(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
30 August 2012 (30.08.2012)

WIPO | PCT

(10) International Publication Number
WO 2012/114749 A1

(51) International Patent Classification:
H02J 7/00 (2006.01) *B23B 45/00* (2006.01)
H01M 10/44 (2006.01) *B25F 5/00* (2006.01)

(21) International Application Number:
PCT/JP2012/001228

(22) International Filing Date:
23 February 2012 (23.02.2012)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
2011-038883 24 February 2011 (24.02.2011) JP
2011-038776 24 February 2011 (24.02.2011) JP

(71) Applicant *(for all designated States except US)*: **HITACHI KOKI CO., LTD.** [JP/JP]; 15-1, Konan 2-chome, Minato-ku, Tokyo, 1086020 (JP).

(72) Inventors; and
(75) Inventors/Applicants *(for US only)*: **SAITOU, Keita** [JP/JP]; c/o Hitachi Koki Co., Ltd., 1060, Takeda, Hitachinaka-shi, Ibaraki, 3128502 (JP). **TAKAHASHI, Shigeru** [JP/JP]; c/o Hitachi Koki Co., Ltd., 1060, Takeda, Hitachinaka-shi, Ibaraki, 3128502 (JP). **WATANABE, Shinji** [JP/JP]; c/o Hitachi Koki Co., Ltd., 1060, Takeda, Hitachinaka-shi, Ibaraki, 3128502 (JP).

(74) Agents: **KITAZAWA, Kazuhiro** et al.; 6F, First Genesis Bldg., 31-14, Yushima 2-chome, Bunkyo-ku, Tokyo, 1130034 (JP).

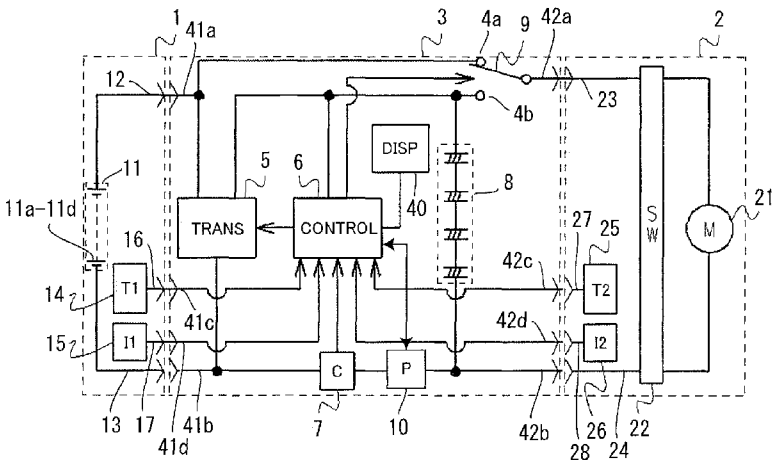
(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:
— *with international search report (Art. 21(3))*

(54) **Title**: SECONDARY BATTERY PACK, POWER TOOL

FIG. 2



(57) **Abstract**: A power tool system (2) includes: a secondary battery (1); a capacitor (8) configured to supply a power to a motor (21); and a transforming unit (5) configured to boost a battery voltage of the secondary battery to a charging voltage, the capacitor being charged with the charging voltage.

WO 2012/114749 A1

Description

Title of Invention: SECONDARY BATTERY PACK, POWER TOOL

Technical Field

[0001] The invention relates to a battery pack, a power tool, an adapter for connecting a battery pack with a power tool, and a power tool system.

Background Art

[0002] Recently, power tools having a motor driven by power supplied from a battery pack are used widely (For example, refer to Japanese Patent Application Publication No. 2008-178278).

Disclosure of Invention

Solution to Problem

[0003] Although the above-mentioned motor is basically driven by a specific rated voltage, the motor can also be driven by voltages within a predetermined range around the rated voltage. On the other hand, the range of voltages with which the motor can be driven differs depending on a kind of an operation performed by a power tool. For example, the above-mentioned range is narrow when a high-load operation is performed, whereas the above-mentioned range is wide when a light-load operation is performed.

[0004] However, because the above-mentioned range is narrow when a high-load operation is performed, the voltage of a battery pack drops to a voltage below the above-mentioned range in a short period. Hence, when a high-load operation is performed, the amount of operations per charge of the battery pack becomes small, and there arises a need to exchange battery packs frequently.

[0005] Further, because the above-mentioned range is wide when a light-load operation is performed, a voltage higher than necessary is supplied in many situations. Hence, in this case, too, the remaining amount of the battery pack drops in a short period considering the light-load operation, and the amount of operations per charge of the battery pack becomes small.

[0006] In view of the foregoing, it is an object of the invention to provide a battery pack, a power tool, an adapter for connecting a battery pack with a power tool, and a power tool system that are capable of supplying a motor of the power tool with voltages appropriate for a kind of operations.

[0007] In order to attain the above and other objects, the invention provides a power tool system including: a secondary battery; a capacitor configured to supply a power to a

motor; and a transforming unit configured to boost a battery voltage of the secondary battery to a charging voltage, the capacitor being charged with the charging voltage.

[0008] It is preferable that the transforming unit is capable of changing the charging voltage.

[0009] It is preferable that the transforming unit is capable of changing the charging voltage based on a load applied to the motor.

[0010] It is preferable that the transforming unit is capable of arbitrarily changing the charging voltage.

[0011] It is preferable that the transforming unit transforms the battery voltage into a voltage greater than the battery voltage when the load applied to the motor is equal to or greater than a first predetermined value, and the transforming unit transforms the battery voltage into a voltage smaller than the battery voltage when the load applied to the motor is equal to or smaller than a second predetermined value smaller than the first predetermined value.

[0012] It is preferable that the power tool system further includes a switch for switching a voltage supplied to the motor to either one of the battery voltage and the charging voltage.

[0013] Another aspect of the present invention provides a power tool system including: a power tool including a motor; a battery pack; a capacitor configured to be charged with a charging voltage; an output terminal including: a first output terminal disposed between the battery pack and the motor to output a battery voltage of the battery pack to the motor; and a second output terminal disposed between the capacitor and the motor to output the charging voltage to the motor; and a control unit configured to allow one of the output terminal to perform the output operation and configured to prevent remaining one of the output terminal to perform the output operation.

[0014] It is preferable that the power tool system further includes: a transforming unit disposed between the battery pack and the capacitor to transform the battery voltage into the charging voltage different from a rated voltage of the power tool; and a receiving unit configured to receive an output changing instruction. The control unit allows the second output terminal to perform the output operation and prevents the first output terminal to perform the output operation, when the receiving unit receives the output changing instruction.

[0015] It is preferable that the power tool system further includes a storing unit configured to store a number of times the second output terminal outputs the charging voltage to the motor. The transforming unit transforms the battery voltage into the charging voltage higher than the rated voltage when the receiving unit receives the output changing instruction. The control unit prevents the second output terminal from performing the output operation when the number of times is larger than a predetermined number of times.

[0016] It is preferable that the power tool system further includes a measuring unit configured to measure a period during which the second output terminal continues to output the charging voltage to the motor. The transforming unit transforms the battery voltage into the charging voltage higher than the rated voltage when the receiving unit receives the output changing instruction. The control unit prevents the second output terminal from performing the output operation when the period is longer than a predetermined period.

[0017] It is preferable that the power tool system further includes a charge-amount informing unit configured to inform a user of a charge amount of the capacitor.

[0018] It is preferable that the power tool system further includes a control unit configured to determine, based on a load applied to the motor, the output terminal that performs the outputting operation.

[0019] It is preferable that the power tool system further includes an adapter connected between the battery pack and the motor. The capacitor, the output terminal and the control unit are accommodated in the adapter.

[0020] Another aspect of the present invention provides a power tool connectable to a battery pack. The power tool includes: a motor; and a capacitor configured to be charged with a charging voltage; an output terminal including: a first output terminal disposed between the battery pack and the motor to output a battery voltage of the battery pack to the motor; and a second output terminal disposed between the capacitor and the motor to output the charging voltage to the motor; and a control unit configured to allow one of the output terminal to perform the output operation and configured to prevent remaining one of the output terminal to perform the output operation.

[0021] Another aspect of the present invention provides a battery pack connectable to a motor of a power tool. The battery pack includes: a battery; a capacitor configured to be charged with a charging voltage; an output terminal including: a first output terminal disposed between the battery and the motor to output a battery voltage of the battery to the motor; and a second output terminal disposed between the capacitor and the motor to output the charging voltage to the motor; and a control unit configured to allow one of the output terminal to perform the output operation and configured to prevent remaining one of the output terminal to perform the output operation.

[0022] Another aspect of the present invention provides an adapter connectable between a battery pack and a motor of a power tool. The adapter includes: a capacitor configured to be charged with a charging voltage; and an output terminal including: a first output terminal disposed between the battery pack and the motor to output a battery voltage of the battery pack to the motor; and a second output terminal disposed between the capacitor and the motor to output the charging voltage to the motor; and a control unit

configured to allow one of the output terminal to perform the output operation and configured to prevent remaining one of the output terminal to perform the output operation.

[0023] Another aspect of the present invention provides an adapter connectable between a battery pack and a motor of a power tool. The adapter includes: a capacitor configured to be connected to the motor; and a transforming unit configured to boost a battery voltage of the battery pack to a charging voltage, the capacitor being charged with the charging voltage.

[0024] It is preferable that the transforming unit is capable of changing the charging voltage.

[0025] It is preferable that the transforming unit is capable of changing the charging voltage based on a load applied to the motor.

[0026] It is preferable that the transforming unit is capable of arbitrarily changing the charging voltage.

[0027] It is preferable that the adapter further includes a switch for switching a voltage supplied to the motor to either one of the battery voltage and the charging voltage.

Advantageous Effects of Invention

[0028] According to the battery pack, the power tool, the adapter, and the power tool system of the invention, a voltage suitable for the kind of an operation can be supplied to a motor of a power tool.

Brief Description of Drawings

[0029] [fig.1]Fig. 1 is an overall view of a battery pack, a power tool, and an adapter according to a first embodiment of the invention.

[fig.2]Fig. 2 is a circuit diagram of the battery pack, the power tool, and the adapter according to the first embodiment of the invention.

[fig.3]Fig. 3 is a vertical cross-sectional view of the adapter according to the first embodiment of the invention.

[fig.4]Fig. 4 is a bottom view of the adapter according to the first embodiment of the invention.

[fig.5]Fig. 5 is a top view of the adapter according to the first embodiment of the invention.

[fig.6]Fig. 6 is a side view of the adapter according to the first embodiment of the invention.

[fig.7]Fig. 7 is a flowchart of a transformation and switching control according to the first embodiment of the invention.

[fig.8]Fig. 8 is an explanation diagram showing a change of a current flowing into a motor at a boring operation.

[fig.9]Fig. 9 is an explanation diagram showing a change of a current flowing into a

motor at a screw driving operation.

[fig.10]Fig. 10 is a side view of an adapter according to a second embodiment of the invention.

[fig.11]Fig. 11 is a flowchart of the voltage control according to the second embodiment of the invention.

[fig.12]Fig. 12 is an overall view of a battery pack according to a first modification of the invention.

[fig.13]Fig. 13 is a circuit diagram of the battery pack according to the first modification.

[fig.14]Fig. 14 is an overall view of a power tool according to a second modification of the invention.

[fig.15]Fig. 15 is a circuit diagram of the power tool according to the second modification.

Reference Signs List

[0030] 1 Battery Pack
2 Power Tool
3 Adapter
4a Normal Terminal
4b Transformer Terminal
5 Transformer circuit
6 Controller
8 Super Capacitor
21 Motor
43 HIGH Button
44 Low Button
45 Full-charge Informing unit
140 Charge-amount Informing unit

Best Mode for Carrying out the Invention

[0031] Hereinafter, a battery pack 1, a power tool 2, and an adapter 3 according to a first embodiment of the invention will be described while referring to Figs. 1 through 7.

[0032] In the present embodiment, a connecting portion of the battery pack 1 and a connecting portion of the power tool 2 have shapes that enable connection with each other, and the battery pack 1 can be connected directly with the power tool 2. In Fig. 1, however, the battery pack 1 and the power tool 2 are connected with each other via the adapter 3.

[0033] As shown in Fig. 2, the battery pack 1 includes an assembled battery 11 constructed by connecting four lithium unit cells 11a-11d in series. In the present embodiment,

because each lithium unit cell has a rated voltage of 3.6V, the battery pack 1 has a nominal voltage of 14.4V. The battery pack 1 includes a plus terminal 12 connected with a positive electrode of the assembled battery 11, a minus terminal 13 connected with a negative electrode of the assembled battery 11, a temperature detecting element 14 (referred as " T1" in Fig. 2) that outputs a signal in accordance with temperature of the assembled battery 11, an identification element 15 (referred as "I1" in Fig. 2) that outputs a signal in accordance with the number of the unit cells (four in the present embodiment), a temperature terminal 16 connected with the temperature detecting element 14, and an identification terminal 17 connected with the identification element 15.

[0034] As shown in Figs. 1 and 2, the power tool 2 includes a motor 21 and a trigger switch 22 connected with the motor 21 in series, and is so configured that, when the trigger switch 22 is turned on, electrical power is supplied from the battery pack 1 to the motor 21 via the adapter 3. The power tool 2 is a cordless power tool for a common rated voltage of 14.4V, for example, a driver drill, and functions normally when the battery pack 1 of the rated voltage of 14.4V is connected.

[0035] As shown in Fig. 2, the power tool 2 includes a plus terminal 23 connected with one end of the motor 21, a minus terminal 24 connected with another end of the motor 21, a temperature detecting element 25 (referred as "T2" in Fig. 2) that outputs a signal in accordance with temperature of the motor 21, an identification element 26 (referred as "T2" in Fig. 2) that outputs a signal in accordance with the rated voltage of the power tool 2 (the motor 21) (14.4V in the present embodiment), a temperature terminal 27 connected with the temperature detecting element 25, and an identification terminal 28 connected with the identification element 26.

[0036] As shown in Figs. 2 and 3, the adapter 3 includes a case 4 constructed by a lower case 41 and an upper case 42. The case 4 accommodates a normal terminal 4a (first output terminal), a transformer terminal 4b (second output terminal), a transformer circuit 5 (transforming unit), a controller 6 (control unit, storing unit, and measuring unit), a current detecting resistor 7 (referred as "C" in Fig. 2), a super capacitor 8 (capacitor), a switch 9 (control unit), and a protection IC 10 (referred as "P" in Fig. 2).

[0037] As shown in Figs. 2 and 4, the lower case 41 is provided with a lower plus terminal 41a connected with the plus terminal 12 of the battery pack 1, a lower minus terminal 41b connected with the minus terminal 13 of the battery pack 1, a temperature terminal 41c connected with the temperature terminal 16 of the battery pack 1, and an identification terminal 41d connected with the identification terminal 17 of the battery pack 1.

[0038] As shown in Figs. 2 and 5, the upper case 42 is provided with an upper plus terminal 42a connected with the plus terminal 23 of the power tool 2, an upper minus terminal

42b connected with the minus terminal 24 of the power tool 2, a temperature terminal 42c connected with the temperature terminal 27 of the power tool 2, and an identification terminal 42d connected with the identification terminal 28 of the power tool 2.

[0039] As shown in Fig. 6, a display unit 40 is provided near the connection between the lower case 41 and the upper case 42. The display unit 40 includes a "HIGH" button 43 (receiving unit) for increasing voltage to be outputted to the power tool 2, a "LOW" button 44 for decreasing voltage to be outputted to the power tool 2, and a full-charge informing unit 45 (charge-amount informing unit) that informs full charge of the super capacitor 8.

[0040] Next, the electrical configuration of the battery pack 1, the power tool 2, and the adapter 3 will be described while referring to Fig. 2.

[0041] The transformer circuit 5 is constructed from a DC/DC converter or a switching circuit. The transformer circuit 5 transforms a voltage supplied from the battery pack 1 via the lower plus terminal 41a, and outputs the transformed voltage to the transformer terminal 4b. On the other hand, the voltage outputted from the battery pack 1 to the lower plus terminal 41a is also outputted to the normal terminal 4a.

[0042] The controller 6 obtains temperature of the battery pack 1 (the assembled battery 11) based on a temperature signal inputted from the temperature detecting element 14 of the battery pack 1 and, if the temperature of the battery pack 1 is higher than a predetermined value, breaks the circuit with the protection IC 10 to stop supply of electric power to the power tool 2 for protection of the battery pack 1.

[0043] Additionally, the controller 6 obtains temperature of the power tool 2 (the motor 21) based on a temperature signal inputted from the temperature detecting element 25 of the power tool 2 and, if the temperature of the power tool 2 (the motor 21) is higher than a predetermined value, breaks the circuit with the protection IC 10 to stop supply of electric power to the power tool 2 for protection of the motor 21.

[0044] Further, if a current flowing through the motor 21, which is detected by the current detecting resistor 7, is higher than a predetermined value, the controller 6 also breaks the circuit with the protection IC 10 to stop supply of electric power to the power tool 2 for preventing overcurrent.

[0045] The super capacitor 8 is connected between the transformer terminal 4b (an output terminal of the transformer circuit 5) and the upper minus terminal 42b. The super capacitor 8 is constructed by connecting in series four electric double layer capacitors each having a capacity of 2 to 3V, and thus is capable of charging voltage outputted from the transformer circuit 5.

[0046] The switch 9 is connected to the upper plus terminal 42a. By switching the switch 9, the upper plus terminal 42a is connected with either the normal terminal 4a or the transformer terminal 4b.

[0047] Here, the controller 6 of the present embodiment performs a transformation and switching control for controlling an amount of transformation by the transformer circuit 5 and for controlling output of transformed voltages.

[0048] In the transformation and switching control, the controller 6 performs a control operation such that a voltage higher than the rated voltage of the power tool 2 (for example, 15.8V) (hereinafter referred to as "high voltage") is outputted to the power tool 2 if the "HIGH" button 43 is on, and that a voltage lower than the rated voltage of the power tool 2 (for example, 13.0V) (hereinafter referred to as "low voltage") is outputted to the power tool 2 if the "LOW" button 44 is on.

[0049] The transformation and switching control will be described in detail while referring to the flowchart in Fig. 7. The flowchart in Fig. 7 starts when both of the battery pack 1 and the power tool 2 are connected with the adapter 3.

[0050] First, the controller 6 determines whether either the "HIGH" button 43 or the "LOW" button 44 is on (S101).

[0051] If neither the "HIGH" button 43 nor the "LOW" button 44 is on (S101: No), then the controller 6 switches the switch 9 such that the upper plus terminal 42a is connected with the normal terminal 4a (S102). With this operation, if neither the "HIGH" button 43 nor the "LOW" button 44 is on, the power tool 2 is supplied with the voltage of the battery pack 1 as it is.

[0052] If the "HIGH" button 43 is on (S101: "HIGH" button), then the controller 6 controls the transformer circuit 5 to transform the voltage supplied from the battery pack 1 to the high voltage (S103), and switches the switch 9 such that the upper plus terminal 42a is connected with the transformer terminal 4b (S105) when the super capacitor 8 reaches a full charge with the high voltage (S104: Yes). With this operation, if the "HIGH" button 43 is on, the high voltage charged at the super capacitor 8 is outputted to the power tool 2.

[0053] If the "LOW" button 44 is on (S101: "LOW" button), then the controller 6 controls the transformer circuit 5 to transform the voltage supplied from the battery pack 1 to the low voltage (S106), and switches the switch 9 such that the upper plus terminal 42a is connected with the transformer terminal 4b (S105) when the super capacitor 8 reaches a full charge with the low voltage (S104: Yes). With this operation, if the "LOW" button 44 is on, the low voltage charged at the super capacitor 8 is outputted to the power tool 2.

[0054] With this configuration, when a high-load operation is performed, a user can operate the power tool 2 temporarily with high power due to the power charged in the super capacitor 8 by turning on the "HIGH" button 43. Further, when the remaining amount of the battery pack 1 has dropped, the user can also operate the power tool 2 temporarily due to the power charged in the super capacitor 8 by turning on the "HIGH"

button 43. Hence, frequency of exchanging the battery pack 1 can be reduced.

[0055] Here, a construction that is not provided with the super capacitor 8 is conceivable. However, such construction needs an enlarged scale of the transformer circuit 5 in order to deal with a high current flowing through the motor 21 when a lock occurs in the motor 21 due to an extremely high-load.

[0056] In the present embodiment, however, electric power is outputted from the transformer circuit 5 to the power tool 2 via the super capacitor 8. Hence, the circuit can deal with a high current at a high-load condition, without enlarging the scale of the transformer circuit 5.

[0057] Further, the controller 6 of the present embodiment stores both an ON continuation period in which an ON state of the "HIGH" button 43 continues and an ON number of times the "HIGH" button 43 is tuned on. If the ON continuation period exceeds a predetermined period or if the ON number of times exceeds a predetermined number of times, the controller 6 switches the switch 9 such that the upper plus terminal 42a is connected with the normal terminal 4a. This operation can prevent burnout of the motor 21 and shortening of lifetime of the battery pack 1 due to application of the high voltage for a long period or in high frequency.

[0058] Additionally, in the present embodiment, the controller 6 switches the switch 9 such that upper plus terminal 42a is connected with the transformer terminal 4b when the super capacitor 8 reaches full charge with the high voltage. Thus, there is some delay after the "HIGH" button 43 is turned on and before the high voltage is outputted to the power tool 2, which may cause uncomfortable feeling by the user. Hence, in the present embodiment, the full-charge informing unit 45 informs the user of full charge of the super capacitor 8, thereby suppressing occurrence of such uncomfortable feeling.

[0059] In addition, as described above, when a light-load operation is performed, by turning on the "LOW" button 44, the user can prevent that a voltage higher than necessary is supplied to the power tool 2, that the remaining amount of the battery pack 1 drops in a short period, and that the amount of operations per charge of the battery pack 1 becomes small considering the light-load operation Further, when the power charged in the capacitor 8 is run short, the power can be directly outputted from the battery pack 1 to the power tool 1 by switching the switch 9 and the capacitor 8 can be charged in this interval.

[0060] Next, a battery pack 1, a power tool 2, and an adapter 3 according to a second embodiment of the invention will be described while referring to Figs. 8 through 11. Like parts and components are designated by the same reference numerals as those shown in Figs. 1 through 7.

[0061] Although a motor is basically driven by a specific rated voltage, the motor can also

be driven by voltages within a predetermined range around the rated voltage. On the other hand, in a conventional power tool, a voltage supplied to a motor is constant regardless of magnitude of load.

[0062] Hence, at a light-load operation in which a small screw is driven by a driver connected with the power tool, for example, electric power more than necessary is supplied to the motor, thereby wasting electric power.

[0063] Further, for example, at a final phase of a boring operation by a drill connected with the power tool, a load decreases and thus electric current flowing through the motor also decreases (see Fig. 8). In such a case, because the voltage supplied to the motor is constant in the conventional power tool, electric power is wasted. In Fig. 8, electric current increases rapidly when time is 1.0 sec, which shows a state in which the trigger switch 22 is turned on. A starting current flows when the trigger switch 22 is turned on, and thereafter the electric current changes in accordance with load.

[0064] Further, when the drill connected with the power tool is temporarily stuck (locked) in a workpiece, for example, the load increases and thus electric current flowing through the motor also increases. In such a case, because the voltage supplied to the motor is constant in the conventional power tool, it takes time to resolve the temporary stuck state and, in some cases, determination is made as an overcurrent state and supplying of electric power to the motor is stopped.

[0065] Thus, the controller 6 of the present embodiment performs a voltage control in which voltages outputted to the power tool 2 are controlled based on load on the motor 21.

[0066] Specifically, the transformer circuit 5 and the switch 9 are controlled such that a voltage higher than a rated voltage of the power tool 2 (15.8V in the present embodiment) (hereinafter referred to as "high voltage") is outputted to the power tool 2 if an electric current flowing through the motor 21 is larger than an upper limit (35A in the present embodiment) (a high voltage mode in Fig. 9).

[0067] Further, the transformer circuit 5 and the switch 9 are controlled such that a voltage lower than the rated voltage of the power tool 2 (13.0V in the present embodiment) (hereinafter referred to as "low voltage") is outputted to the power tool 2 if the electric current flowing through the motor 21 is smaller than an lower limit (10A in the present embodiment) (a low voltage mode in Fig. 9).

[0068] Fig. 9 indicates changes in electric current during a screw driving operation in which the power tool 2 (driver drill) is used. Electric current increases rapidly when time is 1.0 sec, which shows a state in which the trigger switch 22 is turned on. The starting current of the motor (approximately 60A) flows when the trigger switch 22 is turned on, and thereafter the electric current changes in accordance with load. The power tool 2 operates in the high voltage mode if the electric current exceeds 35A, operates in the low voltage mode if the electric current falls below 10A, and operates in a normal

mode if the electric current is between 10A and 35A. Further, determination of electric current described later is not performed within a predetermined period, 0.4 sec for example, after a startup of the motor, so that starting current at the startup of the motor does not affect mode switching.

[0069] Further, in the present embodiment, as shown in Fig. 10, a charge-amount display unit 140 (charge-amount informing unit) is provided near the connection between the lower case 41 and the upper case 42 instead of the display unit 40. The charge-amount display unit 140 displays a charged amount of the super capacitor 8.

[0070] A voltage control performed by the controller 6 will be described while referring to the flowchart of Fig. 11. The flowchart of Fig. 11 is started when both of the battery pack 1 and the power tool 2 are connected with the adapter 3.

[0071] Firstly, for example, if the battery pack 1 has a nominal voltage of 14. 4V and the power tool 2 has a nominal voltage of 18.0V, the inputted voltage is so low that a sufficient torque may not be outputted.

[0072] Therefore, in the present embodiment, first, voltage supplied from the battery pack 1 is automatically transformed so that the rated voltage is supplied to the power tool 2.

[0073] Specifically, the controller 6 obtains the nominal voltage of the battery pack 1 from the discrimination element 15 of the battery pack 1, and obtains the rated voltage of the power tool 2 from the discrimination element 26 of the power tool 2 (S201), and then determines whether both of the nominal voltage and the rated voltage match (S202).

[0074] If the both do not match (S202: No), the controller 6 controls the transformer circuit 5 to transform voltage supplied from the battery pack 1 into the rated voltage (S203), and then switches the switch 9 such that the upper plus terminal 42a is connected with the transformer terminal 4b (S204). With this operation, the rated voltage can be supplied to the power tool 2 even when the nominal voltage and the rated voltage do not match.

[0075] For example, in a case where the nominal voltage of the battery pack 1 is 14.4V and the rated voltage of the power tool 2 is 18.0V, the voltage of the battery pack 1 can be used without transformation. However, in order to obtain an appropriate output, voltage 14.4V of the battery pack 1 is raised to 18.0V by the transformer circuit 5. Conversely, in a case where the nominal voltage of the battery pack 1 is 18.0V and the rated voltage of the power tool 2 is 14.4V, there is a possibility that the power tool 2 (the motor 21) is damaged if a voltage higher than the rated voltage of the power tool 2 is applied for a long period. Hence, the voltage 18.0V of the battery pack 1 is lowered to 14.4V by the transformer circuit 5, and is then outputted.

[0076] Subsequent to S204, or if the nominal voltage and the rated voltage match in S202 (S202: Yes), the controller 6 determines whether the electric current flowing through the motor 21 is larger than the upper limit (S205). Specifically, the controller 6

calculates an average value of electric current values once every 0.1 sec, and determines whether the average value is larger than 35A.

[0077] If the electric current is larger than the upper limit (S205: Yes), it is assumed that it is in a high load condition. Accordingly, in this case, the controller 6 controls the transformer circuit 5 to transform the voltage supplied from the battery pack 1 into a high voltage (15.8V) (S206), and then switches the switch 9 such that the upper plus terminal 42a is connected with the transformer terminal 4b (S207) (the high voltage mode in Fig. 9).

[0078] With this operation, when a large electric current flows through the motor 21, a high voltage (15.8V) charged at the super capacitor 8 is outputted to the power tool 2. Thus, when the drill connected with the power tool 2 is temporarily stuck (locked) in a workpiece, the power tool 2 can be temporarily operated at high power.

[0079] In the present embodiment, the controller 6 stores a duration of the high voltage and the number of times of switching. If the duration exceeds a predetermined period and if the number of times of switching exceeds a predetermined number, the controller 6 switches the switch 9 such that the upper plus terminal 42a is connected with the normal terminal 4a. This can prevent burnout of the motor 21 and shortening of lifetime of the battery pack 1 due to application of the high voltage for a long period or in high frequency.

[0080] On the other hand, if the electric current is smaller than or equal to the upper limit (S205: No), the controller 6 determines whether the electric current is smaller than the lower limit (S208).

[0081] If the electric current is smaller than the lower limit (S208: Yes), it is assumed that it is in a low load condition. Accordingly, in this case, the controller 6 controls the transformer circuit 5 to transform the voltage supplied from the battery pack 1 into a low voltage (13.0V) (S209), and then switches the switch 9 such that the upper plus terminal 42a is connected with the transformer terminal 4b (S207) (the low voltage mode in Fig. 9).

[0082] With this operation, when a small electric current flows through the motor 21, a low voltage charged at the super capacitor 8 is outputted to the power tool 2. This can prevent that a voltage higher than necessary is supplied to the power tool 2 during a light-load operation such as a final phase of a boring operation and a driving operation of a small screw.

[0083] Note that, in the present embodiment, the controller 6 obtains an average value of electric current values once every 3.0 sec, and determines that it is in a low load condition if the number of times the obtained average value becomes smaller than 10A is larger than or equal to ten times. However, other criteria may be used. For example, the controller 6 may determine that it is in a low load condition if the average value

becomes smaller than 10A once. With this criterion, a control can be performed more accurately in accordance with kinds of operations.

[0084] On the other hand, if the electric current is larger than or equal to the lower limit (S208: No), the controller 6 switches the switch 9 such that the upper plus terminal 42a is connected with the normal terminal 4a (S210). Note that, if the switch 9 is switched to the transformer terminal 4b in S204, a voltage is outputted from the transformer terminal 4b even if a "No" determination is made in S208.

[0085] As described above, with the adapter 3 according to the present embodiment, a voltage control is performed in such a manner that a voltage outputted to the power tool 2 is controlled based on a load on the motor 21. Hence, voltages suitable for kinds of operations can be supplied to the motor 21.

[0086] Especially, if a large electric current flows through the motor 21, the voltage of the battery pack 1 is transformed into the high voltage and outputted to the power tool 2. Hence, when a drill connected with the power tool 2 is temporarily stuck in a workpiece, for example, the power tool 2 can be operated temporarily with high power.

[0087] On the other hand, if a small electric current flows through the motor 21, the voltage of the battery pack 1 is transformed into the low voltage and outputted to the power tool 2. This can prevent that a voltage higher than necessary is supplied to the power tool 2 during a light-load operation such as a final phase of a boring operation and a driving operation of a small screw.

[0088] Further, in the adapter 3 according to the present embodiment, if the duration exceeds a predetermined period and if the number of times of switching exceeds a predetermined number, the controller 6 switches the switch 9 such that the upper plus terminal 42a is connected with the normal terminal 4a. This can prevent burnout of the motor 21 and shortening of lifetime of the battery pack 1 due to application of the high voltage for a long period or in high frequency.

[0089] Further, in the adapter 3 according to the present embodiment, the amount of electric power charged at the super capacitor 8 is displayed so that the charged amount of the capacitor can be recognized. Hence, the workability can be improved.

[0090] While the invention has been described in detail with reference to the above embodiments thereof, it would be apparent to those skilled in the art that various changes and modifications may be made therein without departing from the scope of the claims.

[0091] For example, in the above-described embodiments, the normal terminal 4a, the transformer terminal 4b, the transformer circuit 5, the controller 6, the current detecting resistor 7, the super capacitor 8, the switch 9, the protection IC 10, and the display unit 40 (charge-amount display unit 140) are provided at the adapter 3. However, it is not necessary that all of these components be provided at the adapter 3, but it is only necessary that these components be provided within a power tool system

including the battery pack 1, the power tool 2, and the adapter 3.

[0092] Further, the adapter 3 is not necessary if the connecting portion of the battery pack 1 and the connecting portion of the power tool 2 have shapes that enable connection with each other, or if the nominal voltage of the battery pack 1 and the rated voltage of the power tool 2 are identical. In such cases, it is only necessary that the normal terminal 4a, the transformer terminal 4b, the transformer circuit 5, the controller 6, the current detecting resistor 7, the super capacitor 8, the switch 9, the protection IC 10, and the display unit 40 (charge-amount display unit 140) be provided within a power tool system including the battery pack 1 and the power tool 2.

[0093] For example, when the battery pack 1 can be directly connected to the power tool 2 without adapter 3, the configurations of the adapter 3 may be provided in the battery pack 1 as shown in Figs. 12 and 13. In this configuration, the transformer circuit 5, the controller 6, the super capacitor 8, the switch 9, and the display unit 40 etc. are provided in the battery pack 1 in addition to the assembled battery 11 and the temperature detecting element 14. Note that the identification element 15 is not provided in the battery pack 1 since there is no need for informing the adapter 3 of the information with respect to the battery pack 1.

[0094] Further, the configurations of the adapter 3 may be provided in the power tool 2 as shown in Figs. 14 and 15. In this configuration, the transformer circuit 5, the controller 6, the super capacitor 8, the switch 9, and the display unit 40 etc. are provided in the power tool 2 in addition to the motor 21, the trigger switch 22, the temperature detecting element 25, and the identification element 26. If the motor 21 is a brushless motor, controller 6 may control the motor 21. Specifically, the controller 6 controls a plurality of switching elements (for example, six FETs) connected to the motor 21.

[0095] Note that the protection IC 10 may be provided in not the adapter 3 but the battery pack 1 or the power tool 2 since the protection IC 10 only has to protect the battery pack 1 or the power tool 2. It is preferable that the protection IC 10 that cuts off the current pathway when detecting the overdischarge or the overcharge is provided in the battery pack 1 when detecting the voltage of each of the cells 11a-11d.

[0096] Further, when the configuration of the adapter 3 is provided in the battery pack 1, the controller 6 may detect the voltage of each of the cells 11a-11d to protect the overdischarge, the overcharge, and the overcurrent. In this case, the controller 6 cuts off a cut-off member (for example, a switching element such as an FET) disposed on the current pathway when detecting an abnormal condition.

[0097] Additionally, in the first embodiment, the adapter 3 may be so configured that the transformer voltage is changeable depending on the number of times the "HIGH" button 43 or the "LOW" button 44 is pressed. In this case, an output voltage more suitable for the operation condition of the power tool 2 can be obtained.

[0098] Further, the switch 9 may be switched manually, not automatically, so that the switch 9 can be switched arbitrarily depending on the operation.

[0099] Further, for example, if the "LOW" button 44 is pressed, a voltage of 14.4V may be outputted without performing the above-mentioned voltage increase control.

[0100] Further, in the first embodiment as the second embodiment, the controller 6 may also automatically obtain the nominal voltages of the battery pack 1 and the power tool 2 in accordance with signals of the identification element 15 of the battery pack 1 and the identification element 26 of the power tool 2, and control the transformer circuit 5.

[0101] In addition, the controller 6 may automatically control a transforming operation of the transformer circuit 5 in accordance with signals from the temperature detecting element 14 of the battery pack 1 and from the temperature detecting element 25 of the power tool 2.

[0102] For example, if the temperature of the battery pack 1 or the power tool 2 is high, the controller 6 may stop charging at the super capacitor 8 even when the "HIGH" button 43 is pressed, and may control the full-charge informing unit 45 of the display unit 40 to blink so as to inform the user of a high-temperature standby state. In this way, reduction in lifetime of the battery pack 1 or the power tool 2 due to high temperature can be suppressed.

[0103] Further, the load may be determined based on the signal from the temperature detecting elements 14 and 25 or the rotating number of the motor 21etc. although the load is detected based on the current flowing into the motor 21 in the second embodiment.

[0104] Further, the super capacitor 8 may be charged with a power supplied from a power source, such as a solar battery, other than the battery pack 1.

Claims

[Claim 1] A power tool system comprising:
a secondary battery;
a capacitor configured to supply a power to a motor; and
a transforming unit configured to boost a battery voltage of the secondary battery to a charging voltage, the capacitor being charged with the charging voltage.

[Claim 2] The power tool system according to claim 1, wherein the transforming unit is capable of changing the charging voltage.

[Claim 3] The power tool system according to claim 1, wherein the transforming unit is capable of changing the charging voltage based on a load applied to the motor.

[Claim 4] The power tool system according to claim 1, wherein the transforming unit is capable of arbitrarily changing the charging voltage.

[Claim 5] The power tool system according to claim 3, wherein the transforming unit transforms the battery voltage into a voltage greater than the battery voltage when the load applied to the motor is equal to or greater than a first predetermined value, and the transforming unit transforms the battery voltage into a voltage smaller than the battery voltage when the load applied to the motor is equal to or smaller than a second predetermined value smaller than the first predetermined value.

[Claim 6] The power tool system according to claim 1, further comprising a switch for switching a voltage supplied to the motor to either one of the battery voltage and the charging voltage.

[Claim 7] A power tool system comprising:
a power tool including a motor;
a battery pack;
a capacitor configured to be charged with a charging voltage;
an output terminal including: a first output terminal disposed between the battery pack and the motor to output a battery voltage of the battery pack to the motor; and a second output terminal disposed between the capacitor and the motor to output the charging voltage to the motor; and
a control unit configured to allow one of the output terminal to perform the output operation and configured to prevent remaining one of the output terminal to perform the output operation.

[Claim 8] The power tool system according to claim 7, further comprising:

a transforming unit disposed between the battery pack and the capacitor to transform the battery voltage into the charging voltage different from a rated voltage of the power tool; and

a receiving unit configured to receive an output changing instruction,

wherein the control unit allows the second output terminal to perform the output operation and prevents the first output terminal to perform the output operation, when the receiving unit receives the output instruction.

[Claim 9] The power tool system according to claim 8, further comprising a storing unit configured to store a number of times the second output terminal outputs the charging voltage to the motor,

wherein the transforming unit transforms the battery voltage into the charging voltage higher than the rated voltage when the receiving unit receives the output changing instruction, and

wherein the control unit prevents the second output terminal from performing the output operation when the number of times is larger than a predetermined number of times.

[Claim 10] The power tool system according to claim 8, further comprising a measuring unit configured to measure a period during which the second output terminal continues to output the charging voltage to the motor,

wherein the transforming unit transforms the battery voltage into the charging voltage higher than the rated voltage when the receiving unit receives the output changing instruction, and

wherein the control unit prevents the second output terminal from performing the output operation when the period is longer than a predetermined period.

[Claim 11] The power tool system according to claim 7, further comprising a charge-amount informing unit configured to inform a user of a charge amount of the capacitor.

[Claim 12] The power tool system according to claim 7, further comprising a control unit configured to determine, based on a load applied to the motor, the output terminal that performs the outputting operation.

[Claim 13] The power tool system according to claim 7, further comprising an adapter connected between the battery pack and the motor,

wherein the capacitor, the output terminal and the control unit are accommodated in the adapter.

[Claim 14] A power tool connectable to a battery pack, the power tool comprising:

a motor; and

a capacitor configured to be charged with a charging voltage;
an output terminal including: a first output terminal disposed between the battery pack and the motor to output a battery voltage of the battery pack to the motor; and a second output terminal disposed between the capacitor and the motor to output the charging voltage to the motor; and
a control unit configured to allow one of the output terminal to perform the output operation and configured to prevent remaining one of the output terminal to perform the output operation.

[Claim 15] A battery pack connectable to a motor of a power tool, the battery pack comprising:
a battery;
a capacitor configured to be charged with a charging voltage;
an output terminal including: a first output terminal disposed between the battery and the motor to output a battery voltage of the battery to the motor; and a second output terminal disposed between the capacitor and the motor to output the charging voltage to the motor; and
a control unit configured to allow one of the output terminal to perform the output operation and configured to prevent remaining one of the output terminal to perform the output operation.

[Claim 16] An adapter connectable between a battery pack and a motor of a power tool, the adapter comprising:
a capacitor configured to be charged with a charging voltage; and
an output terminal including: a first output terminal disposed between the battery pack and the motor to output a battery voltage of the battery pack to the motor; and a second output terminal disposed between the capacitor and the motor to output the charging voltage to the motor; and
a control unit configured to allow one of the output terminal to perform the output operation and configured to prevent remaining one of the output terminal to perform the output operation.

[Claim 17] An adapter connectable between a battery pack and a motor of a power tool, the adapter comprising:
a capacitor configured to be connected to the motor; and
a transforming unit configured to boost a battery voltage of the battery pack to a charging voltage, the capacitor being charged with the charging voltage.

[Claim 18] The adapter according to claim 17, wherein the transforming unit is

capable of changing the charging voltage.

[Claim 19] The adapter according to claim 17, wherein the transforming unit is capable of changing the charging voltage based on a load applied to the motor.

[Claim 20] The adapter according to claim 17, wherein the transforming unit is capable of arbitrarily changing the charging voltage.

[Claim 21] The adapter according to claim 17, further comprising a switch for switching a voltage supplied to the motor to either one of the battery voltage and the charging voltage.

FIG. 1

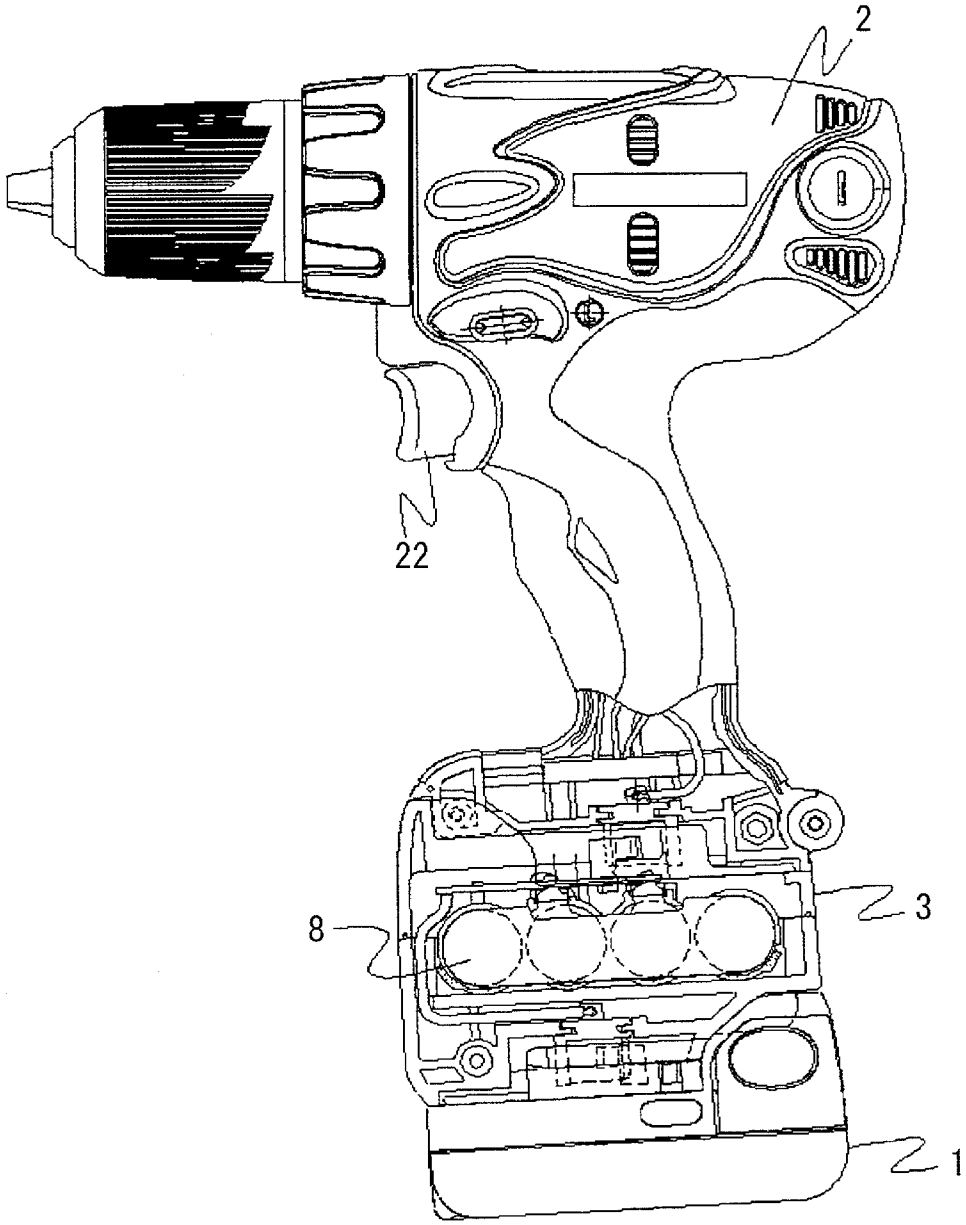


FIG. 2

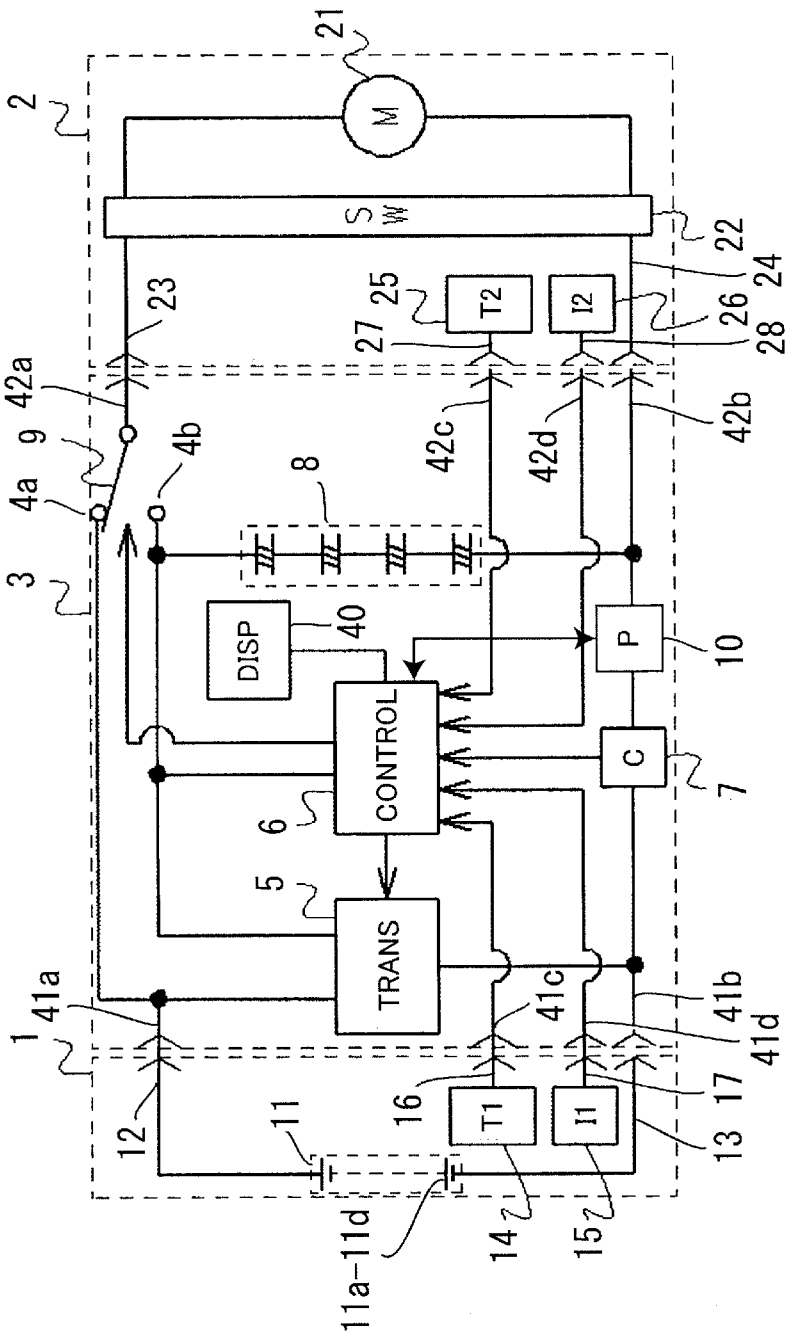

21
M
2
S
W
22
23
24
25
T2
I2
26
27
28
42a
9
4a
4b
8
42c
42d
42b
3
DISP
40
P
10
CONTROL
C
7
6
5
TRANS
41a
41c
41b
41d
1
12
11
16
T1
I1
17
13
11a-11d
14
15

FIG. 3

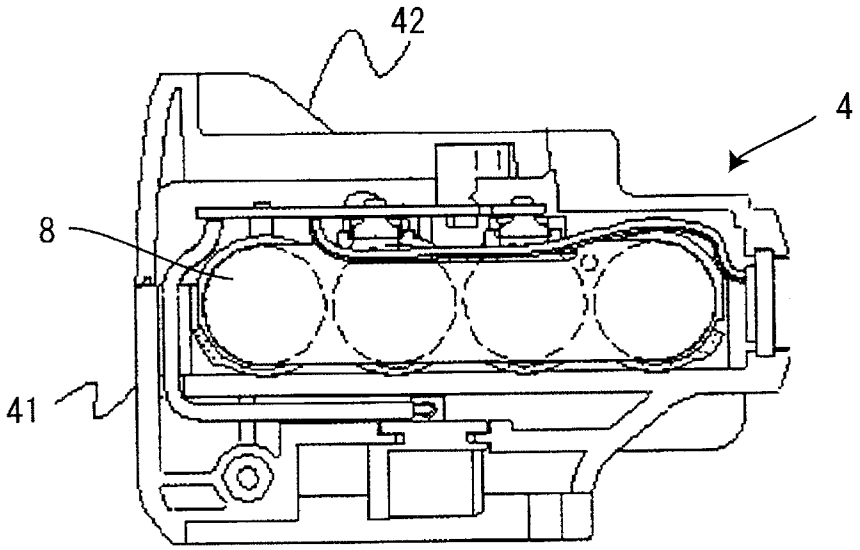


FIG. 4

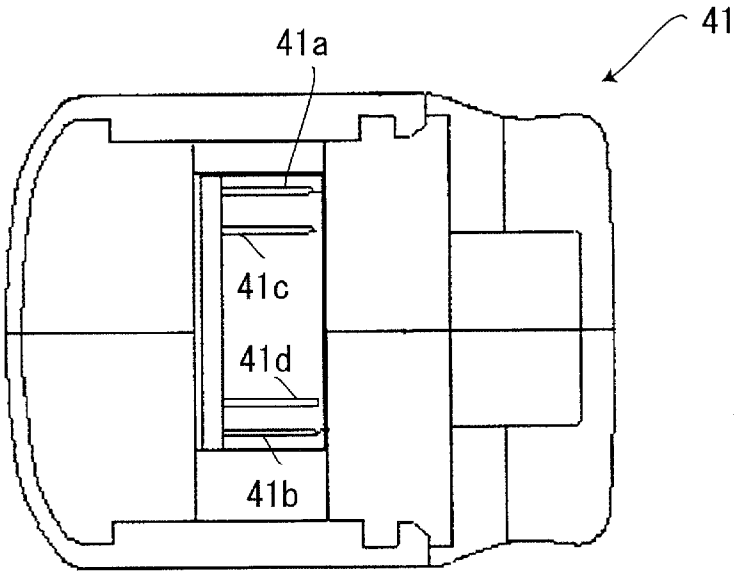


FIG. 5

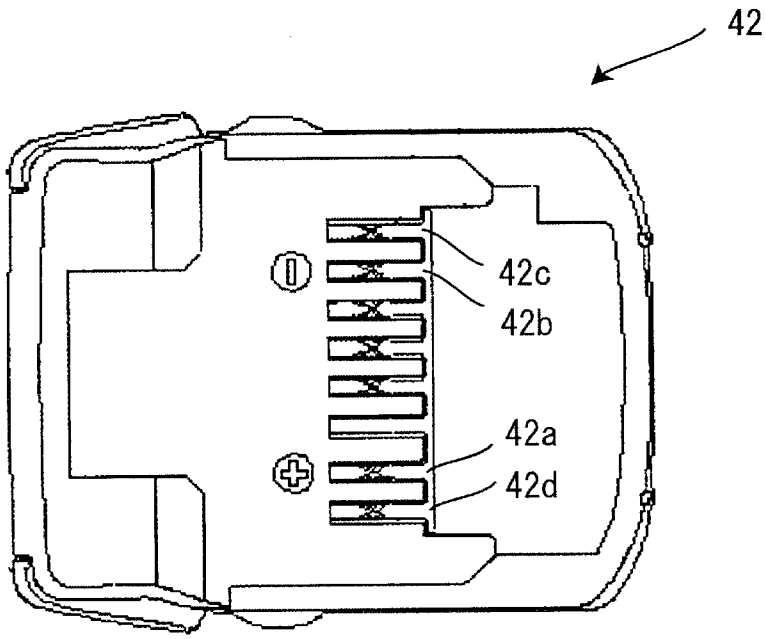


FIG. 6

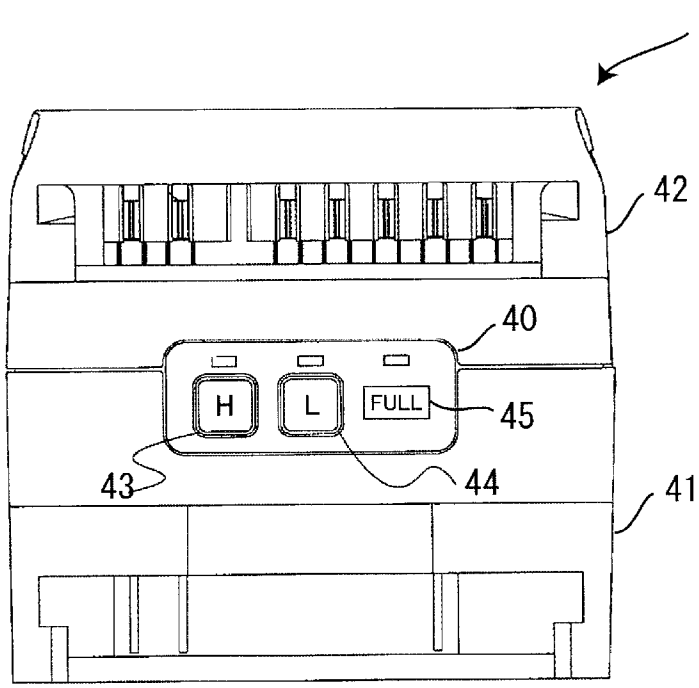


FIG. 7

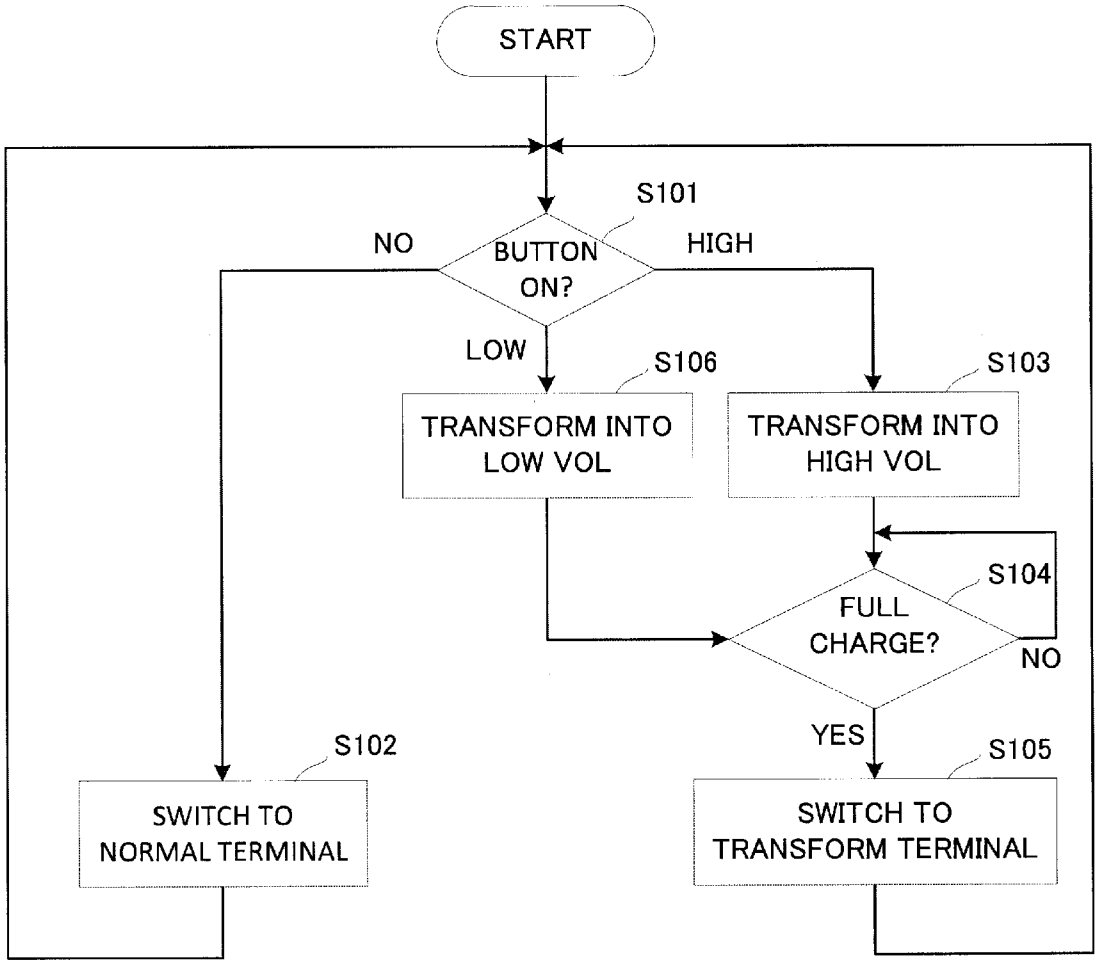

START
S101
BUTTON ON?
NO
HIGH
LOW
S106
TRANSFORM INTO LOW VOL
S103
TRANSFORM INTO HIGH VOL
S104
FULL CHARGE?
NO
YES
S102
SWITCH TO NORMAL TERMINAL
S105
SWITCH TO TRANSFORM TERMINAL

FIG. 8

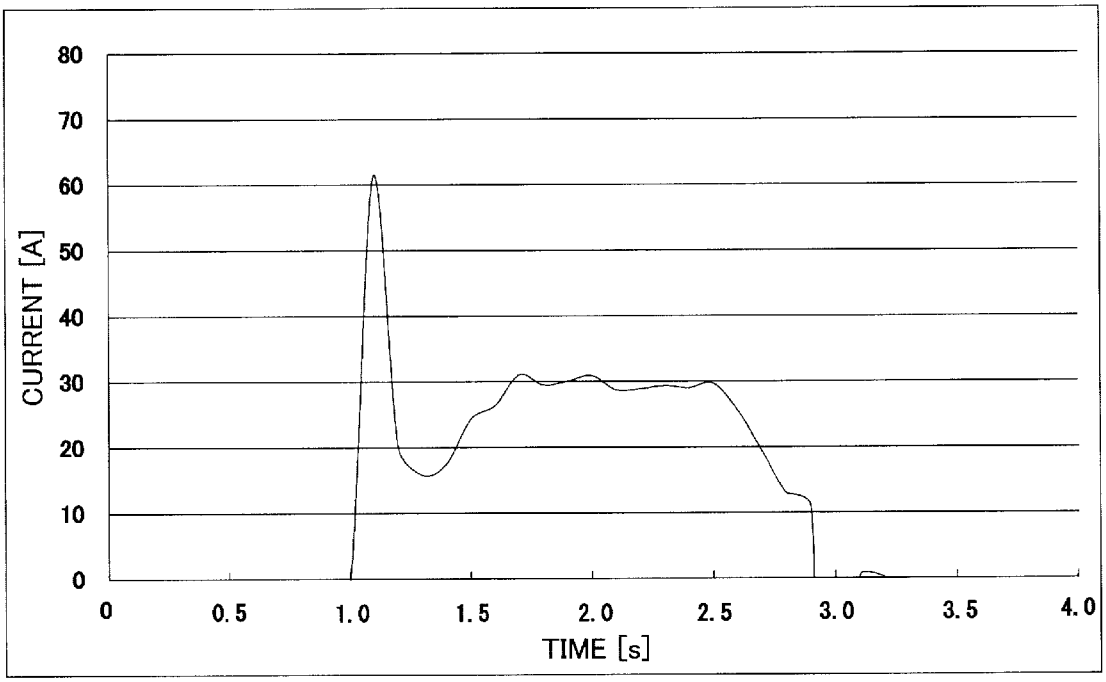


FIG. 9

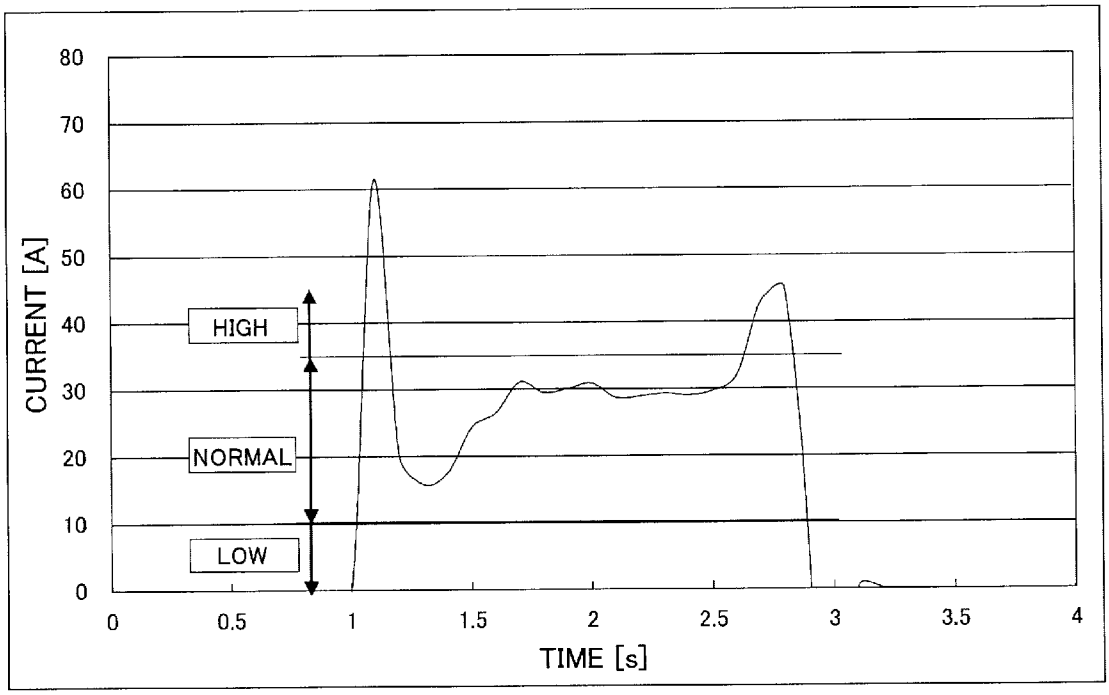

80
70
60
50
40
30
20
10
0
CURRENT [A]
HIGH
NORMAL
LOW
0
0.5
1
1.5
2
2.5
3
3.5
4
TIME [s]

FIG. 10

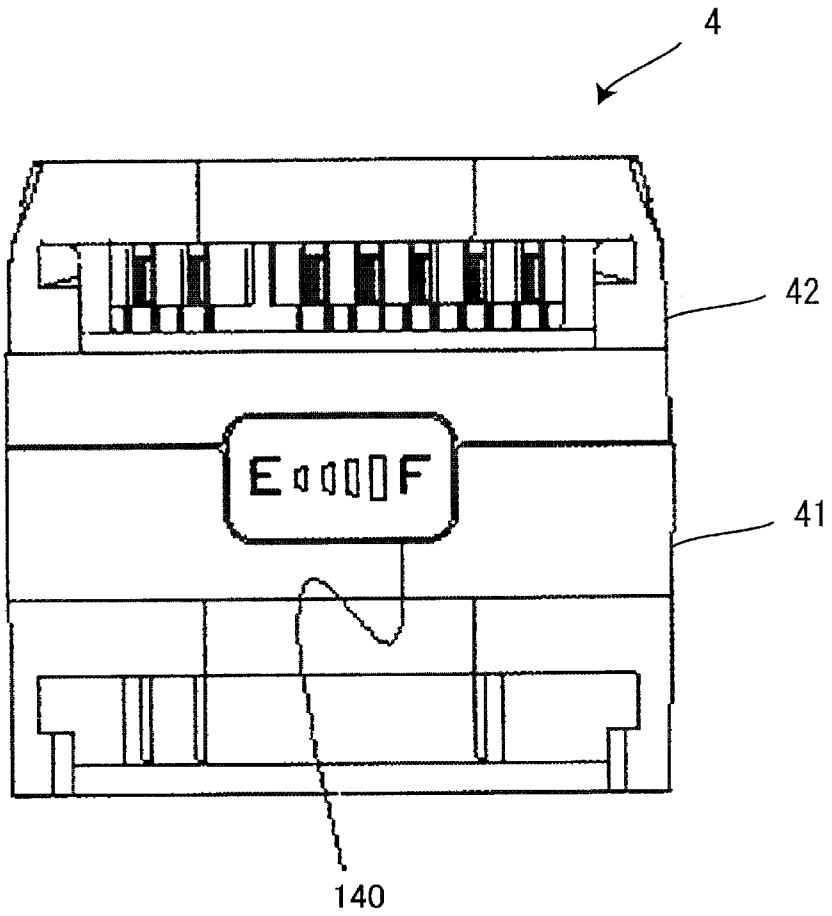


FIG. 11

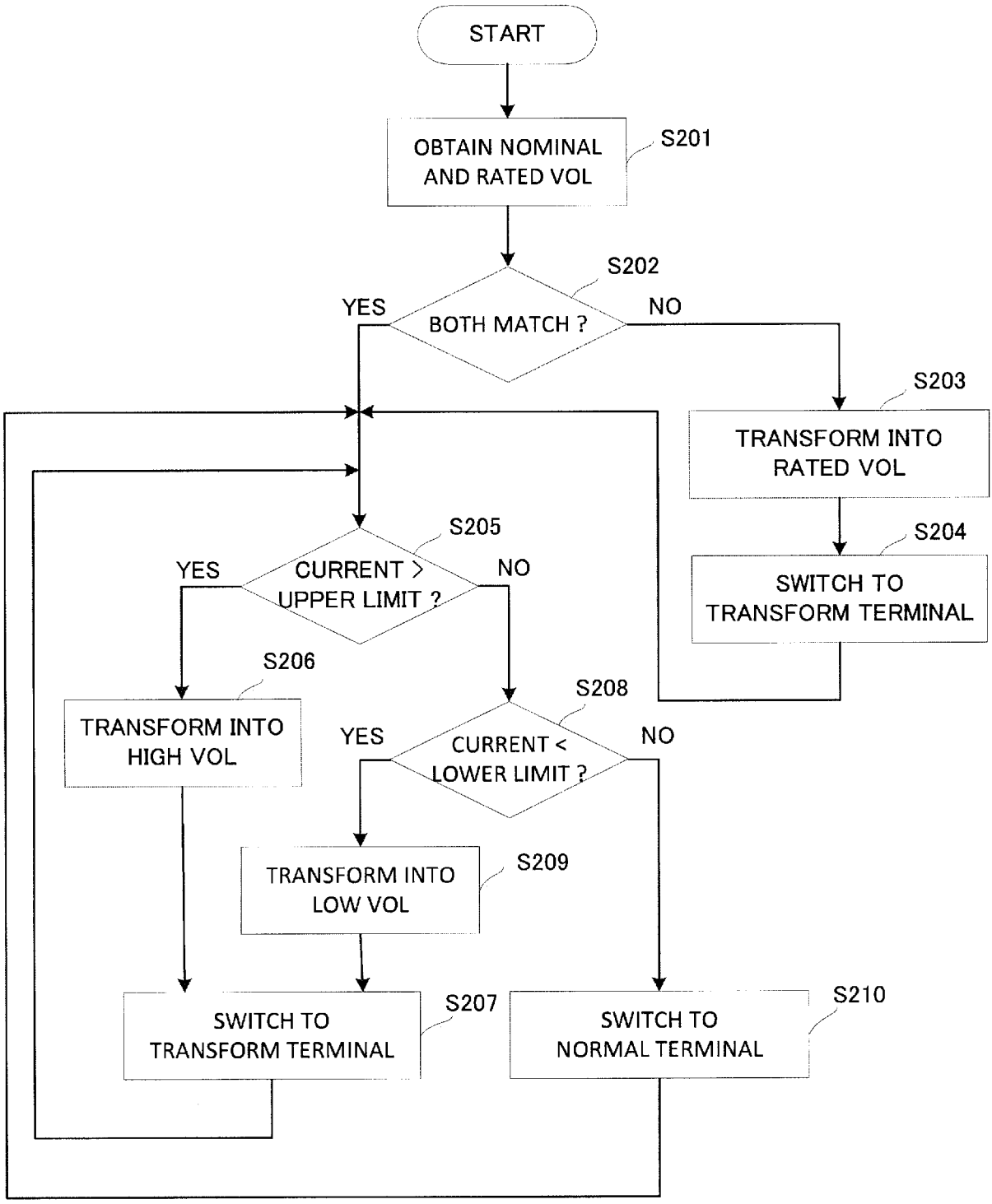

START
OBTAIN NOMINAL AND RATED VOL
S201
S202
BOTH MATCH ?
YES
NO
S203
TRANSFORM INTO RATED VOL
S204
SWITCH TO TRANSFORM TERMINAL
S205
CURRENT > UPPER LIMIT ?
YES
NO
S206
TRANSFORM INTO HIGH VOL
S208
CURRENT < LOWER LIMIT ?
YES
NO
TRANSFORM INTO LOW VOL
S209
SWITCH TO TRANSFORM TERMINAL
S207
SWITCH TO NORMAL TERMINAL
S210

FIG. 12

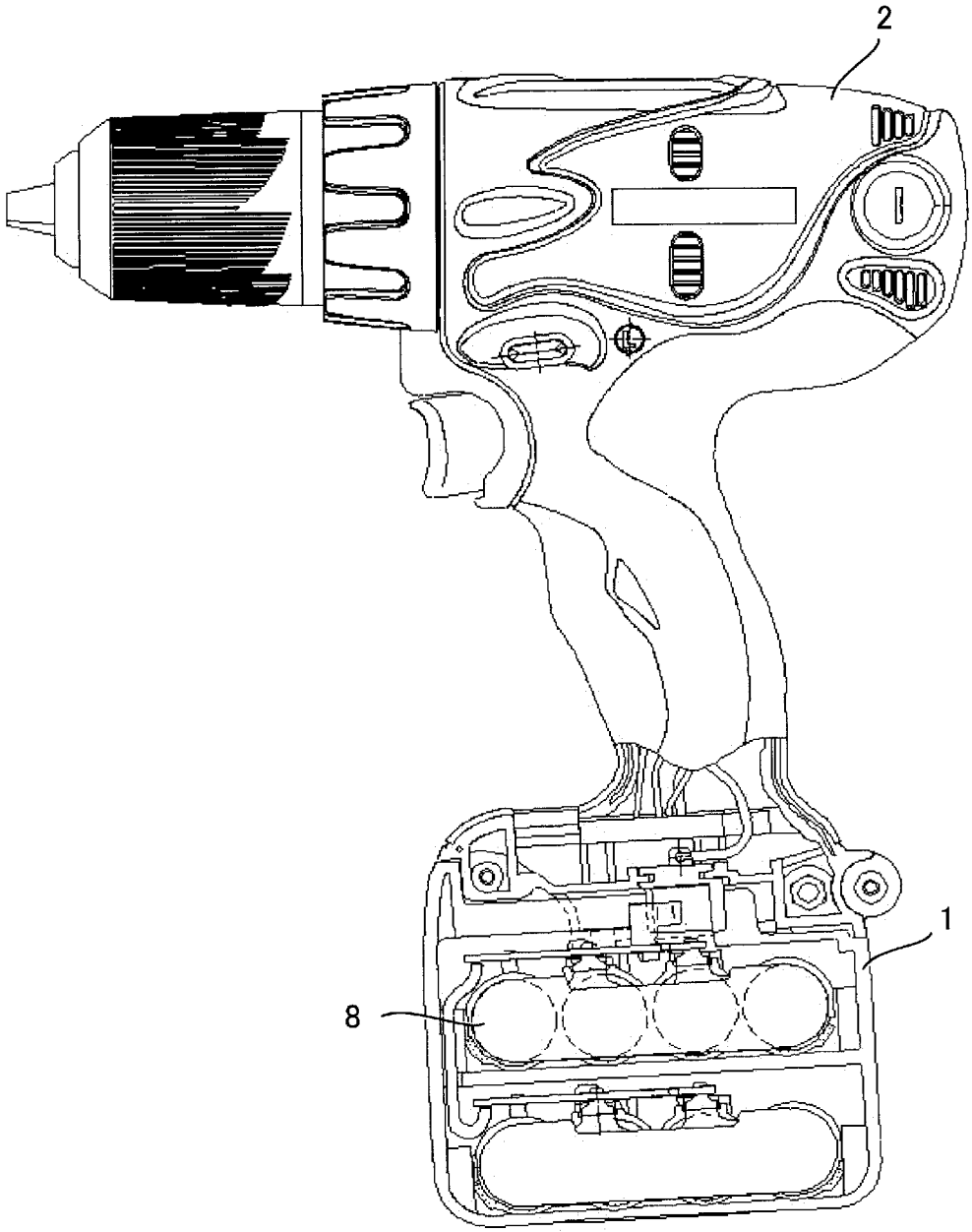


FIG. 13

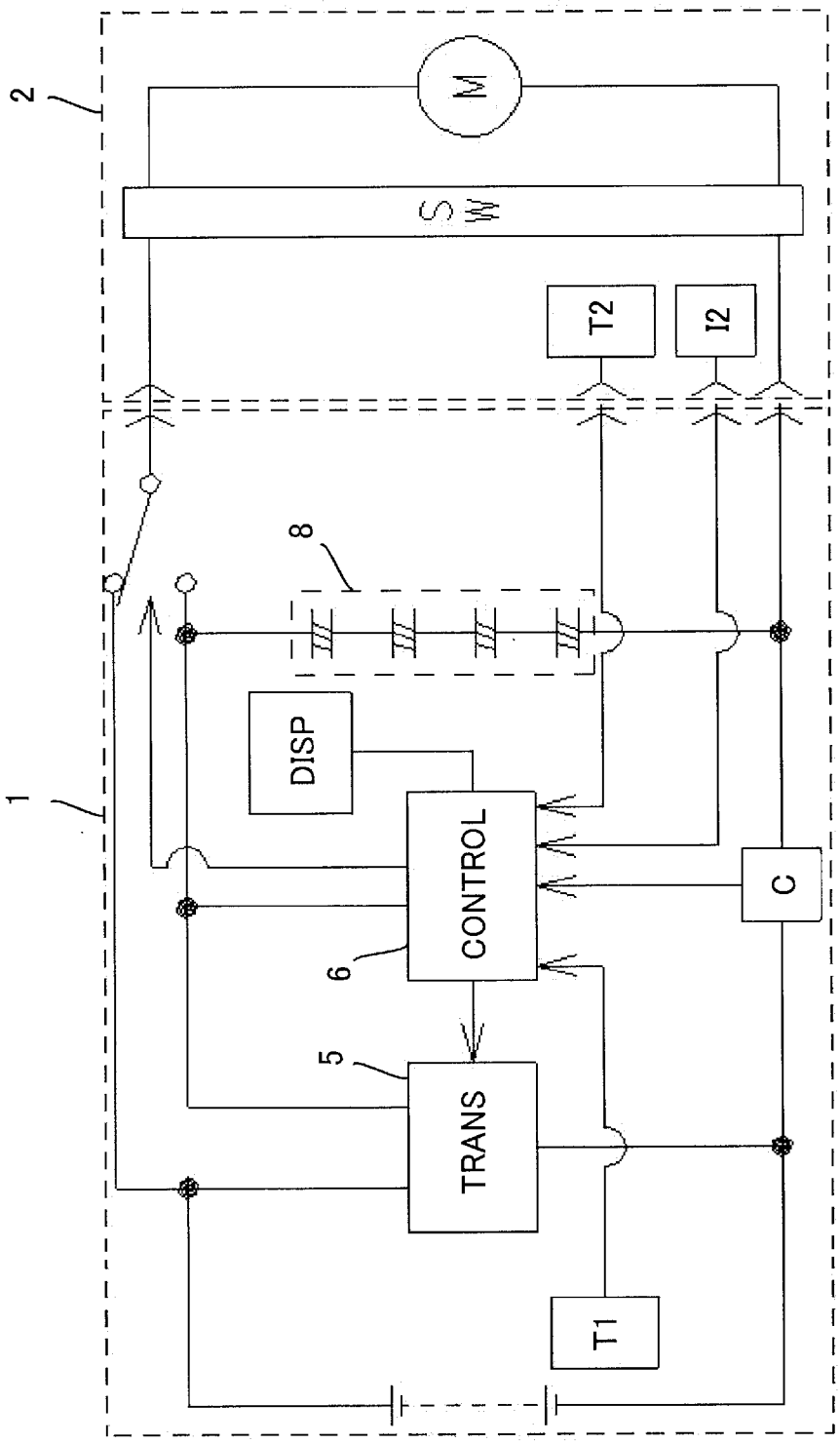


FIG. 14

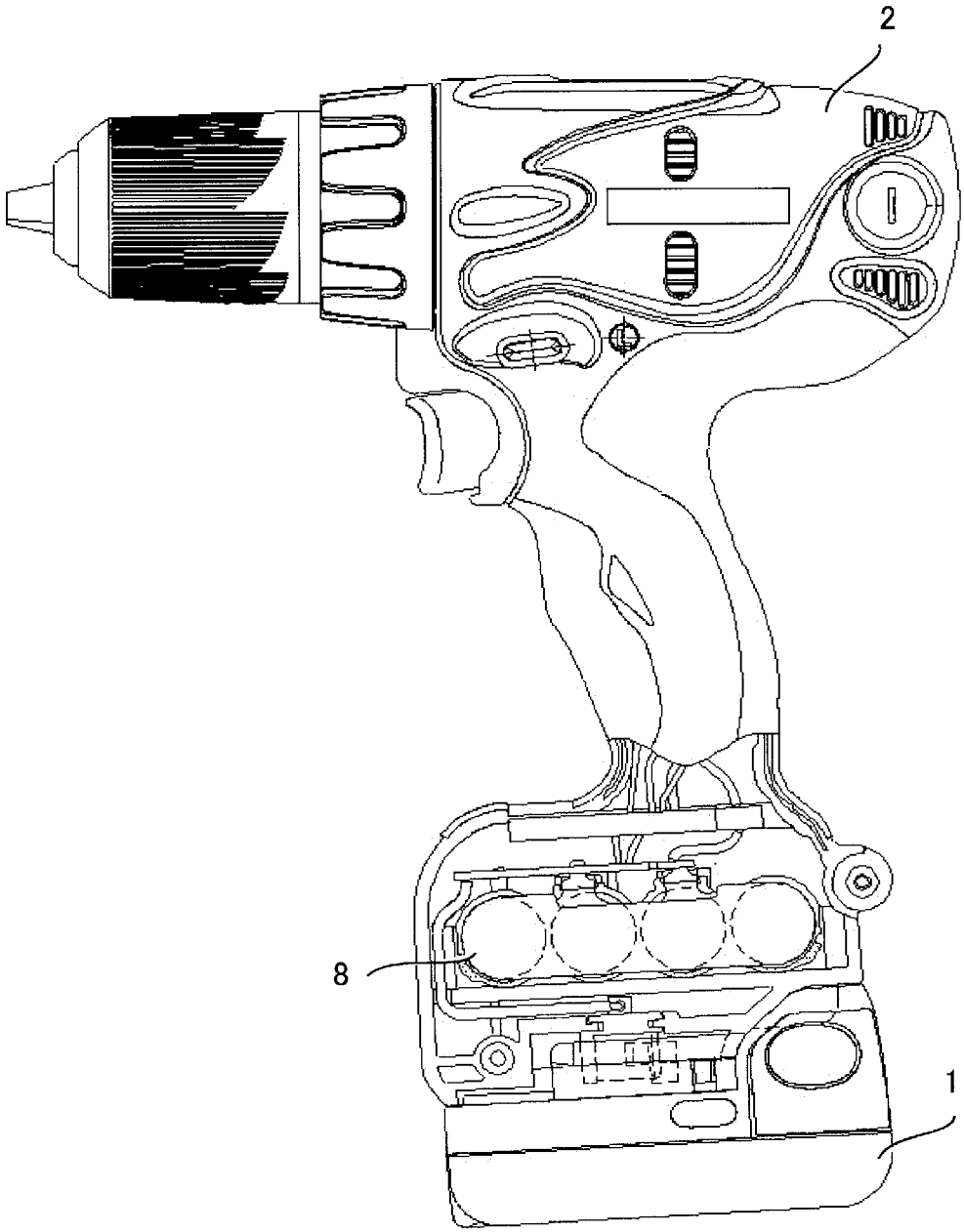
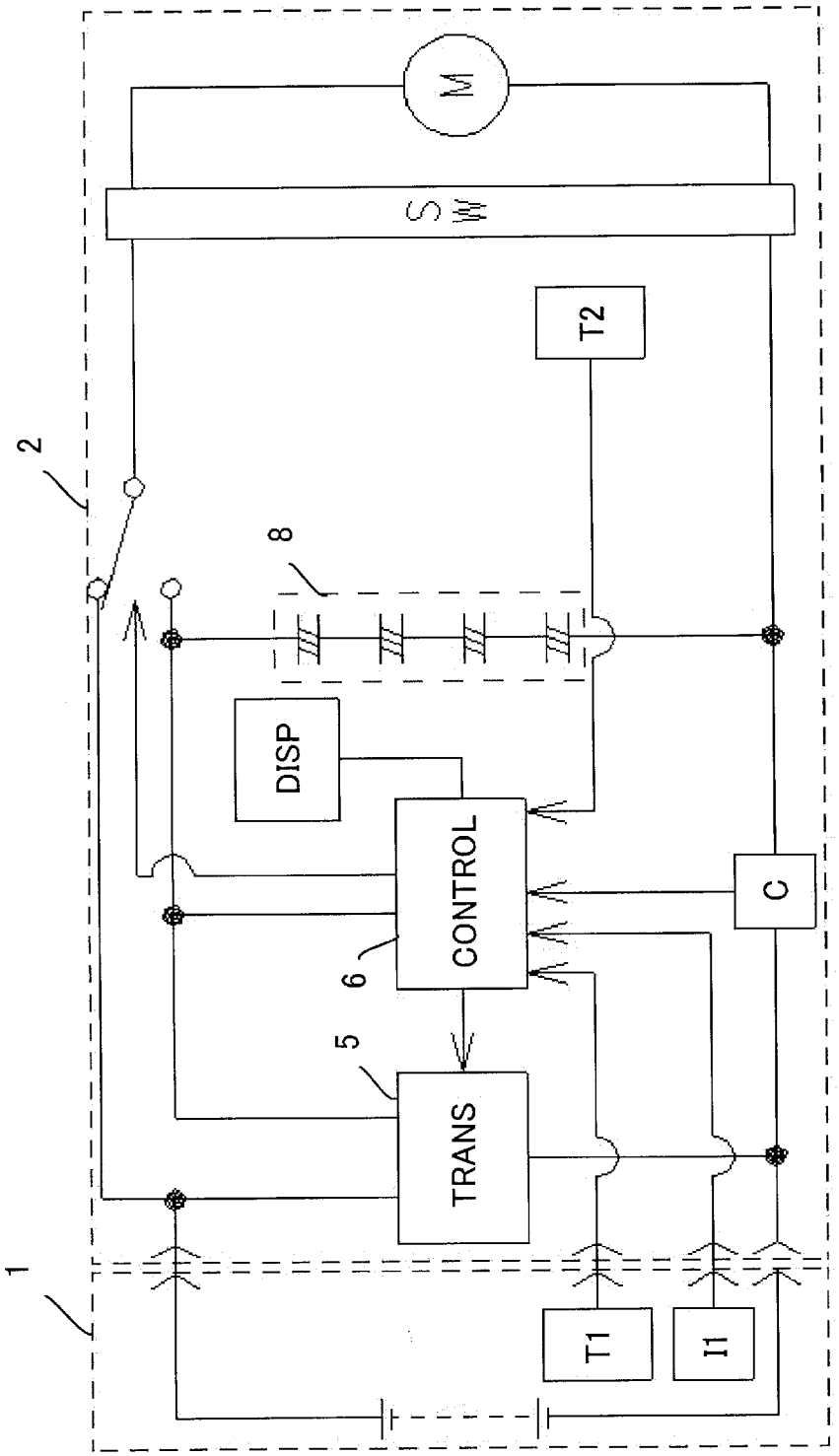


FIG. 15



INTERNATIONAL SEARCH REPORT

International application No
PCT/JP2012/001228

A. CLASSIFICATION OF SUBJECT MATTER
INV. H02J7/00 H01M10/44 B23B45/00 B25F5/00
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 H02J B23B B25F

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, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2009/096416 A1 (TONEGAWA HIROMI [JP] ET AL) 16 April 2009 (2009-04-16) paragraphs [0079] - [0081]; figure 4	1-21
X	US 2006/133007 A1 (SHIUE LIH-REN [TW] ET AL) 22 June 2006 (2006-06-22) paragraphs [0022], [0035], [0049]; claim 8; figure 2	1-21
X	US 2006/108980 A1 (OOKUBO SHINICHI [JP] ET AL) 25 May 2006 (2006-05-25) paragraphs [0018] - [0021]; claim 3; figure 3	1-21
X	US 2009/108806 A1 (TAKANO NOBUHIRO [JP] ET AL) 30 April 2009 (2009-04-30) paragraphs [0003], [0138], [0193]; figures 5,14	1-21

-/--

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

[X] See patent family annex.

* Special categories of cited documents :

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

"E" earlier document 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
18 April 2012	27/04/2012

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	Heusler, Nikolaus

Form PCT/ISA/210 (second sheet) (April 2005)

INTERNATIONAL SEARCH REPORT

International application No
PCT/JP2012/001228

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2003/214269 A1 (SHIUE LIH-REN [TW] ET AL) 20 November 2003 (2003-11-20) abstract; figures paragraphs [0002], [0019]	1-21
A	US 2009/289589 A1 (FUJINO TAKESHI [JP] ET AL) 26 November 2009 (2009-11-26) paragraphs [0032] - [0034]; figure 1	1-21

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/JP2012/001228

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2009096416 A1	16-04-2009	CN 101326076 A	17-12-2008
		EP 1957312 A2	20-08-2008
		JP 2007185083 A	19-07-2007
		US 2009096416 A1	16-04-2009
		WO 2007066198 A2	14-06-2007
US 2006133007 A1	22-06-2006	JP 2006340540 A	14-12-2006
		US 2006133007 A1	22-06-2006
US 2006108980 A1	25-05-2006	AU 2003280826 A1	23-06-2004
		JP 2004181588 A	02-07-2004
		US 2006108980 A1	25-05-2006
		WO 2004050307 A1	17-06-2004
US 2009108806 A1	30-04-2009	JP 2008177138 A	31-07-2008
		US 2009108806 A1	30-04-2009
US 2003214269 A1	20-11-2003	EP 1363386 A1	19-11-2003
		JP 3756850 B2	15-03-2006
		JP 2003333871 A	21-11-2003
		US 2003214269 A1	20-11-2003
US 2009289589 A1	26-11-2009	JP 2010004732 A	07-01-2010
		US 2009289589 A1	26-11-2009