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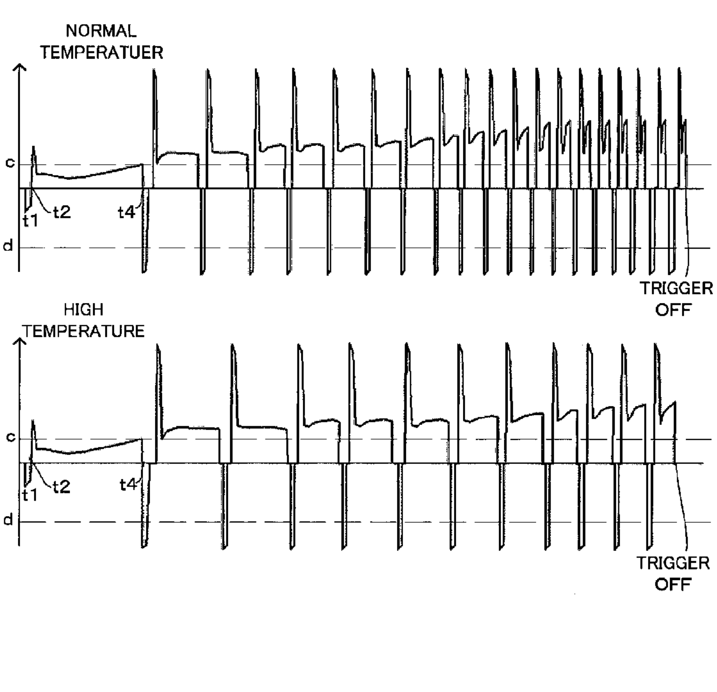
(54) Title: POWER TOOL

FIG. 14



(57) Abstract: An electronic pulse driver (1) includes a motor (3), a hammer (4), an anvil (5), an end tool mounting unit (51), a power supply unit (24), a temperature detecting unit, and a controller (72). The hammer (4) is drivingly rotatable in forward and reverse directions by the motor (3). The anvil (5) is provided separately from the hammer and rotated upon striking of the hammer. The power supply unit (24) alternately supplies a forward electric power and a reverse electric power to the motor in a first cycle. The temperature detecting unit is configured to detect a temperature of the motor. The controller (72) is configured to control the power supply unit to alternately supplies the forward electric power and the reverse electric power in a second cycle longer than the first cycle when the temperature of the motor detected by the temperature detecting unit increases to a prescribed value.

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DESCRIPTION

Title of Invention

Power Tool

Cross Reference to Related Application

[0001] This application claims priority from Japanese Patent Application No. 2010-083756 filed March 31, 2010. The entire content of this priority application is incorporated herein by reference.

Technical Field

[0002] The present invention relates to a power tool and an electric power tool, and particularly to an electronic pulse driver that outputs a rotary drive force.

Background Art

[0003] One conventional power tool is an impact driver provided with a motor that rotates in a fixed direction. The motor drives a hammer to rotate in a fixed direction, and the hammer contacts and rotates an anvil in the same fixed direction.

Citation List

Patent Literature

[0004] PLT1: Japanese Patent Application Publication No. 2008-307664

Summary of Invention

Technical Problem

[0005] This conventional power tool controls the motor without regard for the temperature of components in the housing. In addition, in a power tool capable of driving the motor in forward and reverse directions, the motor can produce a large amount of heat. In such power tools, the motor can become too hot when the power tool does not account for internal temperature when controlling the motor.

Solution to Problem

[0006] Therefore, it is an object of the present invention to provide an electric power tool and an electronic pulse driver capable of controlling a motor based on the internal temperature of the housing. This type of power tool can suppress rises in the internal temperature of the housing.

[0007] In order to attain above and other objects, the present invention provides an electronic pulse driver. The electronic pulse driver includes a motor, a hammer, an anvil, an end tool mounting unit, a power supply unit, a temperature detecting unit, and a controller. The motor is rotatable in a forward and a reverse directions. The hammer is drivingly rotatable in the forward and the reverse directions by the motor. The anvil is provided separately from the hammer and rotated upon striking of the hammer against the anvil as a result of a rotation of the hammer in the forward direction after rotation of the hammer in the reverse direction for obtaining a distance for acceleration in the forward direction. The end tool mounting unit mounts thereon an end tool and transmits a rotation of the anvil to the end tool. The power supply unit alternately supplies a forward electric power and a reverse electric power to the motor in a first cycle. The temperature detecting unit is configured to detect a temperature of the motor. The controller is configured to control the power supply unit to alternately supplies the forward electric power and the reverse electric power in a second cycle longer than the first cycle when the temperature of the motor detected by the temperature detecting unit increases to a prescribed value.

[0008] With this configuration, the controller controls the power supply unit to switch a period for alternately supplying the forward electric power and the reverse electric power from the first cycle to the second cycle when the temperature is increased, thereby increasing the overall service life of the electronic pulse driver.

[0009] According to another aspect, the present invention provides an electric power tool. The electric power tool includes a motor, an output unit, a housing, a temperature detecting unit, and a controller. The output unit is driven by the motor. The housing accommodates therein the motor. The temperature detecting unit is configured to detect a temperature of a component in the housing. The controller is configured to change a control mode to the motor based on the temperature detected by the temperature detecting unit.

[0010] With this construction, the electric power tool can modify the amount of electric power supplied to the motor based on the internal temperature of the housing to prevent the internal temperature from rising too high. Accordingly, the electric power tool can suppress damage to components within the housing caused by high internal temperatures.

[0011] According to still another aspect, the present invention provides an electric power tool. The electric power tool includes a motor unit, an output unit, a housing, a temperature detecting unit, and a controller. The output unit is driven by the motor unit. The housing accommodates therein the motor unit. The temperature detecting unit is configured to detect a temperature of the motor unit. The controller is configured to change electric power to be supplied to the motor unit based on the temperature detected by the temperature detecting unit.

[0012] With this construction, the electric power tool can modify the amount of electric power supplied to the motor unit based on the temperature in the motor unit, thereby preventing the temperature of the motor unit from rising too high. Accordingly, the electric power tool can suppress damage to the motor unit caused by high temperatures.

[0013] It is preferable that the electric power tool further includes a hammer connected to the motor unit, and an anvil against which the hammer strikes. The hammer strikes the anvil at a first interval when the detected temperature is at a first value, whereas the hammer strikes the anvil at a second interval longer than the first interval when the detected temperature is at a second value higher than the first value.

[0014] With this construction, the electric power tool reduces load when the temperature in the motor is high to prevent the temperature in the motor from rising. Accordingly, the electric power tool can suppress damage to the motor caused by excessively high temperatures.

[0015] According to still another aspect, the present invention provides an electric power tool. The electric power tool includes a motor, an output unit, a housing, a temperature detecting unit, and a controller. The motor is intermittently driven. The output unit is driven by the motor. The housing accommodates therein the motor. The temperature detecting unit is configured to detect a temperature of a component accommodated in the housing. The controller is configured to change an intermittently driving cycle of the motor based on the temperature detected by the temperature detecting unit.

Advantageous Effects of Invention

[0016] As described above, an electric power tool, and an electronic pulse driver capable of controlling a motor based on the internal temperature of the housing can be provided.

[0017]

Brief Description of Drawings

[0018] In the drawings;

[0019] Fig. 1 is a cross-sectional view of an electronic pulse driver according to a first embodiment of the present invention;

[0020] Fig. 2 is a block diagram of the electronic pulse driver;

[0021] Fig. 3 is cross-sectional views of the electronic pulse driver taken along the plane and viewed in the direction indicated by the arrows III in Fig. 1;

[0022] Fig. 4 is a graph illustrating a control process of the electronic pulse driver when a fastener is tightened in a drill mode;

[0023] Fig. 5 is a graph illustrating the control process when a bolt is tightened in a clutch mode;

[0024] Fig. 6 is a illustrating the control process when an wood screw is tightened in the clutch mode;

[0025] Fig. 7 is a graph illustrating the control process for tightening a bolt in a pulse mode;

[0026] Fig. 8 is a graph illustrating the control process when not shifting to a second pulse mode while tightening a wood screw in the pulse mode;

[0027] Fig. 9 is a graph illustrating the control process when shifting to the second pulse mode while tightening a wood screw in the pulse mode;

[0028] Fig. 10 is a flowchart illustrating steps in the control process when tightening a fastener in the clutch mode;

[0029] Fig. 11 is a flowchart illustrating steps in the control process when tightening a fastener in the pulse mode;

[0030] Fig. 12 is graphs illustrating how threshold values are modified when tightening a wood screw in a clutch mode according to a second embodiment of the present invention;

[0031] Fig. 13 is graphs illustrating how threshold values are modified when tightening a wood screw in a pulse mode according to the second embodiment;

[0032] Fig. 14 is graphs illustrating how periods for switching between forward and reverse rotations are modified when tightening a wood screw in a pulse mode according to a third embodiment of the present invention;

[0033] Fig. 15 is a flowchart illustrating steps in a control process when tightening a fastener in a pulse mode according to a modification of the present invention;

[0034] Fig. 16 is a cross-sectional view of an electronic pulse driver according to a fourth embodiment of the present invention;

[0035] Fig. 17 is a cross-sectional views of the electronic pulse driver 1 taken along the plane and viewed in the direction indicated by the arrows X VII in Fig. 16 according to the fourth embodiment; and

[0036] Fig. 18 is a flowchart illustrating steps in a control process when loosing a fastener in a pulse mode according to the fourth embodiment.

Description of Embodiments

[0037] Next, a power tool according to a first embodiment of the present invention will be described while referring to Figs. 1 through 11. Fig. 1 shows an electronic pulse driver 1 serving as the power tool of the first embodiment. As shown in Fig. 1, the electronic pulse driver 1 is primarily configured of a housing 2, a motor 3, a hammer unit 4, an anvil unit 5, and a switch mechanism 6. The housing 2 is formed of a resin material and constitutes the outer shell of the electronic pulse driver 1. The housing 2 is configured primarily of a substantially cylindrical body section 21, and a handle section 22 extending from the body section 21.

[0038] As shown in Fig. 1, the motor 3 is disposed inside the body section 21 and oriented with its axis aligned in the longitudinal direction of the body section 21. The hammer unit 4 and the anvil unit 5 are juxtaposed on one axial end of the motor 3. In the following description, forward and rearward directions are defined as directions parallel to the axis of the motor 3, with the forward direction (i.e., the direction toward the front side of the electronic pulse driver 1) being from the motor 3 toward the hammer unit 4 and anvil unit 5. A downward direction is defined as the direction from the body section 21 toward the handle section 22, and left and right directions are defined as directions orthogonal to the forward and rearward directions and the upward and downward directions.

[0039] A hammer case 23 is disposed at a forward position within the body section 21 for housing the hammer unit 4 and the anvil unit 5. The hammer case 23 is formed of a metal and is substantially funnel-shaped with its diameter growing gradually narrower toward the front end, which faces forward. An opening 23a is formed in the front end of the hammer case 23 so that an end tool mounting part 51 described later can protrude forward through the opening 23a. The hammer case 23 also has a bearing metal 23A provided on the inner wall of the hammer case 23 defining the opening 23a for rotatably supporting the anvil unit 5.

[0040] A light 2A is held in the body section 21 at a position beneath the hammer case 23 and near the opening 23a. When a bit (not shown) is mounted in the end tool mounting part 51 described later as the end tool, the light 2A can irradiate light near the front end of the bit. A dial 2B is also provided on the body section 21 below the light 2A. The dial 2B serves as a switching part that is rotatably operated by the operator. Since the body section 21 is constructed to retain the light 2A, there is no particular need to provide a separate part for holding the light 2A. Hence, the light 2A can be reliably held through a simple construction. The light 2A and the dial 2B are both disposed on the body section 21 at positions substantially in the left-to-right center thereof. An intake and an outlet (not shown) are also formed in the body section 21 through which external air is drawn into and discharged from the body section 21 by a fan 32 described later.

[0041] The handle section 22 is integrally configured with the body section 21 and extends downward from a position on the body section 21 in substantially the front-to-rear center thereof. The switch mechanism 6 is built into the handle section 22. A battery 24 is detachably mounted on the bottom end of the handle section 22 for supplying power to the motor 3 and the like. A trigger 25 is provided in the base portion of the handle section 22 leading from the body section 21 at a position on the front side serving as the location of user operations. Further, the trigger 25 is disposed beneath the dial 2B and in proximity to the same. Accordingly, a user can operate both the trigger 25 and the dial 2B with a single finger. The user switches an operating mode of the electronic pulse driver 1 among a drill mode, a clutch mode, and a pulse mode described later by rotating the dial 2B.

[0042] A display unit 26 is disposed on top of the body section 21 at the rear edge thereof. The display unit 26 indicates which of the drill mode, the clutch mode, and the pulse mode described later is currently selected.

[0043] As shown in Fig. 1, the motor 3 is a brushless motor primarily configured of a rotor 3A including an output shaft 31, and a stator 3B disposed in confrontation with the rotor 3A. The motor 3 is arranged in the body section 21 so that the axis of the output shaft 31 is oriented in the front-to-rear direction. The output shaft 31 protrudes from both front and rear ends of the rotor 3A and is rotatably supported in the body section 21 at the protruding ends by bearings. The fan 32 is disposed on the portion of the output shaft 31 protruding forward from the rotor 3A. The fan 32 rotates integrally and coaxially with the output shaft 31. A pinion gear 31A is provided on the forwardmost end of the portion of the output shaft 31 protruding forward from the rotor 3A. The pinion gear 31A rotates integrally and coaxially with the output shaft 31.

[0044] The hammer unit 4 is housed in the hammer case 23 on the front side of the motor 3. The hammer unit 4 primarily includes a gear mechanism 41, and a hammer 42. The gear mechanism 41 includes a single outer ring gear 41A, and two planetary gear mechanisms 41B and 41C that share the same outer ring gear 41A. The outer ring gear 41A is housed in the hammer case 23 and fixed to the body section 21. The planetary gear mechanism 41B is disposed in the outer ring gear 41A and is engaged with the same. The planetary gear mechanism 41B uses the pinion gear 31A as a sun gear. The planetary gear mechanism 41C is also disposed in the outer ring gear 41A and is engaged with the same. The planetary gear mechanism 41C is positioned forward of the planetary gear mechanism 41B and uses the output shaft of the planetary gear mechanism 41B as a sun gear.

[0045] The hammer 42 is defined in the front surface of a planet carrier constituting the planetary gear mechanism 41C. As shown in Fig. 3, the hammer 42 includes a first engaging protrusion 42A disposed at a position offset from the rotational center of the planet carrier and protruding forward, and a second engaging protrusion 42B disposed on the opposite side of the rotational center of the planet carrier from the first engaging protrusion 42A.

[0046] The anvil unit 5 is disposed in front of the hammer unit 4 and primarily includes the end tool mounting part 51, and an anvil 52. The end tool mounting part 51 is cylindrical in shape and rotatably supported in the opening 23a of the hammer case 23 through the bearing metal 23A. The end tool mounting part 51 has an insertion hole 51a penetrating the front end of the end tool mounting part 51 toward the rear end of the same for inserting the bit (not shown), and a chuck 51A at the front end of the end tool mounting part 51 for holding the bit (not shown).

[0047] The anvil 52 is disposed in the hammer case 23 on the rear side of the end tool mounting part 51 and is integrally formed with the end tool mounting part 51. As shown in Fig. 3, the anvil 52 includes a first engagement protrusion 52A disposed at a position offset from the rotational center of the end tool mounting part 51 and protruding rearward, and a second engagement protrusion 52B positioned on the opposite side of the rotational center of the end tool mounting part 51 from the first engagement protrusion 52A. When the hammer 42 rotates, the first engaging protrusion 42A collides with the first engagement protrusion 52A at the same time the second engaging protrusion 42B collides with the second engagement protrusion 52B, transmitting the torque of the hammer 42 to the anvil 52. This operation will be described later in greater detail.

[0048] The switch mechanism 6 is configured of a circuit board 61, a trigger switch 62, a switching board 63, and wiring connecting these components. The circuit board 61 is disposed inside the handle section 22 at a position near the battery 24 and is connected to the battery 24. In addition, the circuit board 61 is connected to the light 2A, the dial 2B, the trigger switch 62, the switching board 63, and the display unit 26.

[0049] Next, the structure of a control system for driving the motor 3 will be described with reference to Fig. 2. In the first embodiment, the motor 3 is configured of a 3-phase brushless DC motor. The rotor 3A of this brushless DC motor is configured of a plurality (two in the first embodiment) of permanent magnets 3C each having an N-pole and an S-pole. The stator 3B is configured of 3-phase, star-connected stator coils U, V, and W. Hall elements 64 are provided on the switching board 63 at prescribed intervals along the circumferential direction of the rotor 3A (every 60 degrees, for example) for detecting the rotated position of the rotor 3A. The Hall elements 64 output position detection signals, based on which signals the time and direction of current supplied to the stator coils U, V, and W can be controlled to control the rotation of the motor 3. The Hall elements 64 are disposed at positions confronting the permanent magnets 3C of the rotor 3A on the switching board 63.

[0050] Electronic elements mounted on the switching board 63 include six switching elements Q1-Q6 configured of FETs or the like connected in a 3-phase bridge configuration. The gates of the switching elements Q1-Q6 are connected to a control signal output circuit 65 mounted on the circuit board 61, and the drains or sources of the switching elements Q1-Q6 are connected to the stator coils U, V, and W. The switching elements Q1-Q6 constitute an inverter circuit 66. With this configuration, the switching elements Q1-Q6 perform switching operations based on switching element drive signals (drive signals H4, H5, H6, and the like) inputted from the control signal output circuit 65 and supplies power to the stator coils U, V, and W by converting the DC voltage of the battery 24 applied to the inverter circuit 66 to 3-phase (U-phase, V-phase, and W-phase) voltages Vu, Vv, and Vw.

[0051] Of the switching element drive signals (3-phase signals) used to drive the gates of the six switching elements Q1-Q6, pulse width modulation signals (PWM signals) H4, H5, and H6 are supplied to the switching elements Q4, Q5, and Q6 on the negative power supply side. An arithmetic unit 67 mounted on the circuit board 61 adjusts the quantity of power supplied to the motor 3 by modifying the pulse width (duty cycle) of the PWM signal based on a detection signal for the operation time (stroke) of the trigger 25 in order to control starting, stopping, and rotational speed of the motor 3.

[0052] The PWM signal is supplied to one of either the switching elements Q1-Q3 on the positive power supply side of the inverter circuit 66 or the switching elements Q4-Q6 on the negative power supply side. By rapidly switching the switching elements Q1-Q3 or the switching elements Q4-Q6, it is possible to control the DC voltage of power supplied to each of the stator coils U, V, and W from the battery 24. Since the PWM signal is supplied to the switching elements Q4-Q6 on the negative power supply side, it is possible to adjust the power supplied to the stator coils U, V, and W by controlling the pulse width of the PWM signal, thereby controlling the rotational speed of the motor 3.

[0053] A control unit 72 is also mounted on the circuit board 61. The control unit 72 includes the control signal output circuit 65 and the arithmetic unit 67, as well as a current detection circuit 71, a switch operation detection circuit 76, an applied voltage setting circuit 70, a rotating direction setting circuit 68, a rotor position detection circuit 69, a rotating speed detection circuit 75, and an impact detection circuit 74. While not shown in the drawings, the arithmetic unit 67 is configured of a central processing unit (CPU) for outputting a drive signal based on a program and control data, a ROM for storing the program and control data, a RAM for temporarily storing process data during the process, and a timer. The arithmetic unit 67 generates drive signals for continually switching prescribed switching elements Q1-Q6 based on output signals from the rotating direction setting circuit 68 and the rotator position detection circuit 69 and for outputting these drive signals to the control signal output circuit 65. Through this construction, a current is supplied in turns to prescribed stator coils U, V, and W in order to rotate the rotor 3A in a desired direction. At this time, the arithmetic unit 67 outputs drive signals to be applied to the switching elements Q4-Q6 on the negative power supply side as PWM signals based on a control signal outputted from the applied voltage setting circuit 70. The current detection circuit 71 measures the current supplied to the motor 3 and outputs this value to the arithmetic unit 67 as feedback, whereby the arithmetic unit 67 adjusts the drive signals to supply a prescribed power for driving the motor 3. Here, the arithmetic unit 67 may also apply PWM signals to the switching elements Q1-Q3 on the positive power supply side.

[0054] The electronic pulse driver 1 is also provided with a forward-reverse lever 27 for toggling the rotating direction of the motor 3. The rotating direction setting circuit 68 detects changes in the forward-reverse lever 27 and transmits a control signal to the arithmetic unit 67 to toggle the rotating direction of the motor 3. An impact force detection sensor 73 is connected to the control unit 72 for detecting the magnitude of impact generated in the anvil 52. A signal outputted from the impact force detection sensor 73 is inputted into the arithmetic unit 67 after passing through the impact detection circuit 74.

[0055] Fig. 3 shows cross-sectional views of the electronic pulse driver 1 taken along the plane and viewed in the direction indicated by the arrows III in Fig. 1. The cross-sectional views in Fig. 3 illustrate the positional relationship between the hammer 42 and the anvil 52 when the electronic pulse driver 1 is operating. Fig. 3(1) shows the states of the hammer 42 and the anvil 52 when the first engaging protrusion 42A is in contact with the first engagement protrusion 52A at the same time the second engaging protrusion 42B is in contact with the second engagement protrusion 52B. The first engaging protrusion 42A has an outer radius RH3 equivalent to an outer radius RA3 of the first engagement protrusion 52A. The state shown in Fig. 3(2) is reached when the hammer 42 is rotated clockwise in Fig. 3 from the state in Fig. 3(1). The first engaging protrusion 42A has an inner radius RH2 that is greater than an outer radius RA1 of the second engagement protrusion 52B. Accordingly, the first engaging protrusion 42A and the second engagement protrusion 52B do not contact each other. Similarly, the second engaging protrusion 42B has an outer radius RH1 set smaller than an inner radius RA2 of the first engagement protrusion 52A. Accordingly, the second engaging protrusion 42B and the first engagement protrusion 52A do not contact each other. When the hammer 42 rotates to the position shown in Fig. 3(3), the motor 3 begins to rotate in forward, driving the hammer 42 to rotate in the counterclockwise direction. In the state shown in Fig. 3(3), the hammer 42 has rotated in reverse to the maximum point relative to the anvil 52 at which point the rotating direction is changed. As the motor 3 rotates forward, the hammer 42 passes through the state shown in Fig.

3(4), and the first engaging protrusion 42A collides with the first engagement protrusion 52A at the same time the second engaging protrusion 42B collides with the second engagement protrusion 52B, as shown in Fig. 3(5). The force of impact rotates the anvil 52 counterclockwise, as shown in Fig. 3(6).

[0056] In this way, the two engaging protrusions provided on the hammer 42 collide with the two engagement protrusions provided on the anvil 52 at positions symmetrical about the rotational centers of the hammer 42 and anvil 52. This configuration provides balance and stability in the electronic pulse driver 1 during impacts so that the operator feels less vibration at this time.

[0057] Since the inner radius RH2 of the first engaging protrusion 42A is greater than the outer radius RA1 of the second engagement protrusion 52B and the outer radius RH1 of the second engaging protrusion 42B is smaller than the inner radius RA2 of the first engagement protrusion 52A, the hammer 42 and anvil 52 can rotate more than 180 degrees relative to each other.. This enables the hammer 42 to reverse directions of rotation at an angle relative to the anvil 52 that allows sufficient distance for acceleration.

[0058] The first engaging protrusion 42A and the second engaging protrusion 42B can collide with the first engagement protrusion 52A and the second engagement protrusion 52B on both circumferential side surfaces thereof, leading to the possibility of impact operations during not only forward rotations, but also reverse rotations. Hence, the present invention provides a user-friendly impact tool. Further, since the hammer 42 does not strike the anvil 52 along an axial direction of the hammer 42 (forward), the end tool is not pressed into the workpiece. This configuration is effective when driving wood screws into wood.

[0059] Next, the operating modes available in the electronic pulse driver 1 according to the first embodiment will be described with reference to Figs. 4 through 9. The electronic pulse driver 1 according to the first embodiment has the drill mode, the clutch mode, and the pulse mode, for a total of three operating modes.

[0060] In the drill mode, the hammer 42 and the anvil 52 are rotated as one. Therefore, this mode is normally used for tightening wood screws and the like. In this mode, the electronic pulse driver 1 gradually increases the supply of electric current to the motor 3 as a fastening operation progresses, as illustrated in Fig. 4.

[0061] The clutch mode is mainly used when emphasizing a proper tightening torque, such as when tightening cosmetic fasteners or the like that remain visible on the exterior of the workpiece after the fastening operation. As shown in Figs. 5 and 6, the hammer 42 and the anvil 52 are integrally rotated in the clutch mode, while gradually increasing the electric current supplied to the motor 3, and driving of the motor 3 is halted when the electric current reaches a target value (target torque). In the clutch mode, the motor 3 is reversed in order to produce a pseudo-clutch effect. The motor 3 is also reversed to prevent the driver from stripping a screw when tightening wood screws (see Fig. 6).

[0062] The pulse mode is used primarily when tightening long screws used in areas that will not be outwardly visible. As illustrated in Figs. 7 through 9, the hammer 42 and the anvil 52 are rotated as one in the pulse mode, while the electric current supplied to the motor 3 is gradually increased. The rotating direction of the motor 3 is alternated between the forward direction and the reverse direction when the electric current reaches prescribed values (prescribed torques) and the fasteners are tightened by impacts generated when switching directions. This mode can supply a strong tightening force, while reducing the reaction force from the workpiece.

[0063] Next, a control process performed by the control unit 72 when the electronic pulse driver 1 of the first embodiment performs the fastening operation will be described. A description of the control process will be omitted for the drill mode since the control unit 72 does not perform any special control in this mode. Further, the following description will not account for a start-up current when making determinations based on the electric current. The description will also not consider any sudden spikes in the electric current when applying a current for forward rotation because spikes in the electric current that occur when applying an electric current for normal rotation, as shown in Figs. 6 through 9 for example, do not contribute to screw or bolt tightening. Such spikes in electric current can be ignored by providing approximately 20 ms of dead time, for example.

[0064] First, a control process during the clutch mode will be described with reference to Figs. 5, 6, and 10. Fig. 5 is a graph describing the control process when a bolt or other fastener (a bolt will be assumed in this example) is tightened in the clutch mode. Fig. 6 is a graph for describing the control process for tightening a wood screw or similar fastener (a wood screw will be assumed in this example) during the clutch mode. Fig. 10 is a flowchart illustrating steps in the control process performed by the control unit 72 when tightening a fastener in the clutch mode.

[0065] The control unit 72 begins the control process illustrated in the flowchart of Fig. 10 when the operator squeezes the trigger 25. In the clutch mode according to the first embodiment, the control unit 72 determines that the target torque has been reached when the current supplied to the motor 3 increases to a target current T (see Figs. 5 and 6) and ends the fastening operation at this time.

[0066] When the operator squeezes the trigger 25, in S601 of Fig. 10 the control unit 72 applies a fitting reverse rotation voltage to the motor 3, causing the hammer 42 to rotate in reverse and lightly tap the anvil 52 (t1 in Figs. 5 and 6). In the first embodiment, the fitting reverse rotation voltage is set to 5.5 V, and the application time for this voltage is 200 ms. This operation ensures that the end tool is reliably seated in the head of the fastener.

[0067] Since the hammer 42 and the anvil 52 might be separated at the time the trigger is pulled, supplying electric current to the motor 3 will cause the hammer 42 to strike the anvil 52. However, in the clutch mode, an electric current is supplied to the motor 3 while the hammer 42 and the anvil 52 rotate together, and driving of the motor 3 is halted when the current value reaches the target current T (target torque). If the anvil 52 is impacted in this mode, the impact alone may transmit torque to the fastener that exceeds the target value. This problem is particularly pronounced when retightening a screw or the like that has already been tightened.

[0068] Therefore, in S602 the control unit 72 applies a prestart forward rotation voltage to the motor 3 for placing the hammer 42 in contact with the anvil 52 (a prestart operation) without rotating the anvil 52 (t2 in Figs. 5 and 6). In the first embodiment the prestart forward rotation voltage is set to 1.5 V and the application time of this voltage is set to 800 ms. Since the hammer 42 and the anvil 52 can be separated by as much as 315 degrees, a period t2 is set to the time required for the motor 3 to rotate the hammer 42 315 degrees when the prestart forward rotation voltage is applied to the motor 3.

[0069] In S603 the control unit 72 applies a fastening forward rotation voltage to the motor 3 for tightening a fastener (t3 in Figs. 5 and 6). In S604 the control unit 72 determines whether the electric current flowing to the motor 3 is greater than a threshold value a. In the first embodiment, the fastening forward rotation voltage is set to 14.4 V. The threshold value a is set to a current value marking the final phase in tightening a wood screw within a range that does not strip the screw. In the first embodiment, the threshold value a is set to 15 A.

[0070] When the electric current flowing to the motor 3 exceeds the threshold value a (S604: YES; t4 in Figs. 5 and 6), in S605 the control unit 72 determines whether the rate of increase in electric current exceeds a threshold value b. Using the example shown in Fig. 5, the rate of current increase can be calculated from the expression (A(Tr+t) – A(Tr)) / A(Tr), where t indicates the elapsed time after a certain point Tr. In the example of Fig. 6, the rate of increase in electric current can be calculated from the expression (A(N+1) – A(N)) / A(N), where N is the maximum load current for a first forward rotation current and N+1 is the maximum load current for the forward rotation current following the first forward rotation current. In the example of Fig. 6, the threshold value b of (A(N+1) – A(N)) / A(N) is set to 20%.

[0071] While the electric current flowing to the motor 3 is normally increased abruptly during the final phase of tightening a bolt, as shown in Fig. 5, the electric current is increased gradually when tightening a wood screw, as shown in Fig. 6.

[0072] Therefore, the control unit 72 determines that the fastener is a bolt when the rate of increase in electric current exceeds the threshold value b (S605: YES) at the point that the current flowing to the motor 3 is greater than the threshold value a and determines that the fastener is a wood screw when the rate of increase at this time is less than or equal to the threshold value b (S605: NO).

[0073] When the rate of increase in electric current is greater than the threshold value b (S605: YES), indicating that the fastener is a bolt, then the control unit 72 allows the electric current to increase further since there is no need to account for stripping in this case. In S606 the control unit 72 determines whether the electric current has increased to the target current T and halts the supply of torque to the bolt when the current reaches the target current T (S606: YES; t5 in Fig. 5). However, since the current increases rapidly in the case of a bolt, as described above, simply ceasing to apply a forward rotation voltage to the motor 3 may not be sufficient to halt the supply of torque to the bolt generated by the inertial force of the rotating components. Accordingly, in the first embodiment the control unit 72 applies a braking reverse rotation voltage to the motor 3 in S607 (t5 of Fig. 5) in order to completely halt the supply of torque to the bolt. In the first embodiment, the application time for the braking reverse rotation voltage is set to 5 ms.

[0074] In S608 the control unit 72 alternately applies a forward rotation voltage and a reverse rotation voltage to the motor 3 for a pseudo-clutch (hereinafter collectively referred to as a "pseudo-clutch voltage", t7 in Figs. 5 and 6). In the first embodiment, the application time for the pseudo-clutch forward and reverse rotation voltages is 1000 ms (1 second). Here, the pseudo-clutch functions to notify the operator that the desired torque was produced based on the electric current reaching the target current T. Although the motor 3 has not actually ceased to output power at this time, the pseudo-clutch simulates a loss of power from the motor in order to alert the operator.

[0075] The hammer 42 separates from the anvil 52 when the control unit 72 applies the pseudo-clutch reverse rotation voltage and strikes the anvil 52 when the control unit 72 applies the pseudo-clutch forward rotation voltage. However, since the forward and reverse rotation voltages for the pseudo-clutch are set to a level insufficient to apply a tightening force to the fastener (2 V, for example), the pseudo-clutch is manifested merely as the sound of the hammer 42 impacting the anvil 52. Through the sound of the pseudo-clutch, the operator can tell when tightening has finished.

[0076] On the other hand, if the rate of increase in electric current is less than or equal to the threshold value b (S605: NO), indicating that the fastener is a wood screw for which stripping must be considered, in S609 the control unit 72 applies an anti-stripping reverse rotation voltage to the motor 3 at prescribed intervals during the fastening voltage (t5 in Fig. 6). The stripping of screws is a problem that occurs when the cross-shaped protruding part of the end tool (bit) fitted in the cross-shaped recessed part formed in the head of a wood screw becomes unseated from the recessed part and chews up the edges of the recessed part due to the torque of the end tool being unevenly applied to the recessed part. The anti-stripping reverse rotation voltage applied to the motor 3 reverses the rotation of the anvil 52, allowing the cross-shaped protruding part of the end tool attached to the anvil 52 to remain firmly seated in the cross-shaped protruding part of the wood screw head. The anti-stripping reverse rotation voltage is not employed to increase the accelerating distance for the hammer 42 to strike the anvil 52, but rather to have the hammer 42 apply reverse rotation to the anvil 52 sufficient for the anvil 52 to apply reverse torque to the screw. In the first embodiment, the anti-stripping reverse rotation voltage is set to 14.4 V.

[0077] In S610 the control unit 72 determines whether the electric current has risen to the target current T. If so (S610: YES; t6 in Fig. 6), in S608 the control unit 72 alternately applies the pseudo-clutch voltage to the motor 3 (t7 in Fig. 6), notifying the user that the fastening operation has finished.

[0078] In S611 the control unit 72 waits for a prescribed time to elapse after beginning to apply the pseudo-clutch voltage. After the prescribed time has elapsed (S611: YES), in S612 the control unit 72 halts the application of the pseudo-clutch voltage.

[0079] Next, the control process of the control unit 72 when the operating mode is set to the pulse mode will be described with reference to Figs. 7 through 9 and Fig. 11. Fig. 7 is a graph illustrating the control process for tightening a bolt in the pulse mode. Fig. 8 is a graph illustrating the control process when not shifting to a second pulse mode described later while tightening a wood screw in the pulse mode. Fig. 9 is a graph illustrating the control process when shifting to the second pulse mode described later while tightening a wood screw in the pulse mode. Fig. 11 is a flowchart illustrating steps in the control process when tightening a fastener in the pulse mode.

[0080] As in the clutch mode described above, the control unit 72 begins the control process illustrated in the flowchart of Fig. 11 when the operator squeezes the trigger.

[0081] As in the clutch mode described above, when the trigger is squeezed in the pulse mode, in S701 the control unit 72 applies the fitting reverse rotation voltage to the motor 3 (t1 in Figs. 7-9). However, since the control process in the pulse mode does not emphasize tightening with a proper torque, the prestart step in S602 of the clutch mode is omitted from this process.

[0082] In S702 the control unit 72 applies the fastening forward rotation voltage described in the clutch mode (t2 in Figs. 7-9). In S703 the control unit 72 determines whether the electric current flowing to the motor 3 is greater than a threshold value c.

[0083] While the load (current) increases gradually in the earlier stage of tightening a wood screw, the load increases very little in the earlier stage of tightening a bolt, but suddenly spikes at a certain point after tightening has progressed. Once a load is applied while tightening a bolt, the reaction force received from a fastener coupled to the bolt becomes larger than the reaction force received from the workpiece when tightening a wood screw. Hence, when a reverse rotation voltage is applied to the motor 3 while fastening a bolt, the absolute value of the reverse rotation current flowing to the motor 3 is smaller than that when fastening a wood screw since an auxiliary force is received from the fastener coupled to the bolt relative to the reverse rotation voltage. In the first embodiment, the electric current supplied to the motor 3 when fastening a bolt at about the time the load begins to increase is set as the threshold value c (15 A, for example).

[0084] When the electric current supplied to the motor 3 is greater than the threshold value c (S703: YES), in S704 the control unit 72 applies a fastener determining reverse rotation voltage to the motor 3 (t3 in Figs. 7-9). The fastener determining reverse rotation voltage is set to a value that does not cause the hammer 42 to impact the anvil 52 (14.4 V, for example).

[0085] In S705 the control unit 72 determines whether the absolute value of the electric current supplied to the motor 3 when the fastener determining reverse rotation voltage was applied is greater than a threshold value d. The control unit 72 determines that the fastener is a wood screw when the current is greater than the threshold value d (Figs. 8 and 9) and a bolt when the current value is less than or equal to the threshold value d (Fig. 7), and controls the motor 3 to perform impact fastening suited to the determined type of fastener. In the first embodiment, the threshold value d is set to 20 A.

[0086] Impact fastening more specifically refers to alternately applying a forward rotation voltage and a reverse rotation voltage to the motor 3. In the first embodiment, the control unit 72 alternately applies a forward rotation voltage and a reverse rotation voltage to the motor 3 in order that the period for applying the reverse rotation voltage (hereinafter referred to as the "reverse rotation period") relative to the period for applying the forward rotation voltage (hereinafter referred to as the "forward rotation period") increases in proportion to the increase in load.

[0087] It is common for a power tool to shift to tightening by impact when pressure tightening becomes difficult, but preferably the transition is gradual enough to feel smooth to the operator. Hence, the electronic pulse driver 1 according to the first embodiment performs pressure-centric impact fastening in a first pulse mode and impact-centric impact fastening in a second pulse mode.

[0088] More specifically, in the first pulse mode the control unit 72 supplies a pressing force to the fastener using a longer forward rotation period. However, in the second pulse mode the control unit 72 supplies an impact force by gradually increasing the reverse rotation period while gradually reducing the forward rotation period as load increases. During the first pulse mode in the first embodiment, the control unit 72 gradually decreases the forward rotation while leaving the reverse rotation period unchanged as load increases, in order to lessen the reaction force from the workpiece.

[0089] Returning to the flowchart in Fig. 11, shifts between the first and second pulse modes will be described.

[0090] When the absolute value of electric current applied to the motor 3 is greater than the threshold value d (S705: YES), the control unit 72 shifts between the first and the second pulse modes for tightening a wood screw.

[0091] First, in S706a-S706c the control unit 72 applies first pulse mode voltages to the motor 3 for performing pressure-centric impact tightening (t5 in Figs. 8 and 9). Specifically, in S706a the control unit 72 performs one set comprising: pausing for 5 ms → applying a reverse rotation voltage for 15 ms → pausing for 5 ms → applying a forward rotation voltage for 300 ms. After a prescribed interval has elapsed, in S706b the control unit 72 performs one set comprising: pausing for 5 ms → applying a reverse rotation voltage for 15 ms → pausing for 5 ms → applying a forward rotation voltage for 200 ms. After another prescribed interval has elapsed, in S706c the control unit 72 performs one set comprising: pausing for 5 ms → applying a reverse rotation voltage for 15 ms → pausing for 5 ms → applying a forward rotation voltage for 100 ms.

[0092] In S707 the control unit 72 determines whether the electric current flowing to the motor 3 when applying voltages for the first pulse mode is greater than a threshold value e. The threshold value e is used to determine whether the operating mode should be shifted to the second pulse mode and is set to 75 A in the first embodiment.

[0093] If the electric current supplied to the motor 3 when applying the first pulse mode voltage (forward rotation voltage) is less than or equal to the threshold value e (S707: NO), the control unit 72 repeats the processes in S706a-S706c and S707. As the number of applications of voltages for the first pulse mode increases, load increases and the reaction force from the workpiece increases. In order to lessen this reaction force, the control unit 72 applies voltages in the first pulse mode for gradually reducing the forward rotation period, while maintaining the reverse rotation period unchanged. In the first embodiment, the forward rotation period decreases according to the steps 300 ms → 200 ms → 100 ms.

[0094] However, if the electric current flowing to the motor 3 when applying the first pulse mode voltage (forward rotation voltage) is greater than the threshold value e (S707: YES; t6 in Figs. 8 and 9), in S708 the control unit 72 determines whether the rate of increase in electric current due to the first pulse mode voltage (forward rotation voltage) is greater than a threshold value f. The threshold value f is used to determine whether the wood screw is seated in the workpiece and is set to 4% in the first embodiment.

[0095] If the rate of increase in electric current is greater than the threshold value f (S708: YES), it is assumed that the wood screw is seated in the workpiece. Accordingly, in S709 the control unit 72 applies a seated voltage to the motor 3 for reducing the subsequent reaction force (t11 in Fig. 8). In the first embodiment, the seated voltage involves repeating the following set: pausing for 5 ms → applying a reverse rotation voltage for 15 ms → pausing for 5 ms → applying a forward rotation voltage for 40 ms.

[0096] However, if the rate of increase in electric current is less than or equal to the threshold value f (S708: NO), then it is assumed that the load has increased regardless of whether the wood screw is seated in the workpiece. Hence, the pressure-centric tightening force provided by the first pulse mode voltage is considered insufficient, and the control unit 72 subsequently shifts the operating mode to the second pulse mode.

[0097] In the first embodiment, the voltage in the second pulse mode is selected from among five second pulse mode voltages 1-5. The second pulse mode voltages 1-5 are each configured as a set that includes a reverse rotation voltage and a forward rotation voltage such that the reverse rotation period sequentially increases while the forward rotation period sequentially decreases in order from voltage 1 to voltage 5. Specifically, second pulse mode voltage 1 comprises pausing for 5 ms → applying a reverse rotation voltage for 15 ms → pausing for 5 ms → applying a forward rotation voltage for 75 ms; second pulse mode voltage 2 comprises pausing for 7 ms → applying a reverse rotation voltage for 18 ms → pausing for 10 ms → applying a forward rotation voltage for 65 ms; second pulse mode voltage 3 comprises pausing for

9 ms → applying a reverse rotation voltage for 20 ms → pausing for 12 ms → applying a forward rotation voltage for 59 ms; second pulse mode voltage 4 comprises pausing for 11 ms → applying a reverse rotation voltage for 23 ms → pausing for 13 ms → applying a forward rotation voltage for 53 ms; and second pulse mode voltage 5 comprises pausing for 15 ms → applying a reverse rotation voltage for 25 ms → pausing for 15 ms → applying a forward rotation voltage for 45 ms.

[0098] When the control unit 72 determines in S708 that the operating mode should be shifted to the second pulse mode (i.e., when the rate of increase in electric current is not greater than the threshold value f; S708: NO), in S710 the control unit 72 determines whether the electric current supplied to the motor 3 when applying the forward rotation voltage of the first pulse mode voltage (the falling edge) is greater than a threshold value g1. The threshold value g1 is used to determine whether a second pulse mode voltage of a higher order than the second pulse mode voltage 1 should be applied to the motor 3 and is set to 76 A in the first embodiment. Hereinafter, the electric current supplied to the motor 3 when applying the forward rotation voltage of each pulse mode voltage will be generically referred to as the reference current.

[0099] If the reference current is greater than the threshold value g1 (S710: YES), in S711 the control unit 72 determines whether the reference current is greater than a threshold value g2. The threshold value g2 is used to determine whether a second pulse mode voltage of a higher order than the second pulse mode voltage 2 should be applied to the motor 3 and is set to 77 A in the first embodiment.

[00100] If the reference current is greater than the threshold value g2 (S711: YES), in S712 the control unit 72 determines whether the reference current is greater than a threshold value g3. The threshold value g3 is used to determine whether a second pulse mode voltage of a higher order than the second pulse mode voltage 3 should be applied to the motor 3 and is set to 79 A in the first embodiment.

[00101] If the reference current is greater than the threshold value g3 (S712: YES), in S713 the control unit 72 determines whether the reference current is greater than a threshold value g4. The threshold value g4 is used to determine whether a second pulse mode voltage of a higher order than second pulse mode voltage 4 (i.e., second pulse mode voltage 5) should be applied to the motor 3 and is set to 80 A in the first embodiment.

[00102] As described above, the control unit 72 first determines which of the second pulse mode voltages to apply to the motor 3 based on the electric current flowing to the motor 3 when applying the first pulse mode voltage (forward rotation voltage) and subsequently applies the determined second pulse mode voltage to the motor 3.

[00103] For example, when the reference current is not greater than the threshold value g1 (S710: NO), in S714 the control unit 72 applies second pulse mode voltage 1 to the motor 3. When the reference current is greater than the threshold value g1 but not greater than the threshold value g2 (S711: NO), in S715 the control unit 72 applies second pulse mode voltage 2 to the motor 3. When the reference current is greater than the threshold value g2 but not greater than the threshold value g3 (S712: NO), in S716 the control unit 72 applies second pulse mode voltage 3 to the motor 3. When the reference current is greater than the threshold value g3 but not greater than the threshold value g4 (S713: NO), in S717 the control unit 72 applies second pulse mode voltage 4 to the motor 3. When the reference current is greater than the threshold value g4 (S713: YES), in S718 the control unit 72 applies second pulse mode voltage 5 to the motor 3.

[00104] After applying the second pulse mode voltage 1 (S714), in S719 the control unit 72 determines whether the reference current supplied to the motor 3 when second pulse mode voltage 1 (forward rotation voltage) was applied is greater than the threshold value g1.

[00105] If the reference current is not greater than the threshold value g1 (S719: NO), the control unit 72 returns to S707 and again determines which of the first pulse mode voltage and the second pulse mode voltage 1 should be applied to the motor 3. However, if the reference current is greater than the threshold value g1 (S719: YES), in S715 the control unit 72 applies second pulse mode voltage 2 to the motor 3.

[00106] After applying second pulse mode voltage 2 (S715), in S720 the control unit 72 determines whether the reference current supplied to the motor 3 when second pulse mode voltage 2 (forward rotation voltage) was applied is greater than the threshold value g2.

[00107] If the reference current is not greater than the threshold value g2 (S720: NO), the control unit 72 returns to S710 and again determines which of second pulse mode voltage 1 and second pulse mode voltage 2 should be applied to the motor 3. However, if the reference current is greater than the threshold value g2 (S720: YES), in

S716 the control unit 72 applies second pulse mode voltage 3 to the motor 3.

[00108] After applying second pulse mode voltage 3 (S716), in S721 the control unit 72 determines whether the reference current supplied to the motor 3 when second pulse mode voltage 3 (forward rotation voltage) was applied is greater than the threshold value g3.

[00109] If the reference current is not greater than the threshold value g3 (S721: NO), the control unit 72 returns to S711 and again determines which of second pulse mode voltage 2 and second pulse mode voltage 3 should be applied to the motor 3. However, if the reference current is greater than the threshold value g3 (S721: YES), in S717 the control unit 72 applies second pulse mode voltage 4 to the motor 3.

[00110] After applying second pulse mode voltage 4 (S717), in S722 the control unit 72 determines whether the reference current supplied to the motor 3 when second pulse mode voltage 4 (forward rotation voltage) was applied is greater than the threshold value g4.

[00111] If the reference current is not greater than the threshold value g4 (S722: NO), the control unit 72 returns to S712 and again determines which of second pulse mode voltage 3 and second pulse mode voltage 4 should be applied to the motor 3. However, if the reference current is greater than the threshold value g4 (S722: YES), in S718 the control unit 72 applies second pulse mode voltage 5 to the motor 3.

[00112] After applying second pulse mode voltage 5 (S718), in S723 the control unit 72 determines whether the reference current supplied to the motor 3 when second pulse mode voltage 5 (forward rotation voltage) was applied is greater than a threshold value g5. The threshold value g5 is used to determine whether second pulse mode voltage 5 should be applied to the motor 3 and is set to 82 A in the first embodiment.

[00113] If the reference current is not greater than the threshold value g5 (S723: NO), the control unit 72 returns to S713 and again determines which of second pulse mode voltage 4 and second pulse mode voltage 5 should be applied to the motor 3. However, if the reference current is greater than the threshold value g5 (S723: YES), in S718 the control unit 72 applies second pulse mode voltage 5 to the motor 3.

[00114] Further, if the control unit 72 determines in S705 that the absolute value of electric current supplied to the motor 3 is not greater than the threshold value d (S705: NO), indicating that a bolt is being tightened, then there is no need to tighten the

bolt using pressure and it is preferable to tighten with impacts in a mode that minimizes reaction force (or kickback). Hence, in this case, the control unit 72 jumps to S718 and applies second pulse mode voltage 5 to the motor 3 without going through the first pulse mode voltage and second pulse mode voltages 1-4.

[00115] In the pulse mode described above, the electronic pulse driver 1 according to the first embodiment increases the ratio of the reverse rotation period to the forward rotation period as the current (load) supplied to the motor 3 increases (i.e., decreases the forward rotation period in the first pulse mode (S706), shifts from the first pulse mode to the second pulse mode (S707), and shifts among the second pulse mode voltages 1 through 5 (S719: S722)). Therefore, the present invention can provide an impact tool that minimizes reaction force from the workpiece, achieving better handling and feel for the operator.

[00116] Also, when fastening a wood screw in the pulse mode described above, the electronic pulse driver 1 according to the first embodiment tightens the screw in the first pulse mode emphasizing a pressing force when the electric current supplied to the motor 3 is no greater than the threshold value e, and tightens the screw in the second pulse mode emphasizing an impact force when the electric current is greater than the threshold value e (S707 of Fig. 11). Accordingly, the electronic pulse driver 1 can perform tightening in the most suitable mode for wood screws.

[00117] Further, in the pulse mode described above, the electronic pulse driver 1 according to the first embodiment applies the fastener determining reverse rotation voltage to the motor 3 (S704) and determines that the fastener is a wood screw when the current supplied to the motor 3 at this time is greater than the threshold value d or a bolt when the current is less than or equal to the threshold value d (S705). Consequently, the electronic pulse driver 1 can shift to the most suitable pulse mode based on this determination to perform optimum tightening for the type of fastener.

[00118] In the pulse mode described above, when the control unit 72 determines that the rate of increase in electric current exceeds the threshold value f at the time the electric current flowing to the motor 3 rises to the threshold value e (S708: YES), the electronic pulse driver 1 of the first embodiment assumes that the wood screw is seated in the workpiece and begins applying the seated voltage to the motor 3 with a reduced switching period between the forward and reverse rotation voltages. In this way, the electronic pulse driver 1 can simultaneously reduce the subsequent reaction force from the workpiece while providing the same handling feel to the operator as a conventional electronic pulse driver that reduces impact intervals as tightening progresses.

[00119] In the pulse mode described above, the electronic pulse driver 1 according to the first embodiment shifts from the first pulse mode to the most suitable second pulse mode based on the current flowing to the motor 3 (S710-S713). Accordingly, the electronic pulse driver 1 can perform tightening using the most suitable impact mode, even when the electric current flowing to the motor 3 increases rapidly.

[00120] In the pulse mode described above, the electronic pulse driver 1 of the first embodiment can only shift to neighboring second pulse modes in terms of the length of the forward and reverse rotation switching periods (S719-S723), thereby preventing a sudden change in handling.

[00121] The electronic pulse driver 1 according to the first embodiment applies the fitting reverse rotation voltage to the motor 3 before applying the fastening forward rotation voltage, rotating the motor 3 in reverse until the hammer 42 collides with the anvil 52 (S601 in Fig. 10). Therefore, even when the end tool is not properly seated in the fastener head, the electronic pulse driver 1 can firmly fit the end tool in the fastener head prior to tightening in order to prevent the end tool from coming unseated during the tightening operation.

[00122] In the clutch mode described above, the electronic pulse driver 1 according to the first embodiment applies the prestart forward rotation voltage to the motor 3 prior to applying the fastening forward rotation voltage to place the hammer 42 in contact with the anvil 52 (S602 in Fig. 10). Accordingly, the electronic pulse driver 1 can prevent the hammer 42 from providing the fastener with torque exceeding the target torque when impacting the anvil 52.

[00123] In the clutch mode described above, the electronic pulse driver 1 according to the first embodiment halts the pseudo-clutch a prescribed interval after producing the same (S612 of Fig. 10). Therefore, the electronic pulse driver 1 can minimize increases in temperature and power consumption.

[00124] In the clutch mode described above, the electronic pulse driver 1 according to the first embodiment applies the braking reverse rotation voltage to the motor 3 at the time the torque for tightening a bolt reaches the target torque (S607 in Fig.

10). Hence, even when tightening a fastener such as a bolt for which torque increases abruptly just before the target torque, the electronic pulse driver 1 can prevent the application of excessive torque caused by inertial force, thereby faithfully providing the target torque.

[00125] Next, an electronic pulse driver 201 according to a second embodiment of the present example will be described with reference to Figs. 12 and 13.

[00126] The electronic pulse driver 1 described in the first embodiment varied the impact mode when electric current or the like rose to predetermined threshold values, without considering changes in temperature. However, since the viscosity of grease in the gear mechanism 41 drops under cold temperatures, for example, electric current flowing to the motor 3 would have a stronger tendency to increase. In such an environment, the current flowing to the motor 3 would more easily exceed the threshold values, causing the electronic pulse driver 1 to vary the impact modes too early.

[00127] Therefore, a feature of the second embodiment is to modify the threshold values to account for changes in temperature. Specifically, a temperature detection unit is provided on the switching board 63 for detecting temperature, and the control unit 72 modifies each threshold value based on the temperature detected by the temperature detection unit.

[00128] Fig. 12 illustrates how the threshold values are modified when tightening a wood screw in the clutch mode. Fig. 13 illustrates how threshold values are modified when tightening a wood screw in the pulse mode.

[00129] In the example of Fig. 12, the control unit 72 sets a threshold value a' and a target current T' to values higher than the threshold value a and the target current T for applying an anti-stripping reverse rotation voltage under normal temperatures. Further, as shown in Fig. 13, the control unit 72 sets a threshold value c' for shifting to the first pulse mode and a threshold value e' for shifting to the second pulse mode under low temperatures to values higher than the corresponding threshold value c and the threshold value e used under normal temperatures.

[00130] By modifying these threshold values to account for changes in temperature in this way, the electronic pulse driver 201 of the second embodiment can change the impact mode to suit the conditions. Note that other threshold values may be modified based on changes in temperature, and not just the threshold values described above. Further, a temperature detection unit may be provided in a location other than near the motor 3.

[00131] Next, an electronic pulse driver 301 according to a third embodiment of the present invention will be described with reference to Fig. 14.

[00132] In the second embodiment described above, the electronic pulse driver 201 modifies threshold values with priority for performance. In the third embodiment, the electronic pulse driver 301 modifies the periods for shifting between forward and reverse rotations with priority for the long service life of the electronic pulse driver 301.

[00133] As described in the second embodiment, a temperature detection unit is provided near the motor 3 in the third embodiment for detecting temperature, and the control unit 72 modifies the periods for switching between forward rotations and reverse rotations based on the temperature detected by the temperature detection unit. The temperature detection unit may also be provided in a location other than near the motor 3.

[00134] Fig. 14 illustrates how the control unit 72 modifies the periods for switching between forward and reverse rotations when tightening a wood screw in the pulse mode.

[00135] In the example shown in Fig. 14, the control unit 72 sets the periods for switching between forward and reverse rotations in the first pulse mode under high temperatures longer than the periods for switching between forward and reverse rotations in the first pulse mode under normal temperatures. With this configuration, the control unit 72 can minimize the heat generated when switching the direction of rotation, thereby minimizing damage to the electronic pulse driver 301 caused by high temperatures in the FETs. This configuration can also suppress heat damage to the shielding of the stator coils, increasing the overall service life of the electronic pulse driver 301.

[00136] Next, an electronic pulse driver 401 according to a fourth embodiment of the present invention will be described with reference to Figs. 16 and 17, wherein like parts and components to the electronic pulse driver 1 according to the first embodiment are designated with the same reference numerals to avoid duplicating description.

[00137] As shown in Fig. 16, the electronic pulse driver 401 includes a hammer 442, and an anvil 452. In the electronic pulse driver 1 according to the first embodiment, the angle of clearance between the hammer 42 and anvil 52 in the rotating

direction is approximately 315 degrees. In the electronic pulse driver 401 according to the fourth embodiment, the angle of clearance between the hammer 442 and anvil 452 in their rotating direction is set to approximately 135 degrees.

[00138] Fig. 17 shows cross-sectional views of the electronic pulse driver 401 taken along the plane and viewed in the direction indicated by the arrows XVII in Fig. 16. The cross-sectional views in Fig. 17 illustrate the positional relationship between the hammer 442 and the anvil 452 when the electronic pulse driver 401 is operating. Fig. 17(1) shows the state of the hammer 442 in contact with the anvil 452. From this state, the hammer 442 is rotated in reverse through the state shown in Fig. 17(2) to the maximum rotation point relative to the anvil 452 shown in Fig. 17(3). As the motor 3 rotates forward, the hammer 442 passes through the state shown in Fig. 17(4) and collides with the anvil 452, as shown in Fig. 17(5). The force of impact rotates the anvil 452 counterclockwise in Fig. 17 to the state shown in Fig. 17(6).

[00139] Here, the values of voltage, current, and duration described in the first embodiment can be modified to suit the electronic pulse driver 401 of the fourth embodiment.

[00140] While the electronic pulse driver of the invention has been described in detail with reference to specific embodiments thereof, it would be apparent to those skilled in the art that many modifications and variations may be made therein without departing from the spirit of the invention, the scope of which is defined by the attached claims.

[00141] When shifting between second pulse mode voltages 1-5 in the first embodiment, the control unit 72 considers cases for returning to earlier second pulse mode voltage in the sequence (S719-S723: NO in Fig. 11). However, comfortable handling and feel for the operator can be achieved through control that does not return to previous second pulse mode voltages, as illustrated in the flowchart of Fig. 15.

[00142] Further, while the first embodiment describe control for tightening wood screws or bolts, the concept of the present invention may also be used when loosening (removing) the same. The flowchart in Fig. 18 illustrates steps for loosening a wood screw or the like. At the beginning of this process, the control unit 72 applies the second pulse mode voltage 5 having the longest reverse rotation period, and subsequently steps down through each second pulse mode voltage to the second pulse mode voltage 1 as the electric current drops below each successive threshold value.

This process can provide the operator with comfortable handling while loosening wood screws or the like.

[00143] In the first embodiment described above, the control unit 72 determines the type of fastener in S705 of Fig. 11 based on the electric current flowing to the motor 3 after applying the fastener determining reverse rotation voltage. However, this determination may be made based on the rotating speed of the motor 3 or the like.

[00144] Further, in the first embodiment described above, the same threshold values g1-g4 are used in the respective steps S719-S722 and S710-S713 of Fig. 11, but different values may be used.

[00145] Since only one anvil 52 is provided in the electronic pulse driver of the first embodiment, the anvil 52 and hammer 42 may be separated by a maximum of 315 degrees, but another anvil may be provided in between these components. With this construction, it is possible to reduce the time required for applying the fitting reverse rotation voltage (S601 of Fig. 10 and S701 of Fig. 11) and the time required for applying the prestart forward rotation voltage (S602 of Fig. 10).

[00146] In the first embodiment described above, the hammer 42 is placed in contact with the anvil 52 by applying the prestart forward rotation voltage, but it is not necessary to place the hammer 42 in contact with the anvil 52. A variation of this process may be implemented, provided that the initial position of the hammer 42 relative to the anvil 52 is fixed.

[00147] The power tool of the present invention is configured to rotate the hammer in forward and reverse directions, but the present invention is not limited to this configuration. For example, the hammer may be configured to strike the anvil by continuously being driven in a forward direction.

[00148] The power tool of the present invention drives the hammer with an electric motor powered by a rechargeable battery, but the hammer may be driven by a power supply other than an electric motor, such as an engine. Further, the electric motor may be driven by fuel cells, solar cells, or the like.

Reference Signs List

1 electrical pulse driver

2 housing

2A light

2B dial

3 motor

3A rotor

3B stator

4 hammer unit

5 anvil unit

6 switching mechanism

21 body section

22 handle section

23 hammer case

23A bearing metal

23a opening

24 battery

25 trigger

31 output shaft

32 fan

41 gear mechanism

41A outer ring gear

41B planetary gear mechanism

41C planetary gear mechanism

42 hammer

42A first engaging protrusion

42B second engaging protrusion

51 end tool mounting part

51A chuck

51a insertion hole

52 anvil

52A first engagement protrusion

52B second engagement protrusion

61 circuit board

62 trigger switch

63 switching board

64 hall element

65 control signal output circuit

66 inverter circuit
67 arithmetic unit
68 rotating direction setting circuit
69 rotor position detection circuit
70 applied voltage setting circuit
71 current detection circuit
72 control unit
73 impact force detection sensor
74 impact detection circuit
75 rotating speed detection circuit
76 switch operation detection circuit

CLAIMS

[Claim 1]

An electronic pulse driver comprising:

a motor rotatable in a forward and a reverse directions;

a hammer drivingly rotatable in the forward and the reverse directions by the motor;

an anvil provided separately from the hammer and rotated upon striking of the hammer against the anvil as a result of a rotation of the hammer in the forward direction after rotation of the hammer in the reverse direction for obtaining a distance for acceleration in the forward direction;

an end tool mounting unit mounting thereon an end tool and transmitting a rotation of the anvil to the end tool;

a power supply unit that alternately supplies a forward electric power and a reverse electric power to the motor in a first cycle;

a temperature detecting unit configured to detect a temperature of the motor; and

a controller configured to control the power supply unit to alternately supplies the forward electric power and the reverse electric power in a second cycle longer than the first cycle when the temperature of the motor detected by the temperature detecting unit increases to a prescribed value.

[Claim 2]

An electric power tool comprising:

a motor;

an output unit driven by the motor;

a housing accommodating therein the motor;

a temperature detecting unit configured to detect a temperature of a component in the housing; and

a controller configured to change a control mode to the motor based on the temperature detected by the temperature detecting unit.

[Claim 3]

An electric power tool comprising:

a motor unit;

an output unit driven by the motor unit;

a housing accommodating therein the motor unit;

a temperature detecting unit configured to detect a temperature of the motor unit; and

a controller configured to change electric power to be supplied to the motor unit based on the temperature detected by the temperature detecting unit.

[Claim 4]

The electric power tool according to claim 3, further comprising a hammer connected to the motor unit, and an anvil against which the hammer strikes,

wherein the hammer strikes the anvil at a first interval when the detected temperature is at a first value, whereas the hammer strikes the anvil at a second interval longer than the first interval when the detected temperature is at a second value higher than the first value.

[Claim 5]

An electric power tool comprising:

a motor that is intermittently driven;

an output unit driven by the motor;

a housing accommodating therein the motor;

a temperature detecting unit configured to detect a temperature of a component accommodated in the housing; and

a controller configured to change an intermittently driving cycle of the motor based on the temperature detected by the temperature detecting unit.

FIG.1

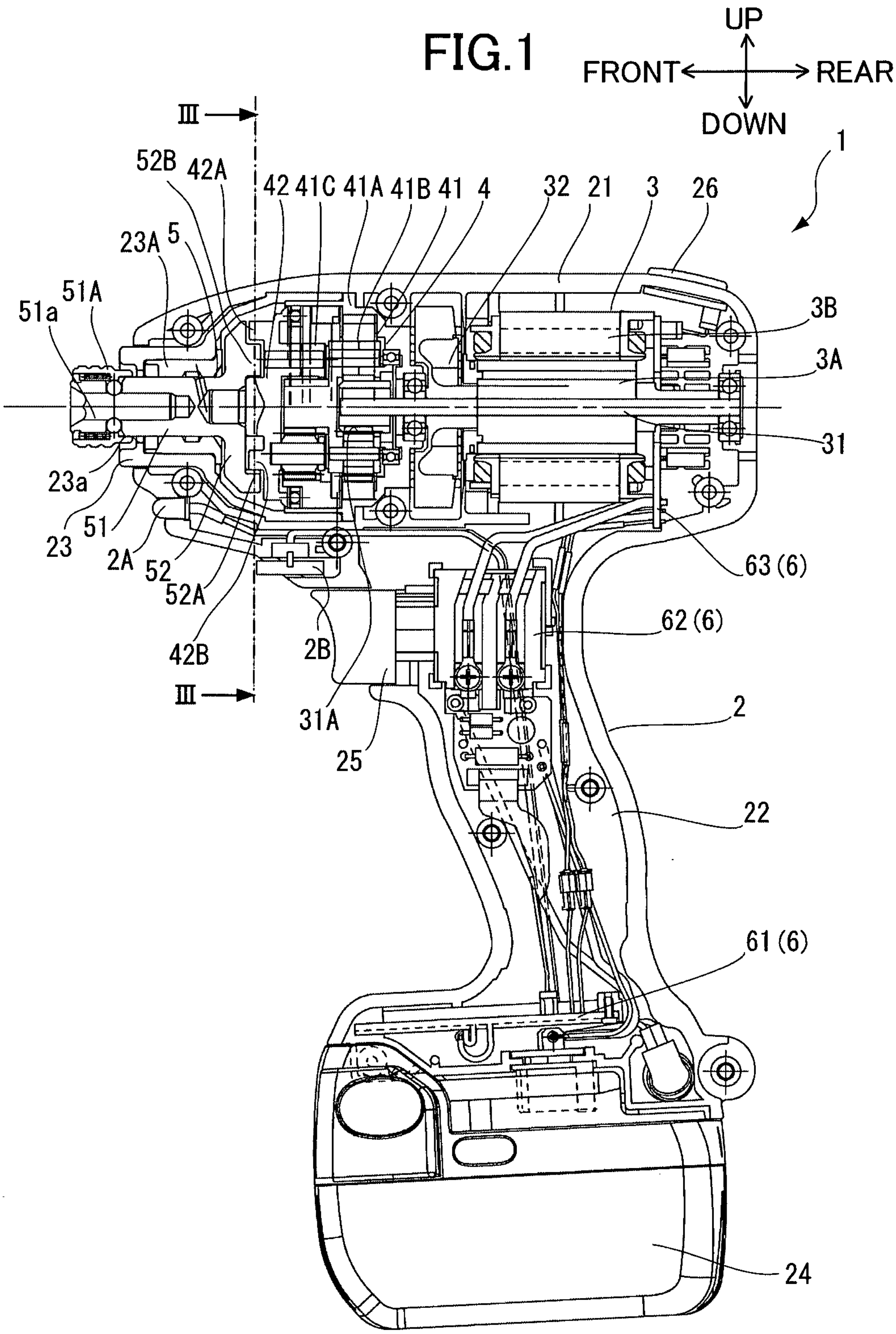

UP
FRONT
REAR
DOWN
1
Ⅲ
Ⅲ
52B
42A
42
41C
41A
41B
41
4
32
21
3
26
23A
5
51A
51a
3B
3A
31
23a
23
51
2A
52
52A
42B
63(6)
62(6)
2B
31A
25
2
22
61(6)
24

FIG. 2

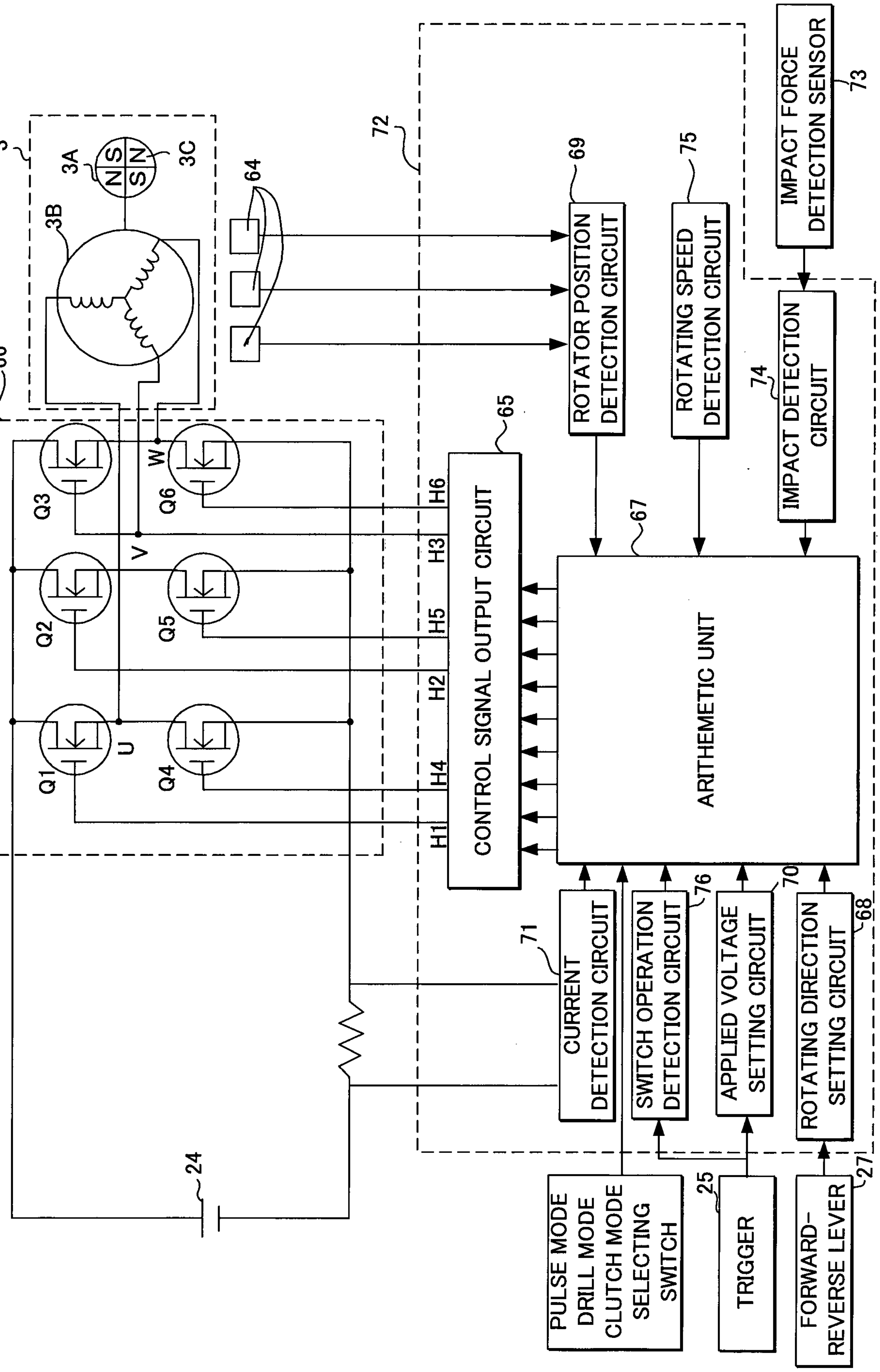

3
3A
3B
3C
N
S
66
64
72
69
ROTATOR POSITION DETECTION CIRCUIT
75
ROTATING SPEED DETECTION CIRCUIT
73
IMPACT FORCE DETECTION SENSOR
74
IMPACT DETECTION CIRCUIT
65
CONTROL SIGNAL OUTPUT CIRCUIT
67
ARITHEMETIC UNIT
Q1
Q2
Q3
Q4
Q5
Q6
U
V
W
H1
H2
H3
H4
H5
H6
24
71
CURRENT DETECTION CIRCUIT
76
SWITCH OPERATION DETECTION CIRCUIT
70
APPLIED VOLTAGE SETTING CIRCUIT
68
ROTATING DIRECTION SETTING CIRCUIT
PULSE MODE DRILL MODE CLUTCH MODE SELECTING SWITCH
25
TRIGGER
27
FORWARD-REVERSE LEVER

FIG.3

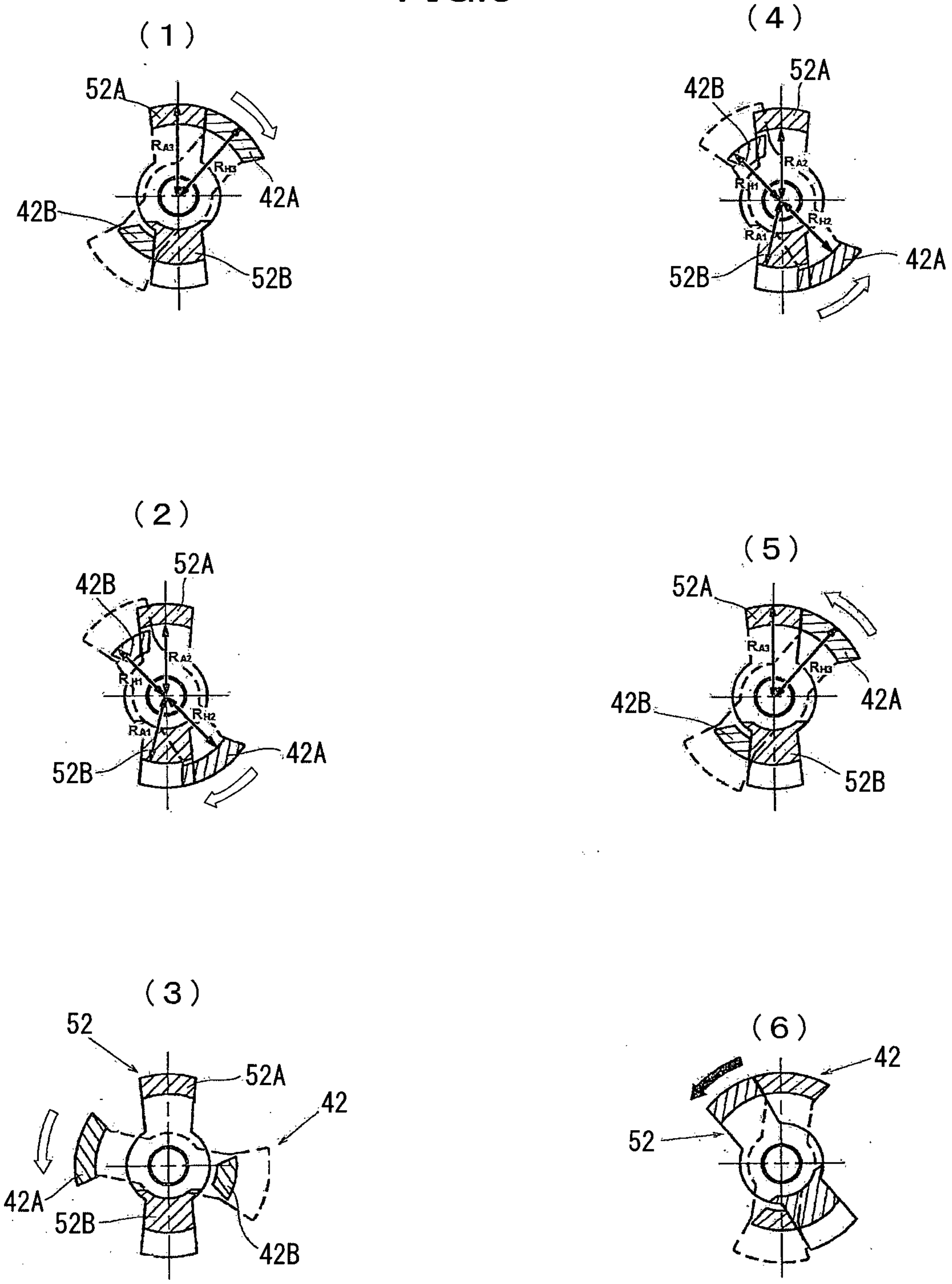

(1)
52A
42A
42B
52B
(2)
52A
42B
42A
52B
(3)
52
52A
42
42A
52B
42B
(4)
52A
42B
42A
52B
(5)
52A
42B
42A
52B
(6)
42
52

FIG. 4

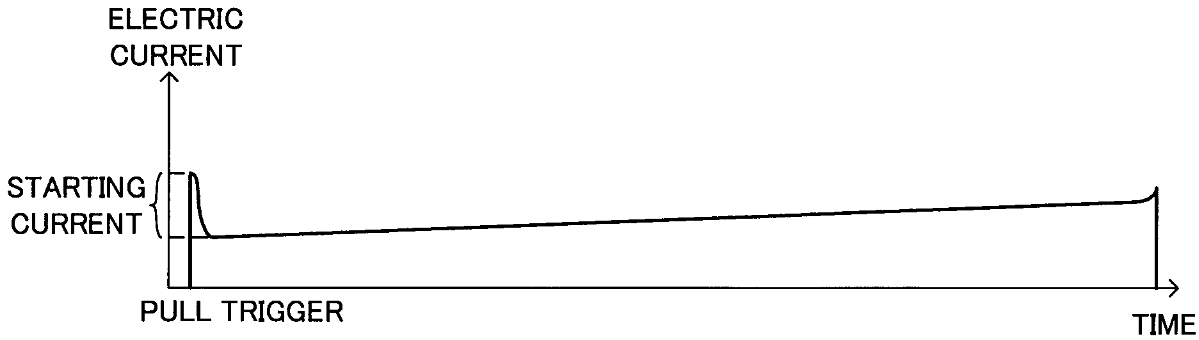

ELECTRIC
CURRENT
STARTING
CURRENT
PULL TRIGGER
TIME

FIG. 5

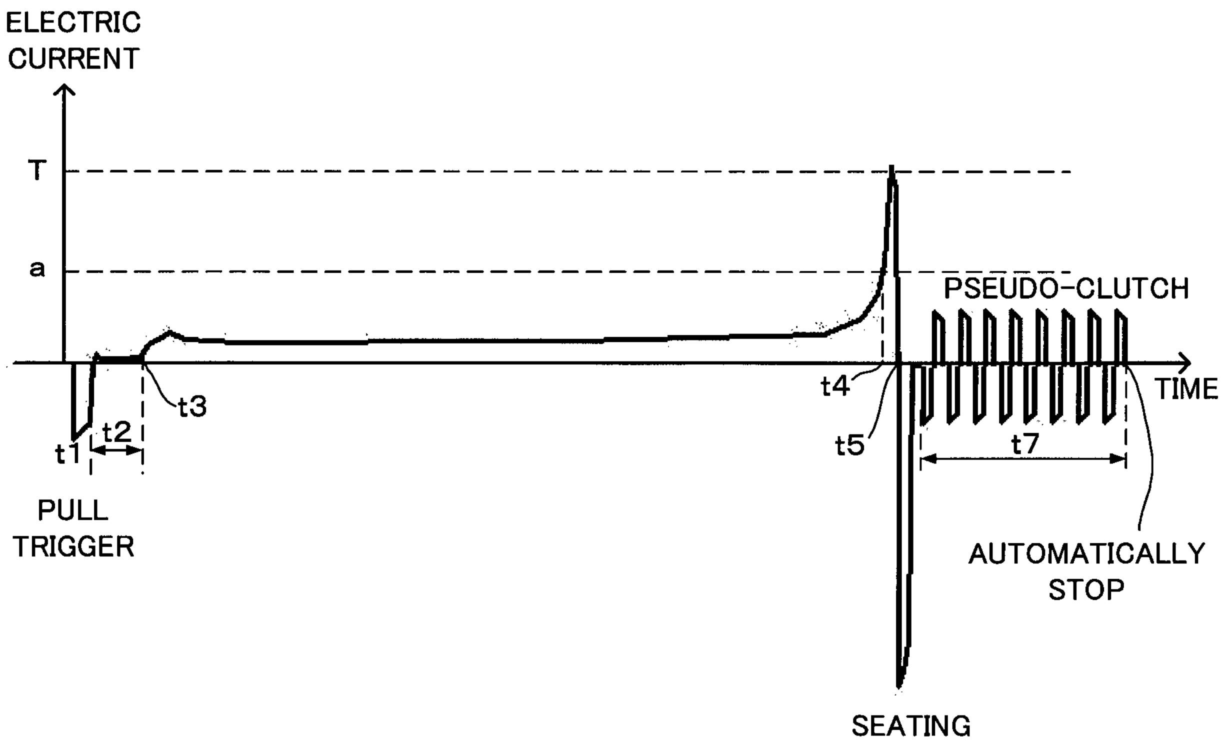

ELECTRIC
CURRENT
T
a
PSEUDO-CLUTCH
TIME
t1
t2
t3
t4
t5
t7
PULL
TRIGGER
AUTOMATICALLY
STOP
SEATING

FIG. 6

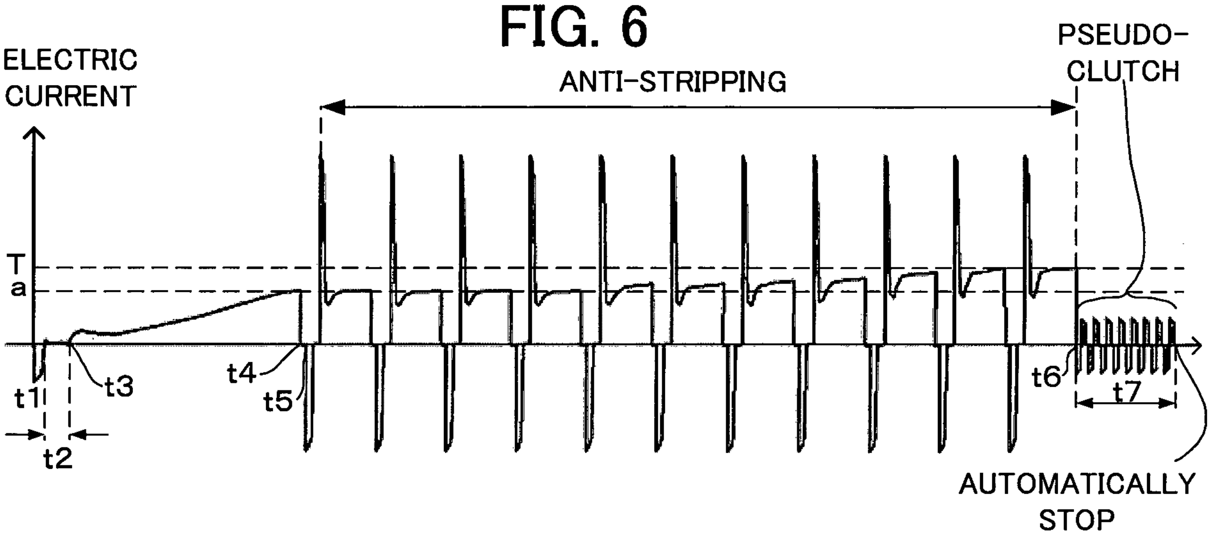

ELECTRIC
CURRENT
ANTI-STRIPPING
PSEUDO-
CLUTCH
T
a
t1
t2
t3
t4
t5
t6
t7
AUTOMATICALLY
STOP

FIG. 7

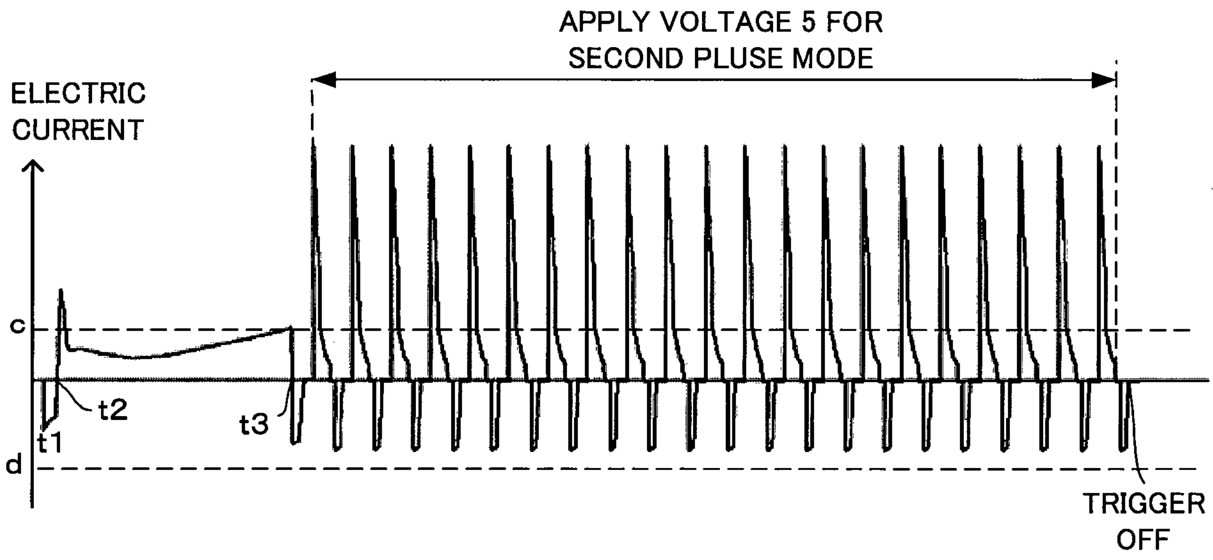

APPLY VOLTAGE 5 FOR
SECOND PLUSE MODE
ELECTRIC
CURRENT
c
d
t1
t2
t3
TRIGGER
OFF

FIG. 8

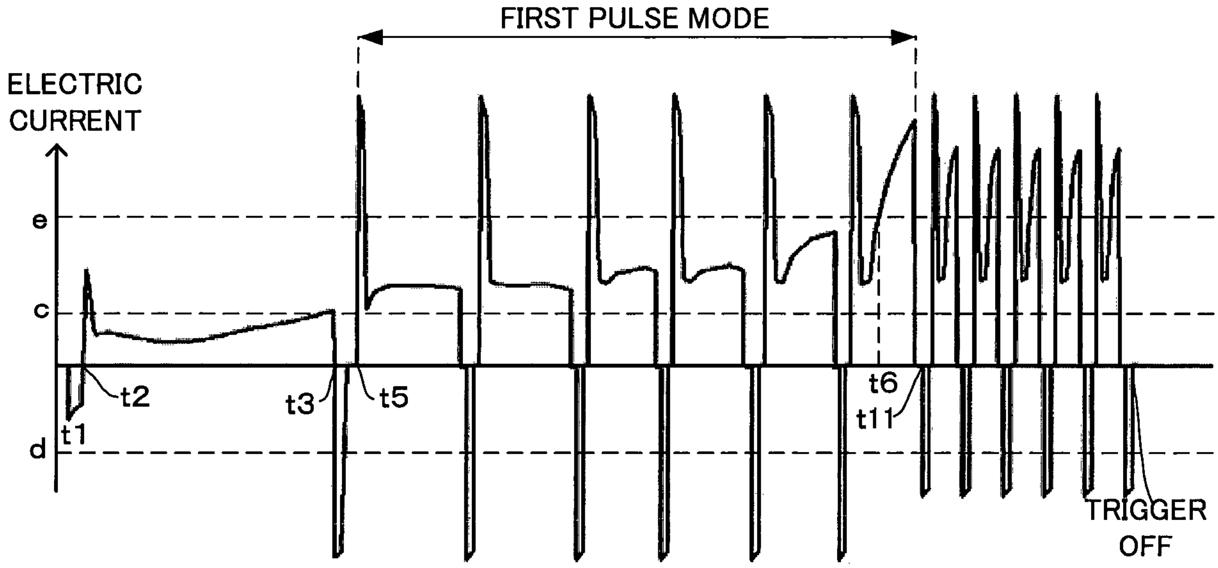

FIRST PULSE MODE
ELECTRIC
CURRENT
e
c
d
t1
t2
t3
t5
t6
t11
TRIGGER
OFF

FIG. 9

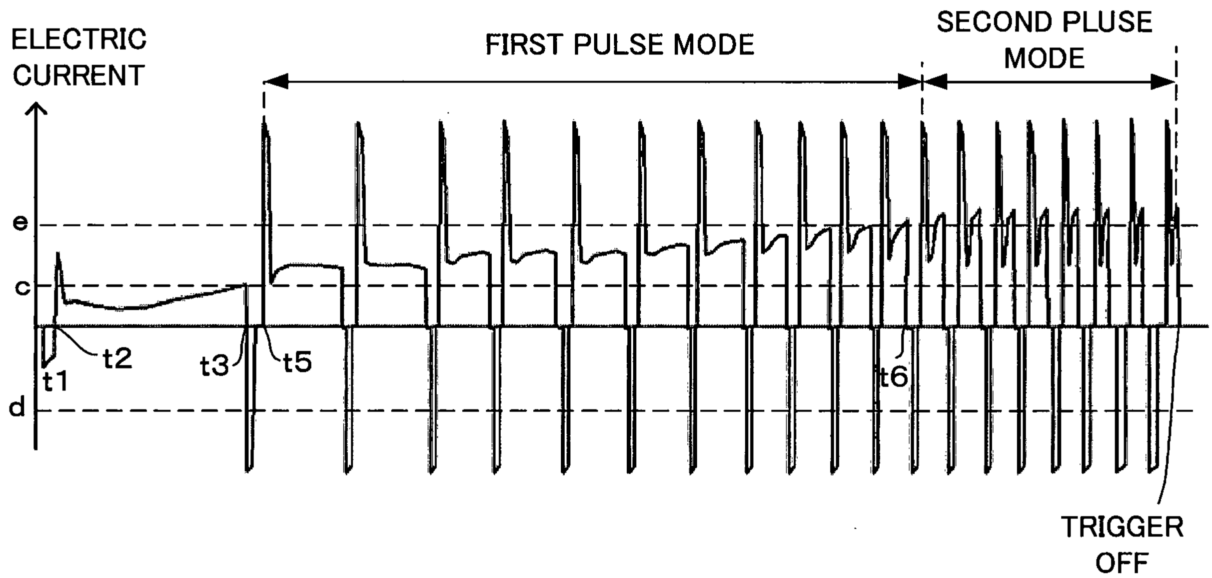

FIRST PULSE MODE
SECOND PLUSE
MODE
ELECTRIC
CURRENT
e
c
d
t1
t2
t3
t5
t6
TRIGGER
OFF

FIG. 10

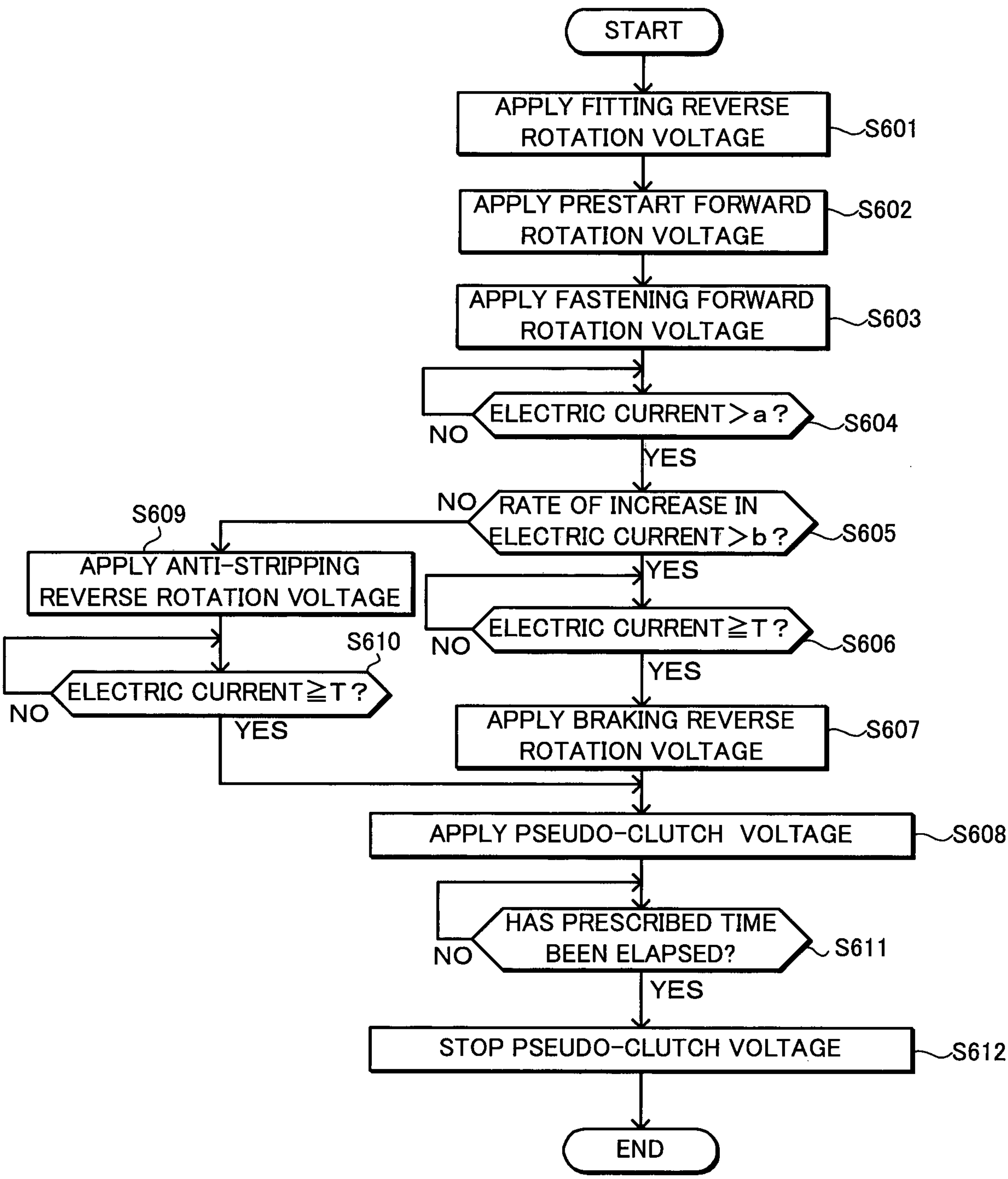

START
APPLY FITTING REVERSE ROTATION VOLTAGE
S601
APPLY PRESTART FORWARD ROTATION VOLTAGE
S602
APPLY FASTENING FORWARD ROTATION VOLTAGE
S603
ELECTRIC CURRENT＞a？
S604
NO
YES
RATE OF INCREASE IN ELECTRIC CURRENT＞b？
S605
NO
YES
S609
APPLY ANTI-STRIPPING REVERSE ROTATION VOLTAGE
ELECTRIC CURRENT≧T？
S610
NO
YES
ELECTRIC CURRENT≧T？
S606
NO
YES
APPLY BRAKING REVERSE ROTATION VOLTAGE
S607
APPLY PSEUDO-CLUTCH VOLTAGE
S608
HAS PRESCRIBED TIME BEEN ELAPSED?
S611
NO
YES
STOP PSEUDO-CLUTCH VOLTAGE
S612
END

FIG. 11

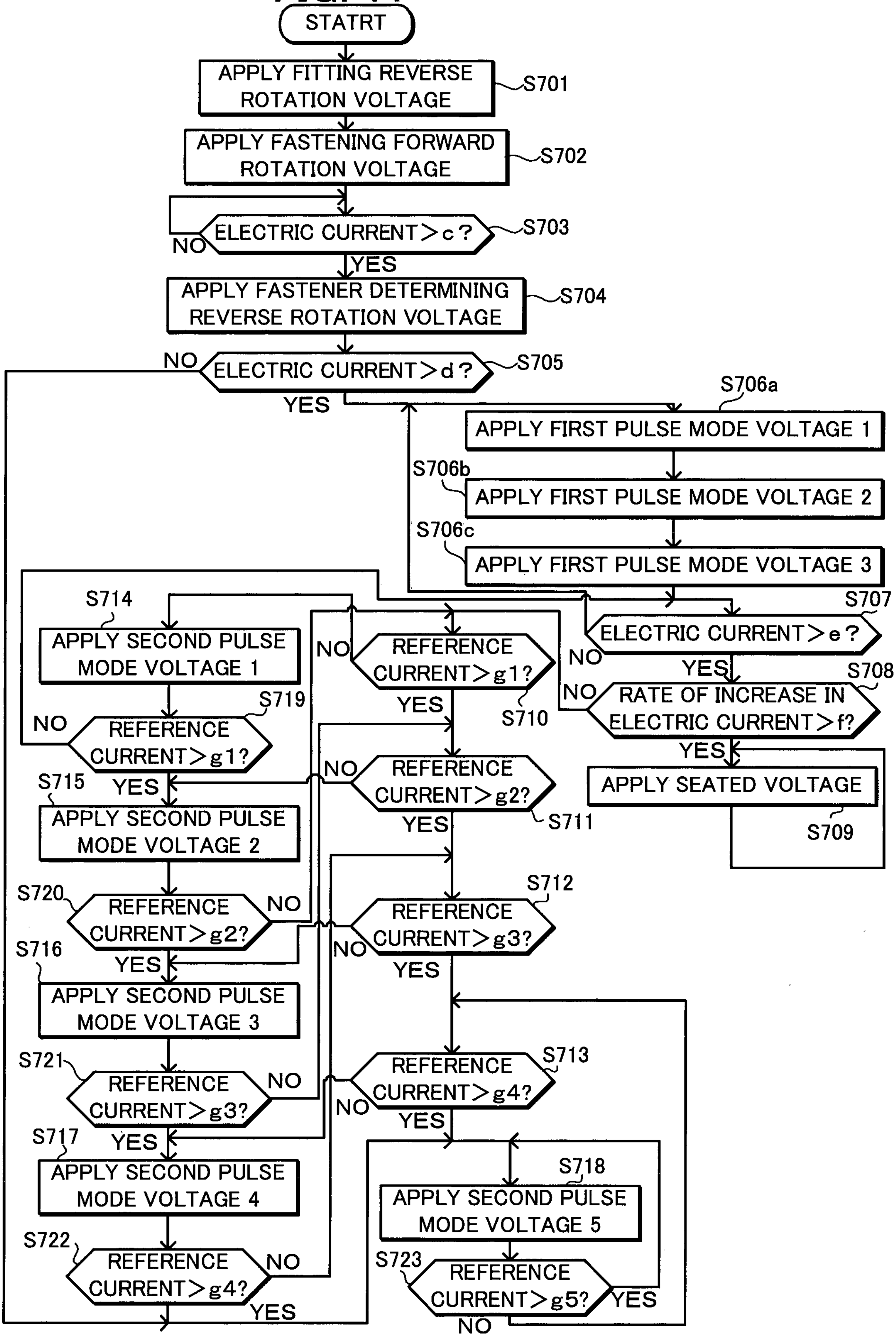

STATRT
APPLY FITTING REVERSE ROTATION VOLTAGE
S701
APPLY FASTENING FORWARD ROTATION VOLTAGE
S702
ELECTRIC CURRENT > c ?
S703
NO
YES
APPLY FASTENER DETERMINING REVERSE ROTATION VOLTAGE
S704
ELECTRIC CURRENT > d ?
S705
NO
YES
S706a
APPLY FIRST PULSE MODE VOLTAGE 1
S706b
APPLY FIRST PULSE MODE VOLTAGE 2
S706c
APPLY FIRST PULSE MODE VOLTAGE 3
S707
ELECTRIC CURRENT > e ?
NO
YES
S708
RATE OF INCREASE IN ELECTRIC CURRENT > f?
NO
YES
APPLY SEATED VOLTAGE
S709
S710
REFERENCE CURRENT > g1?
S711
REFERENCE CURRENT > g2?
S712
REFERENCE CURRENT > g3?
S713
REFERENCE CURRENT > g4?
S714
APPLY SECOND PULSE MODE VOLTAGE 1
S719
REFERENCE CURRENT > g1?
S715
APPLY SECOND PULSE MODE VOLTAGE 2
S720
REFERENCE CURRENT > g2?
S716
APPLY SECOND PULSE MODE VOLTAGE 3
S721
REFERENCE CURRENT > g3?
S717
APPLY SECOND PULSE MODE VOLTAGE 4
S722
REFERENCE CURRENT > g4?
S718
APPLY SECOND PULSE MODE VOLTAGE 5
S723
REFERENCE CURRENT > g5?
YES
NO

FIG. 12

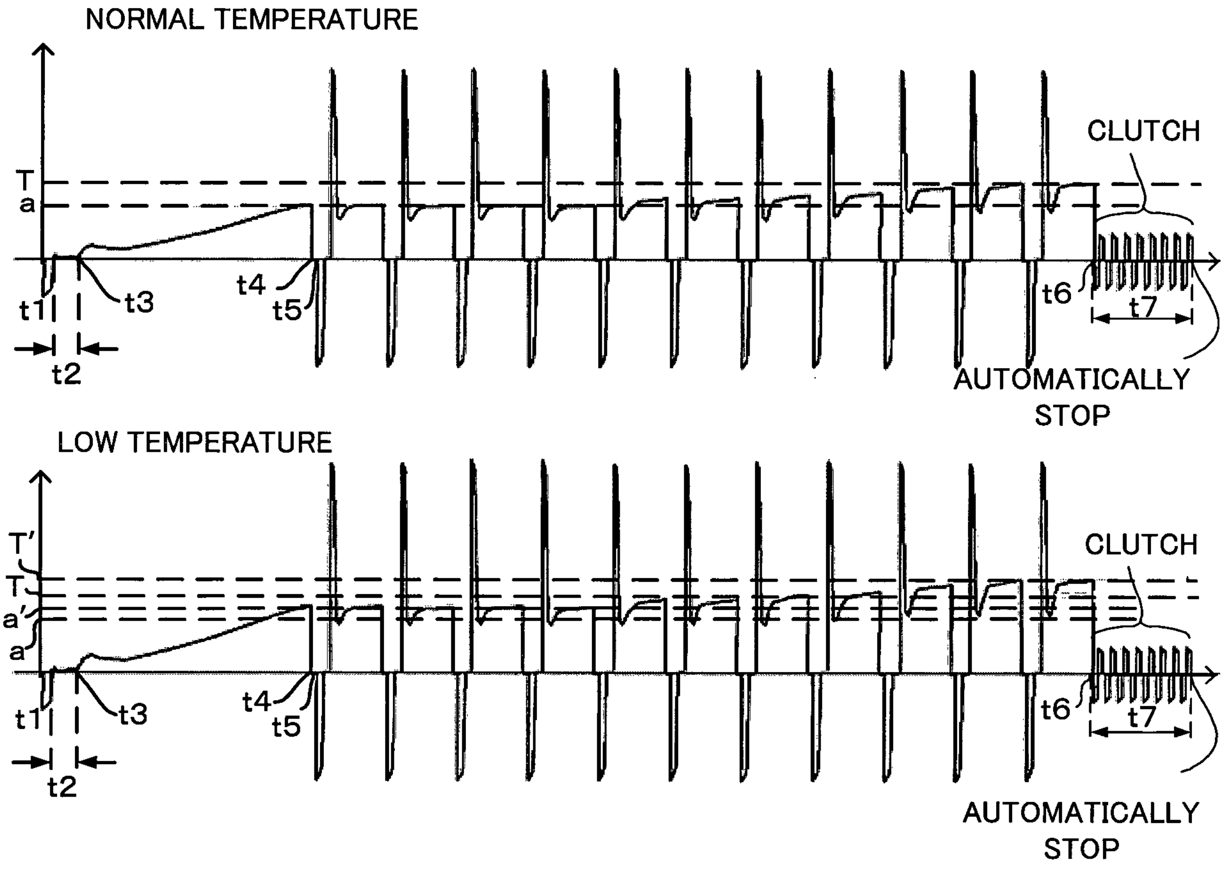

NORMAL TEMPERATURE
T
a
t1
t2
t3
t4
t5
t6
t7
CLUTCH
AUTOMATICALLY STOP
LOW TEMPERATURE
T'
T
a'
a
t1
t2
t3
t4
t5
t6
t7
CLUTCH
AUTOMATICALLY STOP

FIG. 13

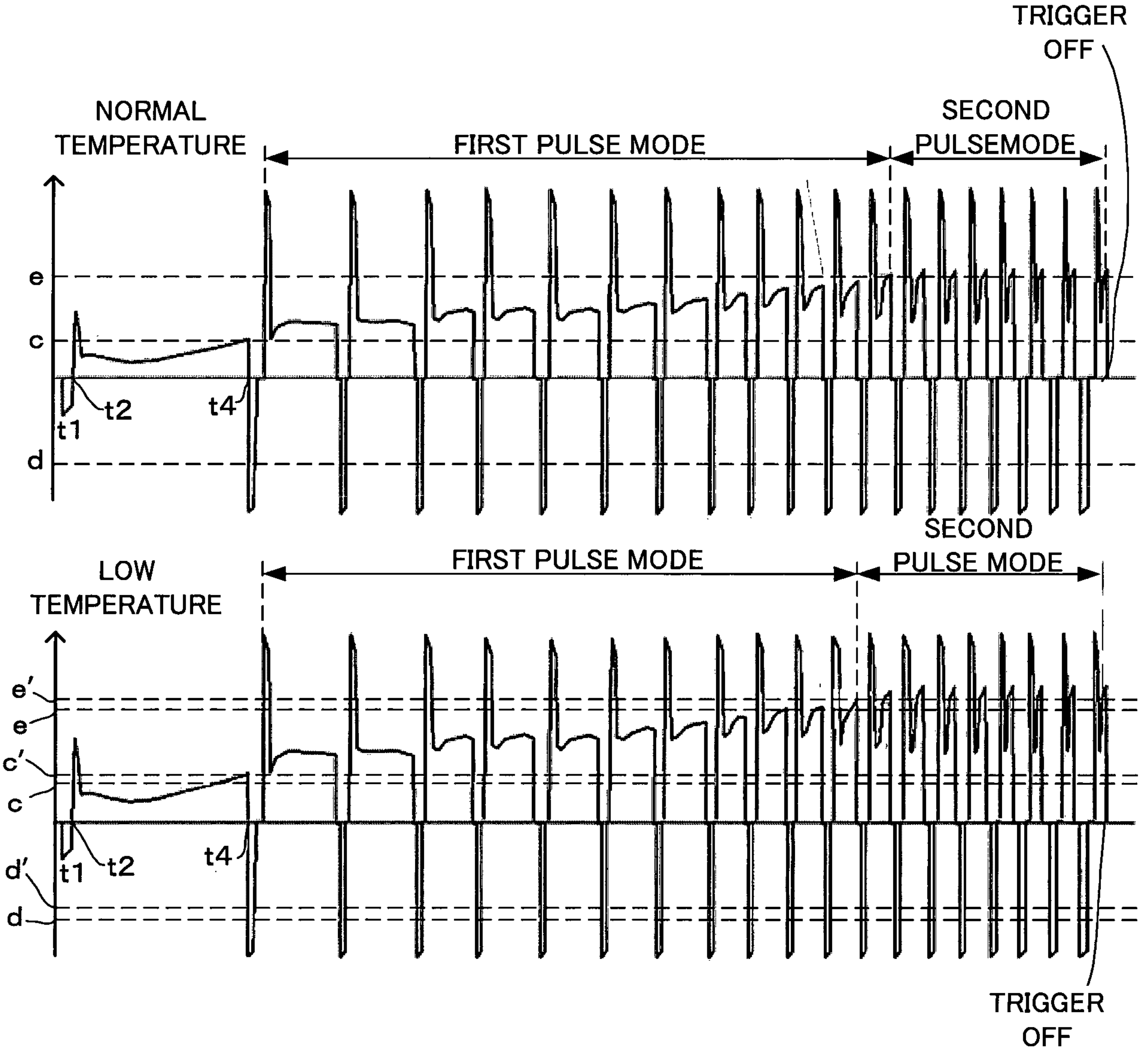

TRIGGER OFF
NORMAL TEMPERATURE
FIRST PULSE MODE
SECOND PULSEMODE
e
c
d
t1
t2
t4
LOW TEMPERATURE
FIRST PULSE MODE
SECOND PULSE MODE
e'
e
c'
c
d'
d
t1
t2
t4
TRIGGER OFF

FIG. 14

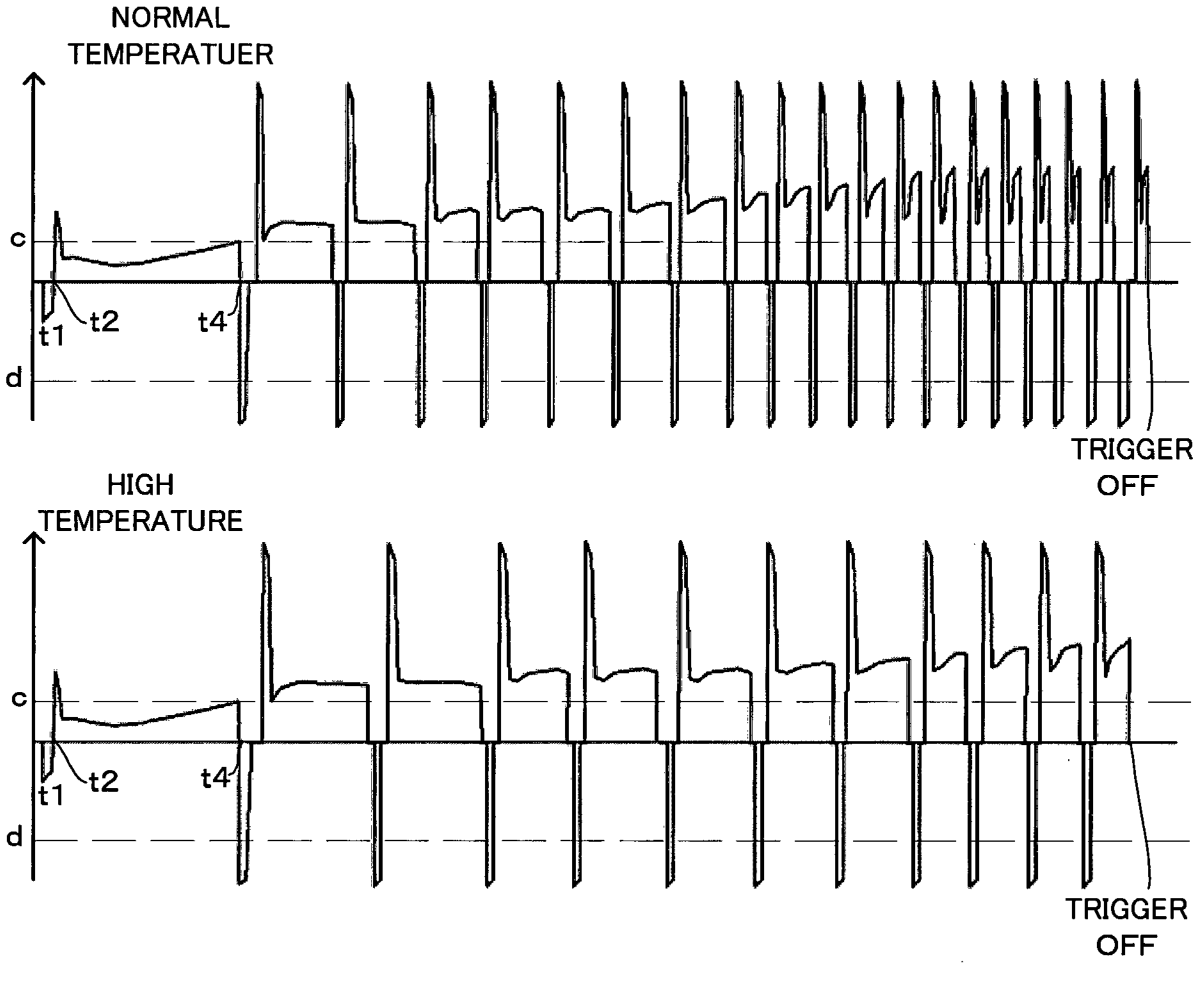

NORMAL
TEMPERATUER
c
d
t1
t2
t4
TRIGGER
OFF
HIGH
TEMPERATURE
c
d
t1
t2
t4
TRIGGER
OFF

FIG. 15

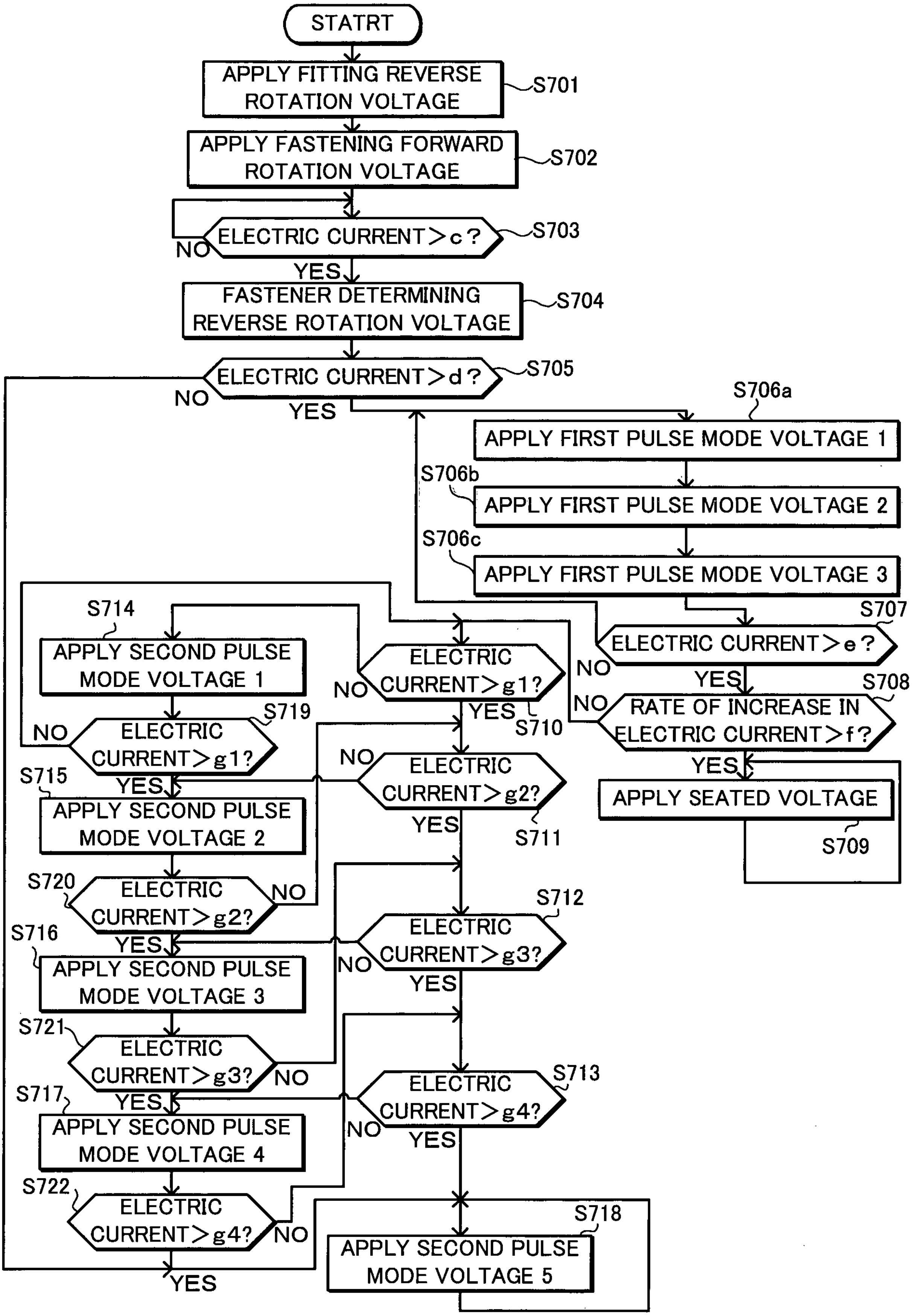

STATRT
APPLY FITTING REVERSE ROTATION VOLTAGE
S701
APPLY FASTENING FORWARD ROTATION VOLTAGE
S702
ELECTRIC CURRENT > c ?
S703
NO
YES
FASTENER DETERMINING REVERSE ROTATION VOLTAGE
S704
ELECTRIC CURRENT > d ?
S705
NO
YES
S706a
APPLY FIRST PULSE MODE VOLTAGE 1
S706b
APPLY FIRST PULSE MODE VOLTAGE 2
S706c
APPLY FIRST PULSE MODE VOLTAGE 3
S707
ELECTRIC CURRENT > e ?
NO
YES
S708
RATE OF INCREASE IN ELECTRIC CURRENT > f ?
NO
YES
APPLY SEATED VOLTAGE
S709
S714
APPLY SECOND PULSE MODE VOLTAGE 1
ELECTRIC CURRENT > g1?
S719
NO
YES
S715
APPLY SECOND PULSE MODE VOLTAGE 2
S720
ELECTRIC CURRENT > g2?
NO
YES
S716
APPLY SECOND PULSE MODE VOLTAGE 3
S721
ELECTRIC CURRENT > g3?
NO
YES
S717
APPLY SECOND PULSE MODE VOLTAGE 4
S722
ELECTRIC CURRENT > g4?
NO
YES
ELECTRIC CURRENT > g1?
NO
YES
S710
ELECTRIC CURRENT > g2?
NO
YES
S711
ELECTRIC CURRENT > g3?
S712
NO
YES
ELECTRIC CURRENT > g4?
S713
NO
YES
S718
APPLY SECOND PULSE MODE VOLTAGE 5

FIG.16

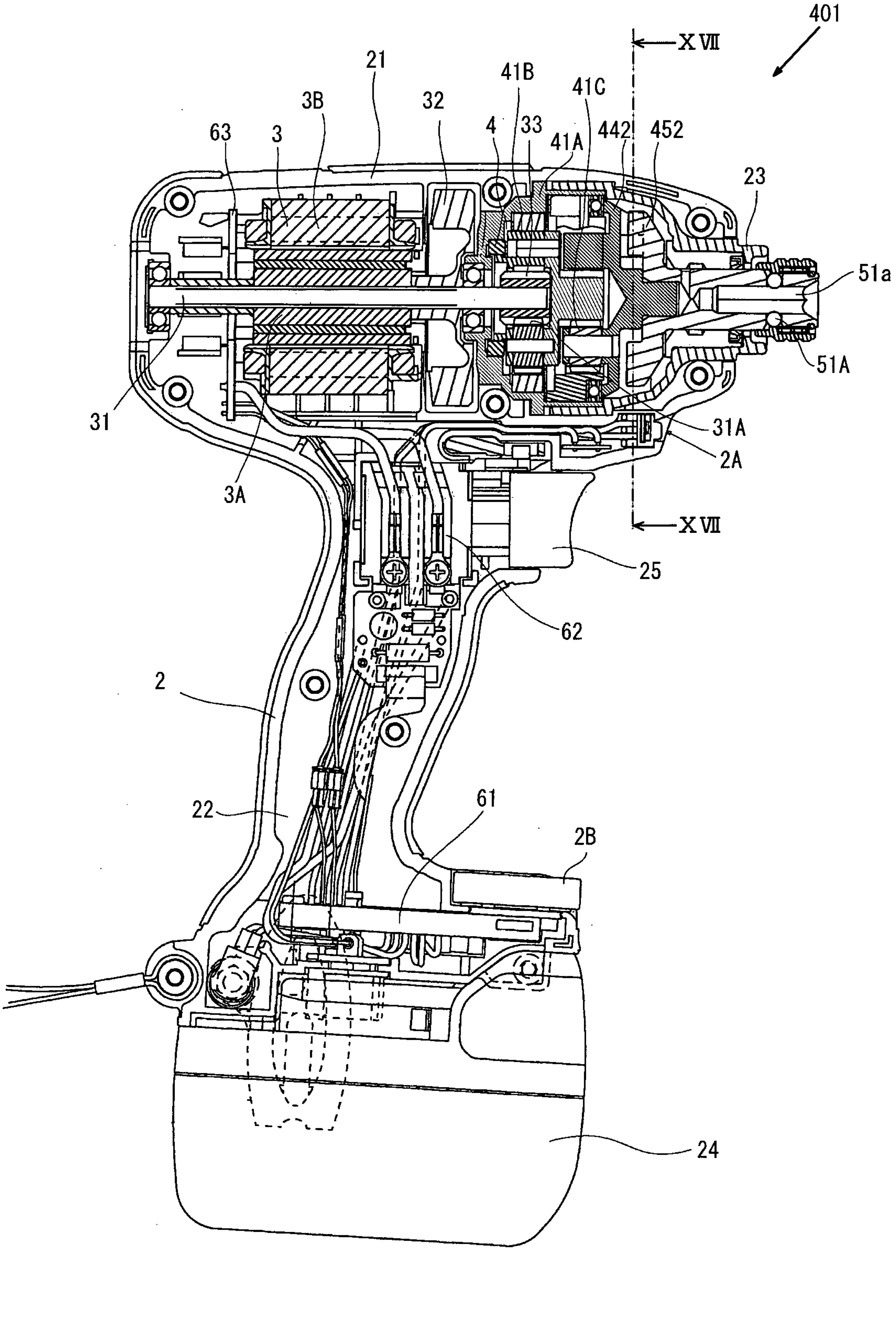

401
XVII
21
41B
41C
3B
32
63
3
4
33
41A
442
452
23
51a
51A
31
31A
2A
3A
XVII
25
62
2
22
61
2B
24

FIG. 17

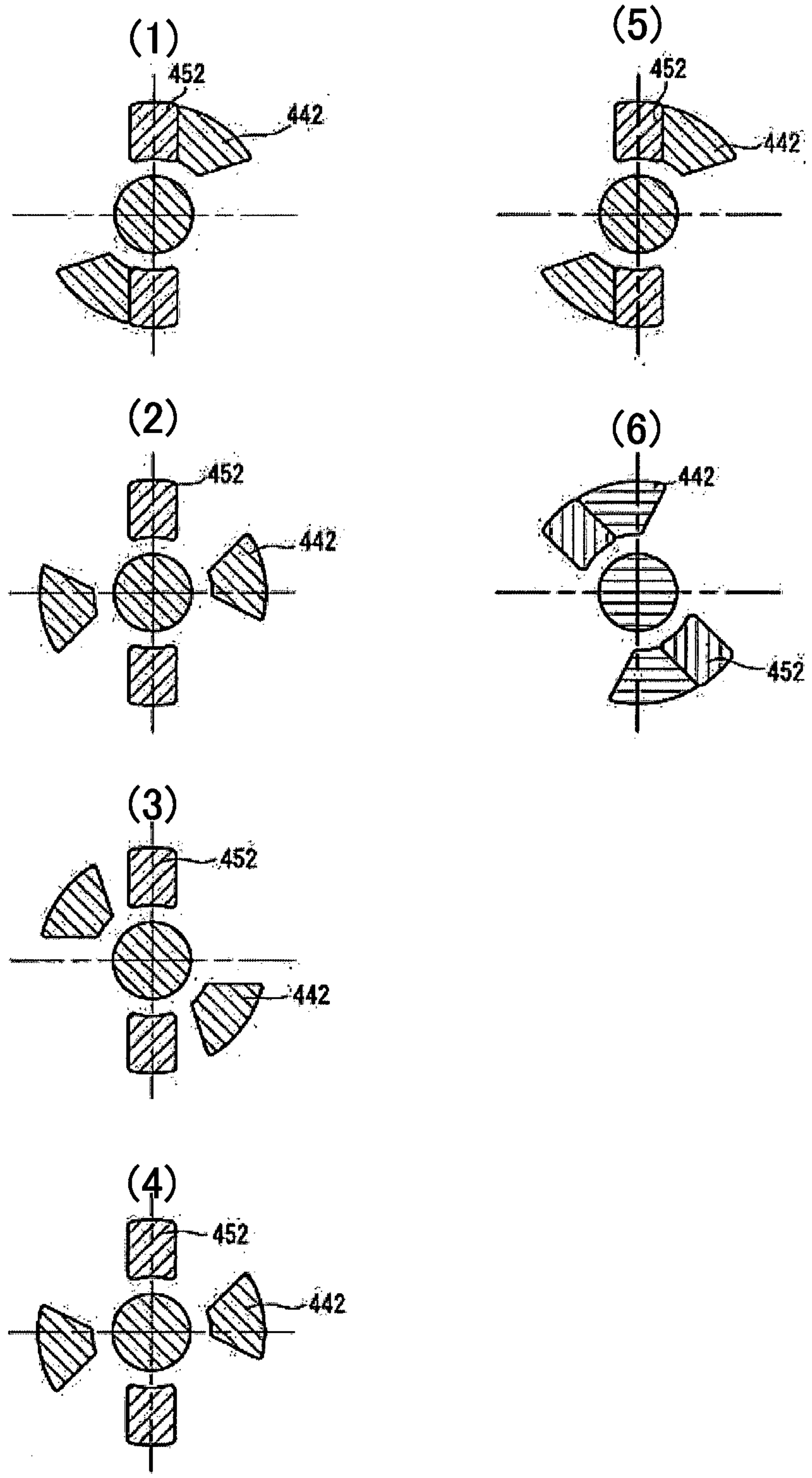
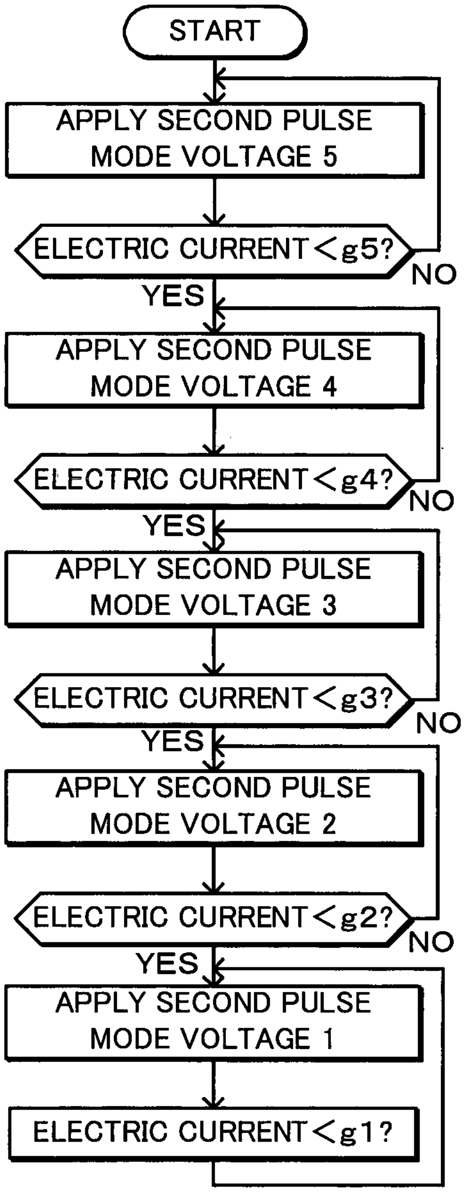


FIG. 18


START
APPLY SECOND PULSE MODE VOLTAGE 5
ELECTRIC CURRENT < g5?
NO
YES
APPLY SECOND PULSE MODE VOLTAGE 4
ELECTRIC CURRENT < g4?
NO
YES
APPLY SECOND PULSE MODE VOLTAGE 3
ELECTRIC CURRENT < g3?
NO
YES
APPLY SECOND PULSE MODE VOLTAGE 2
ELECTRIC CURRENT < g2?
NO
YES
APPLY SECOND PULSE MODE VOLTAGE 1
ELECTRIC CURRENT < g1?

INTERNATIONAL SEARCH REPORT

International application No
PCT/JP2011/056485

A. CLASSIFICATION OF SUBJECT MATTER
INV. B25B21/02 B25B23/14 B25B23/147
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)
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	DE 43 33 675 A1 (BOSCH GMBH ROBERT [DE]) 6 April 1995 (1995-04-06)	2,3
A	the whole document -----	1,4
X	JP 2009 262273 A (PANASONIC ELEC WORKS CO LTD) 12 November 2009 (2009-11-12) paragraph [0022] - paragraph [0023] -----	2,5
X	JP 2009 172740 A (PANASONIC ELEC WORKS CO LTD) 6 August 2009 (2009-08-06) paragraph [0019] - paragraph [0022] -----	2,5
X	US 2007/084613 A1 (ZHANG QIANG [US] ET AL) 19 April 2007 (2007-04-19) paragraph [0038] - paragraph [0040] -----	2

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

☒ See patent family annex.

* Special categories of cited documents :

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"O" document referring to an oral disclosure, use, exhibition or other means
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"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
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"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
26 May 2011	06/06/2011

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	Pothmann, Johannes

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/JP2011/056485

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
DE 4333675 A1	06-04-1995	CN 1132575 A	02-10-1996
		WO 9510135 A1	13-04-1995
		EP 0721695 A1	17-07-1996
		JP 9503377 T	31-03-1997
JP 2009262273 A	12-11-2009	NONE	
JP 2009172740 A	06-08-2009	NONE	
US 2007084613 A1	19-04-2007	NONE	