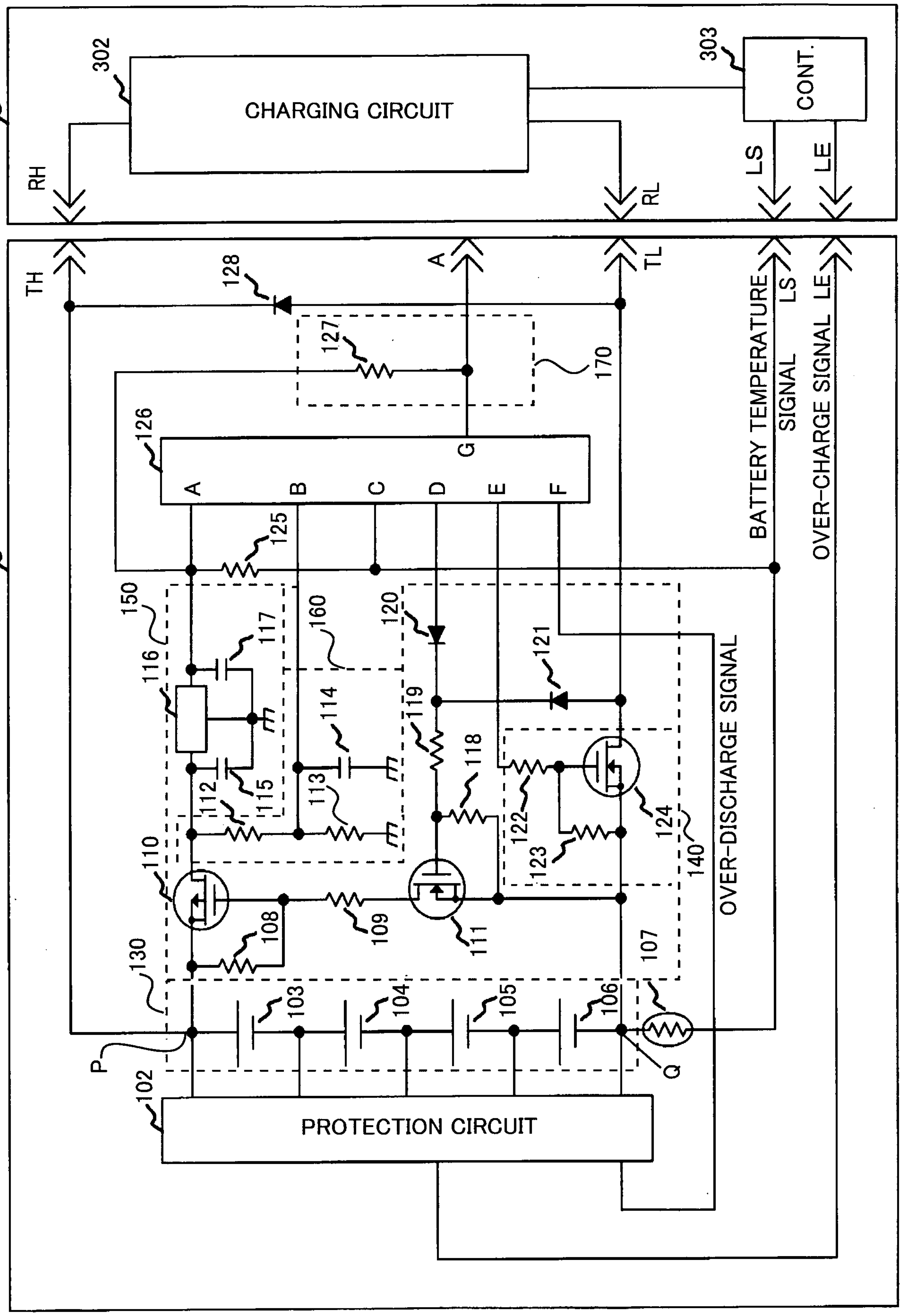
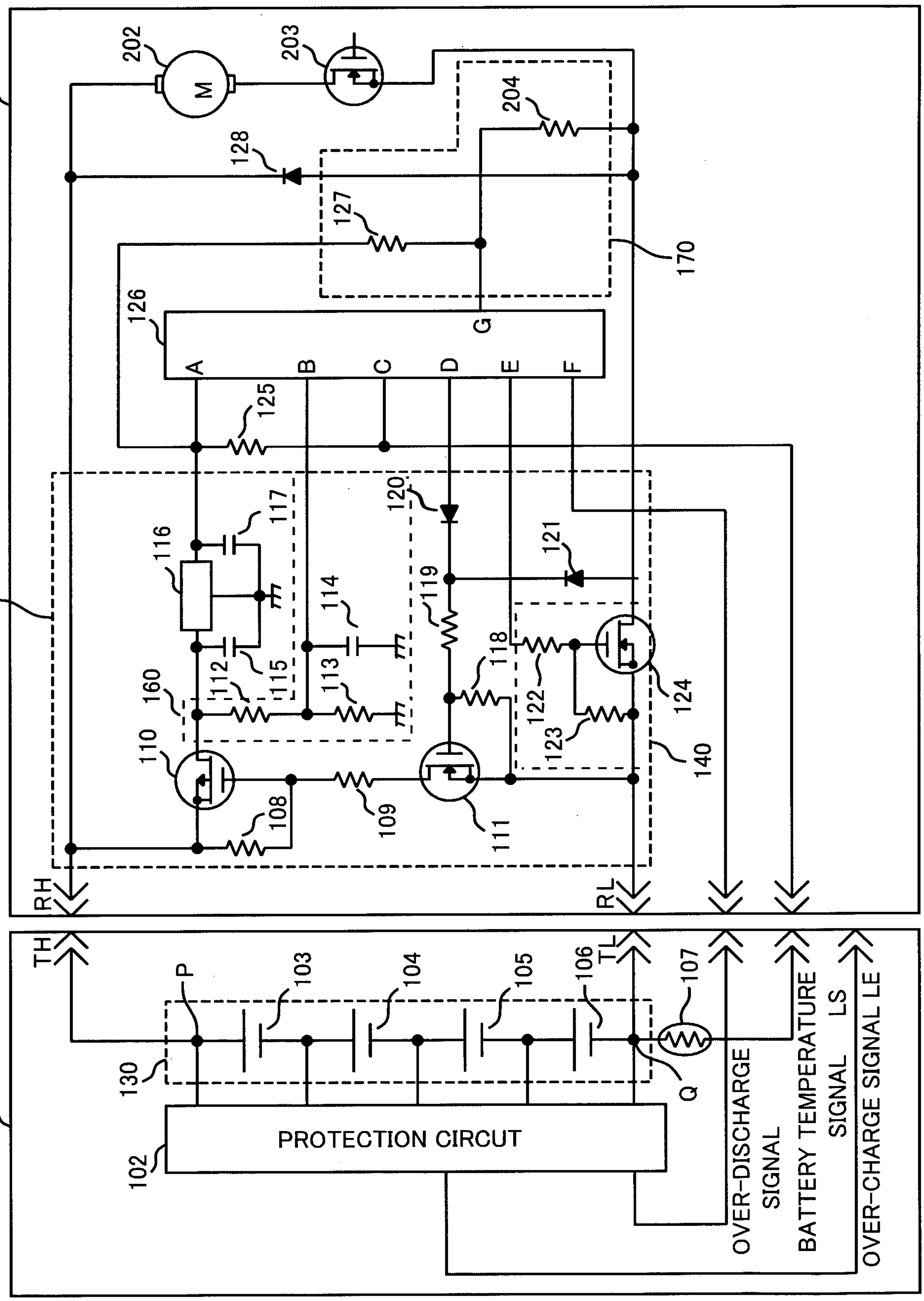

301
302
CHARGING CIRCUIT
303
CONT.
RH
RL
LS
LE
101
TH
TL
A
128
127
170
126
A
B
C
D
E
F
G
125
BATTERY TEMPERATURE SIGNAL
LS
OVER-CHARGE SIGNAL
LE
150
116
117
115
160
114
112
113
120
119
118
121
122
123
124
140
110
111
108
109
107
OVER-DISCHARGE SIGNAL
130
103
104
105
106
P
Q
102
PROTECTION CIRCUIT

FIG.5

10


201
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127
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126
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B
C
D
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125
150
117
116
114
119
120
121
118
160
112
115
113
122
124
123
140
110
108
109
111
RH
RL
TH
TL
101
P
103
104
105
106
107
130
Q
102
PROTECTION CIRCUT
OVER-DISCHARGE SIGNAL
BATTERY TEMPERATURE SIGNAL LS
OVER-CHARGE SIGNAL LE

INTERNATIONAL SEARCH REPORT

International application No
PCT/JP2010/066461

A. CLASSIFICATION OF SUBJECT MATTER
INV. H01M10/48 G01R31/36 B25B21/00
ADD.

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)
H01M G01R B25B

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

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

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2005/038952 A2 (BLACK & DECKER INC [US]; CARRIER DAVE [US]; PHILLIPS STEVE [US]; FRANC) 28 April 2005 (2005-04-28) paragraph [0044] - paragraph [0045] paragraph [0050] paragraph [0054] paragraph [0060] -----	1-12
X	US 2009/108806 A1 (TAKANO NOBUHIRO [JP] ET AL) 30 April 2009 (2009-04-30) figures 10,11,12 paragraph [0069] - paragraph [0071] paragraph [0074] paragraph [0077] - paragraph [0078] paragraph [0084] ----- -/--	1-12

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
20 December 2010	29/12/2010

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Horváth, László

INTERNATIONAL SEARCH REPORT

International application No
PCT/JP2010/066461

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 2008 178278 A (HITACHI KOKI KK) 31 July 2008 (2008-07-31) * abstract figures 10-12,16,17-19 -----	1-12

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/JP2010/066461

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		EP 1673828 A2	28-06-2006
		JP 2007520180 T	19-07-2007
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JP 2008178278 A	31-07-2008	NONE	