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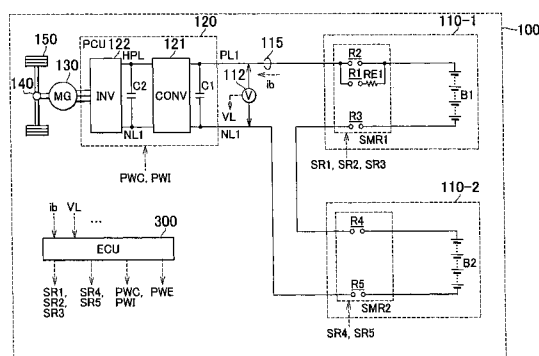
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(54) Title: ELECTRIC POWER SUPPLY APPARATUS FOR VEHICLE, AND CONTROL METHOD THEREOF

FIG. 1



(57) **Abstract:** An electric power supply apparatus for a vehicle includes: a plurality of electricity storage devices (B1, B2) configured to connect to an electric load (120, 130) in series; a plurality of relays (R1, R3, R4, R5) provided on an electric conduction pathway interconnecting the electric load and the electricity storage devices, corresponding to positive and negative electrodes of the electricity storage devices; and a controller (300) that controls the relays. The controller outputs to the relays a first signal for causing one of the relays, as a determination-object relay, to be in a non-conductive state and causing relays other than the determination-object relay to be in a conductive state. Then, the controller executes a determination process of determining whether or not the determination-object relay has been fused, based on a first voltage that is output from the electricity storage devices to the electric load when the first signal is output.

ELECTRIC POWER SUPPLY APPARATUS FOR VEHICLE, AND CONTROL METHOD THEREOF

BACKGROUND OF THE INVENTION

5 1. Field of the Invention

[0001] The invention relates to an electric power supply apparatus for a vehicle equipped with a plurality of electricity storage devices that are configured to connect to an electric load in series.

2. Description of the Related Art

10 [0002] In recent years, as environmentally friendly motor vehicles, vehicles that move by using an electric motor that is driven by electric power stored in a high-voltage battery, such as electric vehicles and hybrid vehicles, have been commercialized.

[0003] Normally in these vehicles, each of the positive electrode and the
15 negative electrode of a high-voltage battery is provided with a system relay that switches between connection and disconnection between the battery and another component part.

[0004] Japanese Patent Application Publication No. 2008-278560 (JP-A-2008-278560) describes a vehicle equipped with a motor driving device. The
20 motor driving device increases the voltage of a battery via a converter, and converts the increased-voltage direct-current electric power into alternating-current electric power, and supplies the converted alternating power to an electric motor. Furthermore, this publication also describes a technology that determines whether or not a system main relay has been fused, on the basis of the voltage V_H between the positive electrode line
25 and the negative electrode line that interconnect the converter and the inverter.

[0005] However, in conjunction with the case where a plurality of batteries are connected to an electric load in series and each of the positive and the negative electrodes of the batteries is provided with a relay, Japanese Patent Application Publication No. 2008-278560 (JP-A-2008-278560) does not describe any concrete
30 solution regarding how to determine the presence or absence of fusion of any one of the relays.

SUMMARY OF THE INVENTION

[0006] The invention provides an electric power supply apparatus that

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appropriately determines the state of a plurality of relays that are provided corresponding to the positive and negative electrodes of a plurality of electricity storage devices that are equipped in a vehicle and configured to connect to an electric load in series.

5 **[0007]** A first aspect of the invention is an electric power supply apparatus for a vehicle, including: a plurality of electricity storage devices configured to connect to an electric load in series; a plurality of relays provided on an electric conduction pathway interconnecting the electric load and the plurality of electricity storage devices, corresponding to positive electrodes and negative electrodes of the plurality of
10 electricity storage devices; and a controller that controls the plurality of relays, wherein: the controller outputs to the plurality of relays a first signal for causing one of the plurality of relays, as a determination-object relay, to be in a non-conductive state and causing relays other than the determination-object relay to be in a conductive state; and the controller executes a determination process of determining whether or not the
15 determination-object relay has been fused, based on a first voltage that is output from the plurality of electricity storage devices to the electric load when the first signal is output.

[0008] The plurality of relays may include a first relay to which a resistor is connected in series. In this case, the controller may execute the determination
20 process on the determination-object relay after causing the first relay to be in the conductive state. The determination-object relay may be one of other relays that are other than the first relay.

[0009] The controller may sequentially switch the determination-object relay among the other relays.

25 **[0010]** The plurality of relays may include a plurality of the first relays that are provided individually for the plurality of electricity storage devices. In this case, the controller may execute the determination process on the determination-object relay after causing the plurality of first relays to be in the conductive state. The determination-object relay may be one of other relays that are other than the plurality
30 of first relays.

[0011] The controller may execute the determination process if there is a request to switch the electric load and the plurality of electricity storage devices from an unconnected state to a connected state.

[0012] The controller may determine that the determination-object relay has

been fused, if the first voltage is greater than a predetermined value.

[0013] The electric power supply apparatus may further include a second relay that is connected in parallel with the resistor and the first relay, and that is caused to be in the conductive state when the plurality of electricity storage devices are to be
5 connected to the electric load.

[0014] The controller may execute the determination process on the determination-object relay while keeping the second relay in the non-conductive state. The determination-object relay may be one of other relays that are other than the first relay.

10 [0015] The controller may output to the second relay a second signal that causes the second relay to be in the non-conductive state, if there is a request to switch the electric load and the plurality of electricity storage devices from a connected state to an unconnected state, and may determine that the second relay has been fused, based on a second voltage that is output from the plurality of electricity storage devices to the
15 electric load when the second signal is output.

[0016] The controller may determine that the second relay has been fused, if the second voltage is greater than a predetermined value.

[0017] The electric load may be a drive device that includes an electric motor that drives the vehicle.

20 [0018] A second aspect of the invention is a control method for an electric power supply apparatus for a vehicle, including: providing a plurality of electricity storage devices that are configured to connect to an electric load in series; providing a plurality of relays that are provided on an electric conduction pathway interconnecting the electric load and the plurality of electricity storage devices, corresponding to
25 positive electrodes and negative electrodes of the plurality of electricity storage devices; outputting to the plurality of relays a first signal for causing one of the plurality of relays, as a determination-object relay, to be in a non-conductive state and causing relays other than the determination-object relay to be in a conductive state; and determining whether or not the determination-object relay has been fused, based on a
30 first voltage that is output from the plurality of electricity storage devices to the electric load when the first signal is output.

[0019] According to the foregoing constructions, in a vehicle that includes a plurality of electricity storage devices configured to connect to an electric load in series, it is possible to appropriately determine the state of a plurality of relays that are

provided corresponding to the positive electrodes and the negative electrodes of the electricity storage devices.

BRIEF DESCRIPTION OF THE DRAWINGS

5 **[0020]** The foregoing and further objects, features and advantages of the invention will become apparent from the following description of example embodiments with reference to the accompanying drawings, wherein like numerals are used to represent like elements and wherein:

FIG. 1 is a first overall block diagram of a vehicle;

10 FIG. 2 is a functional block diagram of an ECU;

FIG. 3 is a first flowchart showing a processing procedure of the ECU;

FIG. 4 is a second flowchart showing a processing procedure of the ECU;

FIG. 5 is a third flowchart showing a processing procedure of the ECU;

FIG. 6 is a second overall block diagram of a vehicle;

15 FIG. 7 is a fourth flowchart showing a processing procedure of an ECU; and

FIG. 8 is a fifth flowchart showing a processing procedure of the ECU.

DETAILED DESCRIPTION OF EMBODIMENTS

[0021] Hereinafter, an embodiment of the invention will be described in detail with reference to the drawings. The same or comparable portions in the drawings are denoted by the same reference characters, and descriptions thereof will not be repeated. **[FIRST EMBODIMENT]**

[0022] FIG. 1 is an overall block diagram of a vehicle that is equipped with an electric power supply apparatus in accordance with a first embodiment of the invention.

[0023] As shown in FIG. 1, a vehicle 100 includes an electric power supply apparatus constructed of a first power supply 110-1 and a second power supply 110-2, and a power control unit (PCU) 120 and a motor-generator (MG) 130 that are drive devices (electric loads) as well as a power transmission gear 140, driving wheels 150, and an electronic control unit (ECU) 300 that functions as a controller.

[0024] Although the vehicle 100 shown in FIG. 1 is provided with one motor-generator, the number of the motor-generators provided in a vehicle is not limited so, that is, a plurality of motor-generators may be provided. Besides, as a motive power source, an engine (not shown) may also be provided, besides the

motor-generator. That is, the invention is applicable generally to electric vehicles that include hybrid motor vehicles that produce drive force using an engine and a motor-generator as well as electric motor vehicles and fuel cell electric motor vehicles that are not equipped with an engine.

5 **[0025]** The first power supply 110-1 and the second power supply 110-2 are configured to connect to the PCU 120 in series via a positive electrode line PL1 and a negative electrode line NL1. Specifically, a positive electrode of the first power supply 110-1 is connected to the positive electrode line PL1, and a negative electrode of the first power supply 110-1 is connected to a positive electrode of the second power
10 supply 110-2, and a negative electrode of the second power supply 110-2 is connected to the negative electrode line NL1.

[0026] The first power supply 110-1 is a battery pack that includes a battery B1 and a system main relay SMR1 (hereinafter, sometimes referred to simply as “SMR1”). The second power supply 110-2 is a battery pack that includes a battery
15 B2 and a system main relay SMR2 (hereinafter, sometimes referred to simply as “SMR2”). The first power supply 110-1 and the second power supply 110-2 may be mounted at different locations according to the space in the vehicle 100.

[0027] Each of the batteries B1 and B2 is constructed of secondary batteries, such as lithium-ion batteries, nickel metal hydride batteries, lead storage batteries, etc.,
20 or electricity storage elements such as electric double layer capacitors and the like. The batteries B1 and B2 supply the PCU 120 with electric power for generating drive force for the vehicle 100. Besides, the batteries B1 and B2 store electric power generated by the MG 130.

[0028] The system main relay SMR1 includes relays R1, R2 and R3, and a
25 resistor RE1. The system main relay SMR2 includes relays R4 and R5.

[0029] One end of the relay R2 is connected to a positive electrode of the battery B1, and the other end of the relay R2 is connected to the positive electrode line PL1. One end of the relay R3 is connected to a negative electrode of the battery B1, and the other end of the relay R3 is connected to the relay R4. One end of the relay
30 R4 is connected to the relay R3, and the other end of the relay R4 is connected to a positive electrode of the battery B2. One end of the relay R5 is connected to a negative electrode of the battery B2, and the other end of the relay R5 is connected to the negative electrode line NL1. The relay R1 is connected to the resistor RE1 in series. The relay R1 and the resistor RE1 are connected in parallel with the relay R2.

[0030] The relays R1 to R5 are controlled by control signals SR1 to SR5 from the ECU 300 independently of each other, so that each of the relays R1 to R5 are switched between an on-state (conductive state) and an off-state (non-conductive state), to thereby switch between connection and disconnection between the battery B1 and the PCU 120, or between the battery B2 and the PCU 120.

[0031] Incidentally, the resistor RE1 functions as a decreasing resistor for reducing the inrush current at the time of turning on the system main relay SMR1. The inrush current is an electric current that suddenly flows to charge a capacitor C1. When the system main relay SMR1 is to be turned on, the relays R3 and R1 are firstly turned on. After the capacitor C1 is charged with low current, the relay R2 is turned on and the relay R1 is turned off. Hereinafter, a combination of the relay R1 and resistor RE1 will be referred to as “pre-charge circuit” as well.

[0032] The PCU 120 includes a converter 121, an inverter 122, and capacitors C1 and C2.

[0033] The converter 121 is connected to the positive electrode line PL1 and the negative electrode line NL1, and to a positive electrode line HPL and a negative electrode line NL1. The converter 121 is controlled by a control signal PWC from the ECU 300, and performs voltage conversion between the voltage between the positive electrode line PL1 and the negative electrode line NL1 and the voltage between the positive electrode line HPL and the negative electrode line NL1.

[0034] The inverter 122 is connected to the converter 121 via the positive electrode line HPL and the negative electrode line NL1. The inverter 122 is controlled by a control signal PWI from the ECU 300, and converts direct-current electric power supplied from the converter 121 into alternating-current electric power for driving the MG 130. Besides, the inverter 122 converts alternating-current electric power generated by the MG 130 into direct-current electric power with which the batteries B1 and B2 can be charged.

[0035] The capacitor C1 is connected between the positive electrode line PL1 and the negative electrode line NL1, and reduces fluctuations of the voltage between the positive electrode line PL1 and the negative electrode line NL1. The capacitor C2 is connected between the positive electrode line HPL and the negative electrode line NL1, and reduces fluctuations of the voltage between the positive electrode line HPL and the negative electrode line NL1.

[0036] The MG 130 is an alternating-current rotary electric machine, for

example, a permanent magnet type synchronous electric motor that is equipped with a rotor in which permanent magnets are embedded.

[0037] The output torque of the MG 130 is transmitted to the driving wheels 150 via the power transmission gear 140 constructed of a speed reducer and a power splitting mechanism, so that the vehicle 100 is moved. During the regenerative braking of the vehicle 100, the MG 130 is able to generate electricity from the turning force of the driving wheels 150. The electric power generated by the MG 130 is converted into charging electric power for the electric power supply devices (the batteries B1 and B2) by the PCU 120.

10 [0038] The vehicle 100 further includes a voltage sensor 112 and an electric current sensor 115. The voltage sensor 112 detects the voltage VL between the positive electrode line PL1 and the negative electrode line NL1. The current sensor 115 detects the electric current ib that flows through the positive electrode line PL1. These sensors output the detection results to the ECU 300.

15 [0039] The ECU 300 includes a central processing unit (CPU) and a memory (neither of which is shown in FIG. 1), and generates control signals for controlling various appliances, on the basis of information stored in the memory and signals from various sensors. The ECU 300 performs controls of the vehicle 100 and the various appliances by outputting to the appliances the control signals that the ECU 300 generates. These controls may be processed by dedicated hardware devices (electronic circuits) instead of software processes.

[0040] Incidentally, although FIG. 1 shows the ECU 300 as a single unit, the ECU 300 may also be divided into two or more units according to functions or control objects.

25 [0041] By the way, a conduction pathway that connects the PCU 120 and the batteries B1 and B2 in series is provided with the relays R2 to R5 that correspond to the electrodes of the batteries B1 and B2. The relays R2 to R5 may become fused due to the current that flows therethrough. If such fusion occurs, it becomes impossible to normally switch between the connection and the disconnection between the PCU 120 and the batteries B1 and B2, causing an operation failure of a drive system of the vehicle 100.

[0042] Therefore, when there is a request to start the drive system (a request to switch the state of the PCU 120 and the batteries B1 and B2 from the non-connected state to the connected state), and when there is a request to stop the drive system (a

request to switch the state of the PCU 120 and the batteries B1 and B2 from the connected state to the non-connected state), the relays R2 to R5 are controlled by a technique described below, and a determination process of determining whether or not any one of the relays R2 to R5 has been fused is performed.

5 **[0043]** FIG. 2 is a functional block diagram of a portion of the ECU 300 that relates to the foregoing determination process. The functional blocks shown in FIG. 2 may be realized by hardware processes that are performed by electronic circuits or the like, or may also be realized by software processes that are performed by execution of programs or the like.

10 **[0044]** The ECU 300 includes a control portion 310 and a determination portion 320. When there is a request to start the drive system (when the control portion 310 receives an ignition-on signal IGon from an ignition switch (not shown)), the control portion 310 outputs control signals SR1 to SR5 to the relays according to a procedure described below with reference to FIG. 3 before starting the drive system
15 (before interconnecting the PCU 120 and the batteries B1 and B2 by turning on the system main relays SMR1 and SMR2) (hereinafter, this control will be referred to as “pre-system-start control”). Incidentally, the control portion 310, during execution of the pre-system-start control, turns on the relay R1 while maintaining the off-state of the relay R2 as described below, in order to reduce the electric current by utilizing the
20 pre-charge circuit (made up of the relay R1 and the resistor RE1) of the system main relay SMR1.

[0045] When there is a request to stop the drive system (e.g., when the control portion 310 receives an ignition-off signal IGoff from the ignition switch (not shown)), the control portion 310 controls the relays R1 to R5 according to a procedure described
25 below with reference to FIG. 4 before stopping the drive system (before disconnecting the PCU 120 and the batteries B1 and B2 from each other by turning off the system main relays SMR1 and SMR2) (hereinafter, this control will be referred to as “pre-system-stop control”).

[0046] The determination portion 320 determines whether or not the relays
30 R3, R4 and R5 have been fused on the basis of the voltage VL occurring during execution of the pre-system-start control (hereinafter, this determination will be referred to as “pre-system-start determination”).

[0047] The determination portion 320 determines whether or not the relay R2 has been fused on the basis of the voltage VL occurring during the pre-system-stop

control (hereinafter, referred to as “pre-system-stop determination”). Incidentally, results of the determination by the determination portion 320 are displayed in an information panel (not shown) or the like to inform a user of the results.

[0048] FIG. 3 is a flowchart showing a processing procedure of the pre-system-start determination that is performed by the ECU 300 in accordance with the first embodiment. The process shown by the flowchart of FIG. 3 is started when the request to start the drive system is output during a stop of the drive system. Incidentally, while the drive system is stopped, all the relays R1 to R5 are in an off-state.

10 [0049] In step (hereinafter, abbreviated as “S”) 10, the ECU 300 outputs to the relay R1 a control signal SR1 for turning on the relay R1, in order to utilize the pre-charge circuit. Incidentally, the relay R1 is kept in an on-state until the process following S10 ends. Besides, the relay R2 is kept in the on-state until the process following S10 ends. Therefore, in the process following S10, the relays R3 to R5
15 other than the relays R1 and R2 are the objects of the determination process.

[0050] In S11, the ECU 300 executes the pre-system-start control for the relay R5 as an determination-object relay. Concretely, the ECU 300 outputs control signals SR5, SR3 and SR4 for turning off the determination-object relay R5, among the relays R3 to R5 other than the relays R1 and R2, and for turning on the relays R3 and R4, to
20 the corresponding relays.

[0051] In S12, the ECU 300 determines whether or not the voltage VL is greater than a predetermined value V0. This determination is a process for determining whether or not the conduction pathway connecting the PCU 120 and the batteries B1 and B2 has been formed. Therefore, the predetermined value V0 is set
25 a value that is less than the output voltage of the batteries B1 and B2 (e.g., set at about zero). If the voltage VL is greater than the predetermined value V0 (YES in S12), the ECU 300 determines in S13 that the relay R5 has been fused in the on-state. Otherwise (NO in S12), the ECU 300 determines that the relay R5 has not been fused, and the process proceeds to S14.

30 [0052] In S14, the ECU 300 executes the pre-system-start control for the relay R3 as an determination-object relay. Concretely, the ECU 300 outputs control signal SR3, SR4 and SR5 for turning off the determination-object relay R3 among the relays R3 to R5 other than the relays R1 and R2, and for turning on the relays R4 and R5, to the corresponding relays.

[0053] In S15, the ECU 300 determines whether or not the voltage VL is greater than the predetermined value V0. If the voltage VL is greater than the predetermined value V0 (YES in S15), the ECU 300 determines in S16 that the relay R3 has been fused in the on-state. Otherwise (NO in S15), the ECU 300 determines
5 that the relay R3 has not been fused, and the process proceeds to S17.

[0054] In S17, the ECU 300 executes the pre-system-start control for the relay R4 as an determination-object relay. Concretely, the ECU 300 outputs control signals SR4, SR3 and SR5 for turning off the determination-object relay R4 among the relays R3 to R5 other than the relays R1 and R2, and for turning on the relays R3 and
10 R5, to the corresponding relays.

[0055] In S18, the ECU 300 determines whether or not the voltage VL is greater than the predetermined value V0. If the voltage VL is greater than the predetermined value V0 (YES in S18), the ECU 300 determines in S19 that the relay R4 has been fused in the on-state. Otherwise (NO in S18), the ECU 300 determines
15 that the relay R4 has not been fused, and ends the process.

[0056] FIG. 4 is a flowchart showing a processing procedure of the pre-system-stop determination that is performed by the ECU 300 in accordance with the first embodiment. The process shown by the flowchart in FIG. 4 is started when there is a request to stop the drive system during the operation of the drive system.
20 Incidentally, during the operation of the drive system, the relay R1 for the pre-charge is in the off-state, and all the relays R2 to R5 are in the on-state.

[0057] In S20, the ECU 300 outputs to the relay R2 the control signal SR2 for turning off the relay R2.

[0058] In S21, the ECU 300 determines whether or not the voltage VL is
25 greater than the predetermined value V0. Incidentally, this determination process is performed after the elapse of a predetermination time following the processing of the S20, taking into consideration the time of discharge of the capacitor C1 by the discharge resistance (not shown) of the PCU 120. If the voltage VL is greater than the predetermined value V0 (YES in S21), the ECU 300 determines in S22 that the
30 relay R2 has been fused in the on-state. Otherwise (NO in S21), the ECU 300 determines that the relay R2 has not been fused, and in S23 outputs the control signals SR3, SR4 and SR5 for turning off the relays R3, R4 and R5, to the corresponding relays.

[0059] As described above, if the request to start the drive system arises, the

ECU 300 turns on the relay R1 in the pre-charge circuit of the SMR1 while maintaining the off-state of the relay R2, and turns off one of the relays R3 to R5 other than the relays R1 and R2 as a determination-object relay, and turns on the other ones of the relays R3 to R5.

5 **[0060]** At this time, in the case where the determination-object relay has not been fused, the conduction pathway interconnecting the PCU 120 and the batteries B1 and B2 has been shut off by the determination-object relay, so that the voltage VL is substantially zero, and is therefore less than the predetermined value V0.

10 **[0061]** On the other hand, if the determination-object relay has been fused, the conduction pathway between the PCU 120 and the batteries B1 and B2 has not been shut off, the voltage VL is approximately equal to the output voltage of the batteries B1 and B2, and therefore is greater than the predetermined value V0. Therefore, if the voltage VL is greater than the predetermined value V0, the ECU 300 determines that the determination-object relay has been fused. Incidentally, even in
15 the case where a determination-object relay has been fused, the resistor RE1 in the pre-charge circuit of the system main relay SMR1 functions as a decreasing resistor, so that the current that flows through the conduction pathway can be restricted to a low level.

20 **[0062]** Then, the ECU 300 sequentially determines the presence or absence of fusion with respect to the relays R3 to R5 by switching the determination-object relay among the relays R3 to R5. Therefore, it is possible to appropriately determine the presence or absence of fusion of each one of the relays that are provided individually for the positive electrodes and the negative electrode of the batteries B1 and B2 interconnected in series. Besides, since it is possible to appropriately determine the
25 absence of fusion with regard to any one of the relays, the batteries B1 and B2 and external devices can be more reliably shut off from each other by the system main relays SMR1 and SMR2.

30 **[0063]** Incidentally, the first embodiment can be changed, for example, as follows. Although in the first embodiment, the number of the batteries connected in series are two, the number is not limited to two, but may also be three or more. In the case where the number of the batteries connected in series is n (n is an integer equal to or greater than 3), it suffices that among the relays R3 to RN ($N=n \times 2 + 1$) other than the relay R1 for the pre-charge and the relay R2 connected in parallel with the relay R1, the determination-object relay is turned off and all the other ones of the relays R3 to

RN are turned on, and that on the basis of the voltage VL occurring at that time, the presence or absence of fusion in the determination-object relay is determined on the basis of the voltage VL occurring at that time.

[0064] Besides, although in the process flow shown in FIG. 3, the determination-object relay is switched in the order of the relays R5, R3 and R4, the sequence of the determination is not limited so. For example, as shown in FIG. 5, the determination process regarding the relay R3 (S14, S15 and S16) is performed prior to the determination process regarding the relay R5 (S11, S12 and S13).

[SECOND EMBODIMENT]

10 [0065] In the first embodiment, the invention is applied to the construction in which the pre-charge circuit is provided only in the system main relay SMR1. In contrast, in a second embodiment of the invention described below, the invention is applied to a construction in which pre-charge circuits are provided for both the system main relays SMR1 and SMR2, corresponding to the batteries B1 and B2.

15 [0066] FIG. 6 is an overall block diagram of a vehicle 100A that is equipped with an electric power supply apparatus in accordance with the second embodiment. While the second power supply 110-2 mounted in the vehicle 100 shown in FIG. 1 is provided with the system main relay SMR2 that does not have a pre-charge circuit, a second power supply 110-2A mounted in a vehicle 100A shown in FIG. 6 is provided with a system main relay SMR2A that has a pre-charge circuit (made up of a relay R6 and a resistor RE2) that is connected in parallel with a relay R4. The relay R6 is controlled by a control signal SR6 from an ECU 300. Other structures in the second embodiment are the same as those in the first embodiment, and detailed descriptions thereof will not be repeated below.

25 [0067] FIG. 7 is a flowchart showing a processing procedure of a pre-system-start determination performed by the ECU 300 in accordance with the second embodiment. Incidentally, of steps shown in FIG. 7, the steps denoted by the same reference numerals as those described above with reference to FIG. 3 will not be described again in detail below.

30 [0068] In S10a, the ECU 300 outputs control signals SR1 and SR6 for turning on the relays R1 and R6, to the relays R1 and R6, in order to utilize the pre-charge circuits of the system main relay SMR1 and the system main relay SMR2.

[0069] After that, the ECU 300 performs a determination process (S11, S12 and S13) regarding the relay R5, and a determination process (S14, S15 and S16)

regarding the relay R3. This sequence of the determination processes may be reversed.

[0070] Due to this, even in the case where the relay R5 or the relay R3 has been fused, the resistor RE2 of the pre-charge circuit of the system main relay SMR2 functions as a decreasing resistor in addition to the resistor RE1 of the pre-charge circuit of the system main relay SMR1, so that the current that flows through the conduction pathway can be restricted to an even lower level.

[0071] Incidentally, in the second embodiment, in order to utilize the pre-charge circuit of the system main relay SMR2 in the pre-system-start determination, the determination regarding the fusion of the relay R4 is performed during the pre-system-stop determination instead of during the pre-system-start determination.

[0072] FIG. 8 is a flowchart showing a processing procedure of the pre-system-stop determination that is performed by the ECU 300 in accordance with the second embodiment. Incidentally, of steps shown in FIG. 8, the steps denoted by the same reference numerals as those described above with reference to FIG. 4 will not be described again in detail below.

[0073] In S30, the ECU 300 determines whether or not a determination-object relay in the previous pre-system-stop determination was the relay R4. If the determination-object relay in the previous pre-system-stop determination was the relay R4 (YES in S30), the ECU 300 proceeds to a process of S20 to S23, in which the ECU 300 determines whether or not the relay R2 has been fused.

[0074] On the other hand, if the previous pre-system-stop determination was not the relay R4 (NO in S30), the ECU 300 proceeds to a process of S31 to S34, in which the ECU 300 determines whether or not the relay R4 has been fused. Specifically, in S31, the ECU 300 outputs to the relay R4 the control signal SR4 for turning off the relay R4. Then, in S32, the ECU 300 determines whether or not the voltage VL is greater than the predetermined value V0. If the voltage VL is greater than the predetermined value V0 (YES in S32), the ECU 300 determines that the relay R4 has been fused. Otherwise (NO in S32), the ECU 300 determines that the relay R4 has not been fused. Then, in S34, the ECU outputs the control signals SR2, SR3 and SR5 for turning off the relays R2, R3 and R5, to the corresponding relays.

[0075] As described above, in the second embodiment, both the system main relay SMR1 and the system main relay SMR2 are provided with the pre-charge circuits, and the presence or absence of fusion regarding each of the relays R3 and R5 is

determined by utilizing the two pre-charge circuits. Therefore, even in the case where a determination-object relay has been fused, the current that flows through the conduction pathway between the PCU 120 and the batteries B1 and B2 can be restricted to an even lower level.

- 5 **[0076]** The foregoing embodiment and modifications are illustrative in all respects, and not restrictive at all. The scope of the invention is defined not by the foregoing description, but by the appended claims for patent, and is intended to cover all the changes and modifications within the meaning and scope equivalent to the claims for patent.

CLAIMS

1. An electric power supply apparatus for a vehicle, comprising:
a plurality of electricity storage devices configured to connect to an electric load
5 in series;
a plurality of relays provided on an electric conduction pathway interconnecting
the electric load and the plurality of electricity storage devices, corresponding to
positive electrodes and negative electrodes of the plurality of electricity storage
devices; and
10 a controller that controls the plurality of relays, wherein:
the controller outputs to the plurality of relays a first signal for causing one of the
plurality of relays, as a determination-object relay, to be in a non-conductive state and
causing the plurality of relays other than the determination-object relay to be in a
conductive state; and
15 the controller executes a determination process of determining whether or not the
determination-object relay has been fused, based on a first voltage that is output from
the plurality of electricity storage devices to the electric load when the first signal is
output.
- 20 2. The electric power supply apparatus according to claim 1, wherein:
the plurality of relays include a first relay to which a resistor is connected in
series; and
the controller executes the determination process on the determination-object
relay after causing the first relay to be in the conductive state; and
25 the determination-object relay is one of other relays that are other than the first
relay.
3. The electric power supply apparatus according to claim 2, wherein
the controller sequentially switches the determination-object relay among the
30 other relays.
4. The electric power supply apparatus according to claim 2 or 3, wherein:
the plurality of relays include a plurality of first relays provided individually for
the plurality of electricity storage devices;

the controller executes the determination process on the determination-object relay after causing the plurality of first relays to be in the conductive state; and

the determination-object relay is one of other relays that are other than the plurality of first relays.

5

5. The electric power supply apparatus according to any one of claims 1 to 4, wherein the controller executes the determination process if there is a request to switch the electric load and the plurality of electricity storage devices from an unconnected state to a connected state.

10

6. The electric power supply apparatus according to any one of claims 1 to 5, wherein the controller determines that the determination-object relay has been fused, if the first voltage is greater than a predetermined value.

15

7. The electric power supply apparatus according to claim 2, further comprising a second relay that is connected in parallel with the resistor and the first relay, and that is caused to be in the conductive state when the plurality of electricity storage devices are to be connected to the electric load.

20

8. The electric power supply apparatus according to claim 7, wherein: the controller executes the determination process on the determination-object relay while keeping the second relay in the non-conductive state; and the determination-object relay is one of other relays that are other than the first relay.

25

9. The electric power supply apparatus according to claim 7 or 8, wherein the controller outputs to the second relay a second signal that causes the second relay to be in the non-conductive state, if there is a request to switch the electric load and the plurality of electricity storage devices from a connected state to an unconnected state, and determines that the second relay has been fused, based on a second voltage that is output from the plurality of electricity storage devices to the electric load when the second signal is output.

30

10. The electric power supply apparatus, according to claim 9, wherein

the controller determines that the second relay has been fused, if the second voltage is greater than a predetermined value.

11. The electric power supply apparatus according to any one of claims 1 to 10,
5 wherein

the electric load is a drive device that includes an electric motor that drives the vehicle.

12. A control method for an electric power supply apparatus for a vehicle, comprising:
10 providing a plurality of electricity storage devices that are configured to connect to an electric load in series;

providing a plurality of relays that are provided on an electric conduction pathway interconnecting the electric load and the plurality of electricity storage devices, corresponding to positive electrodes and negative electrodes of the plurality of
15 electricity storage devices;

outputting to the plurality of relays a first signal for causing one of the plurality of relays, as the determination-object relay, to be in a non-conductive state and causing relays other than the determination-object relay to be in a conductive state; and

determining whether or not the determination-object relay has been fused, based
20 on a first voltage that is output from the plurality of electricity storage devices to the electric load when the first signal is output.

FIG. 1

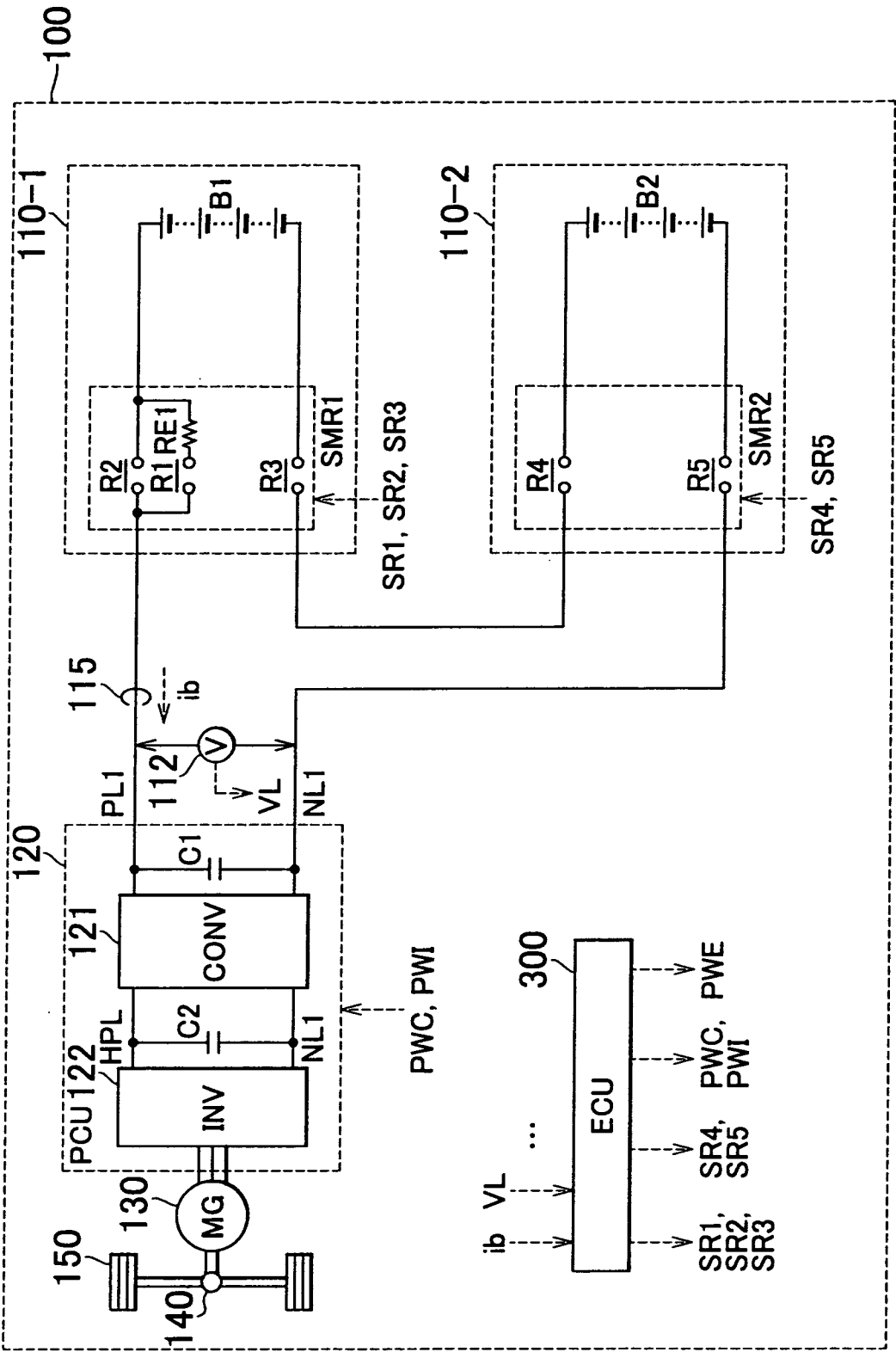
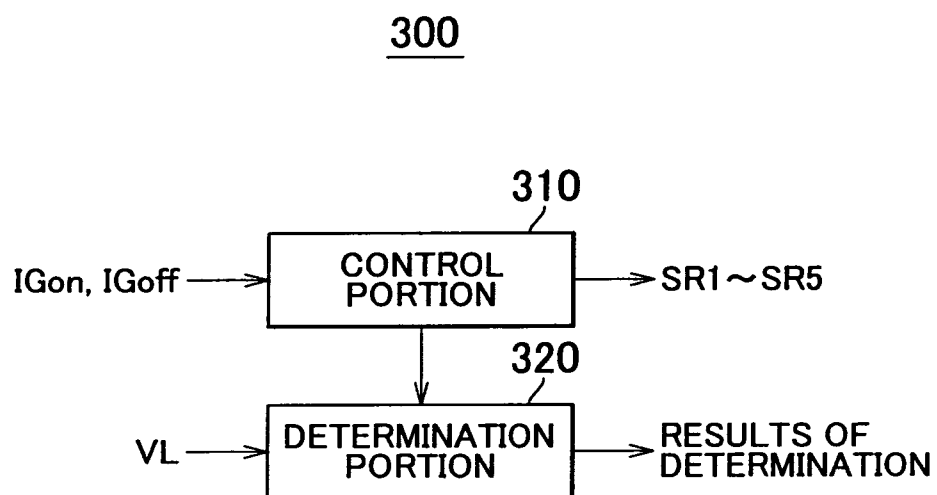


FIG. 2



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FIG. 3

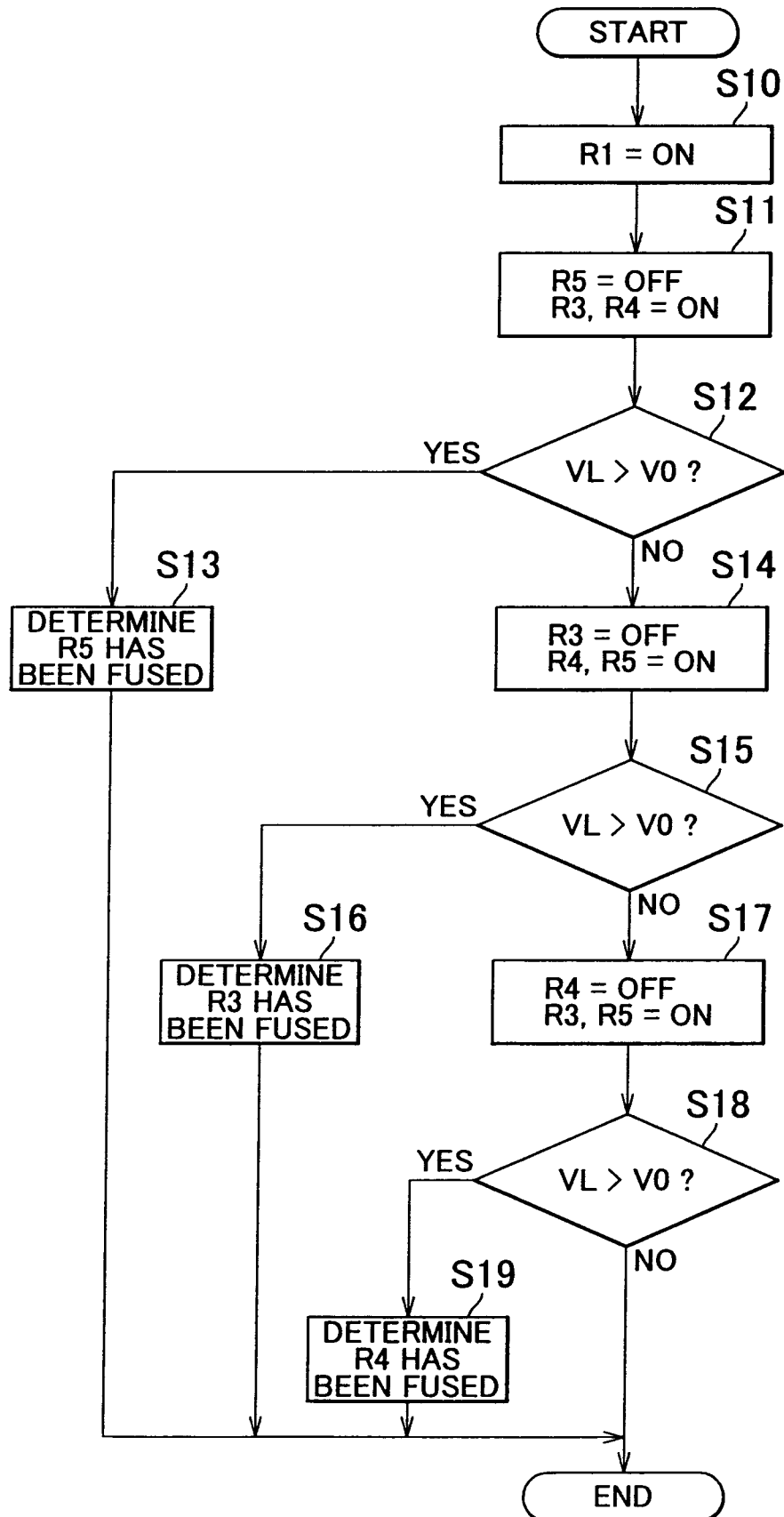
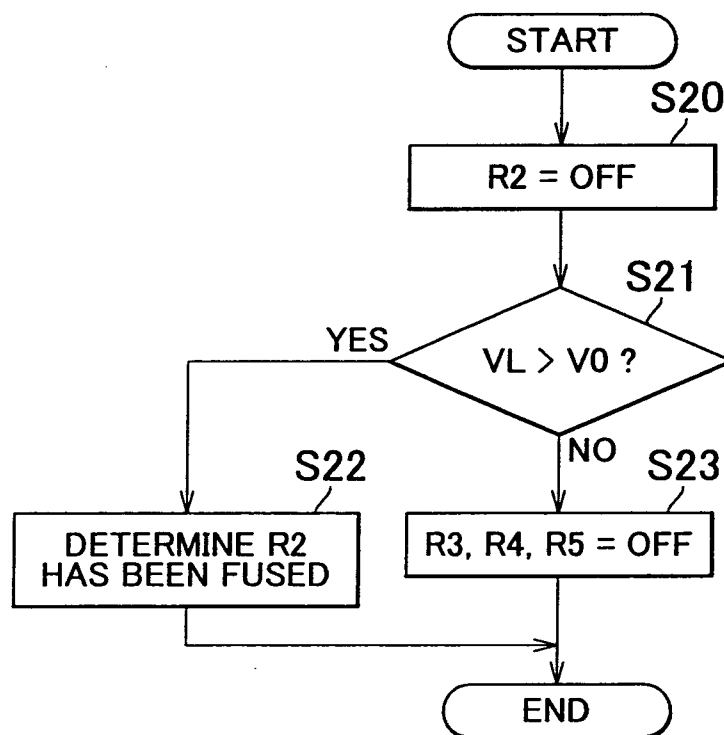


FIG. 4



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FIG. 5

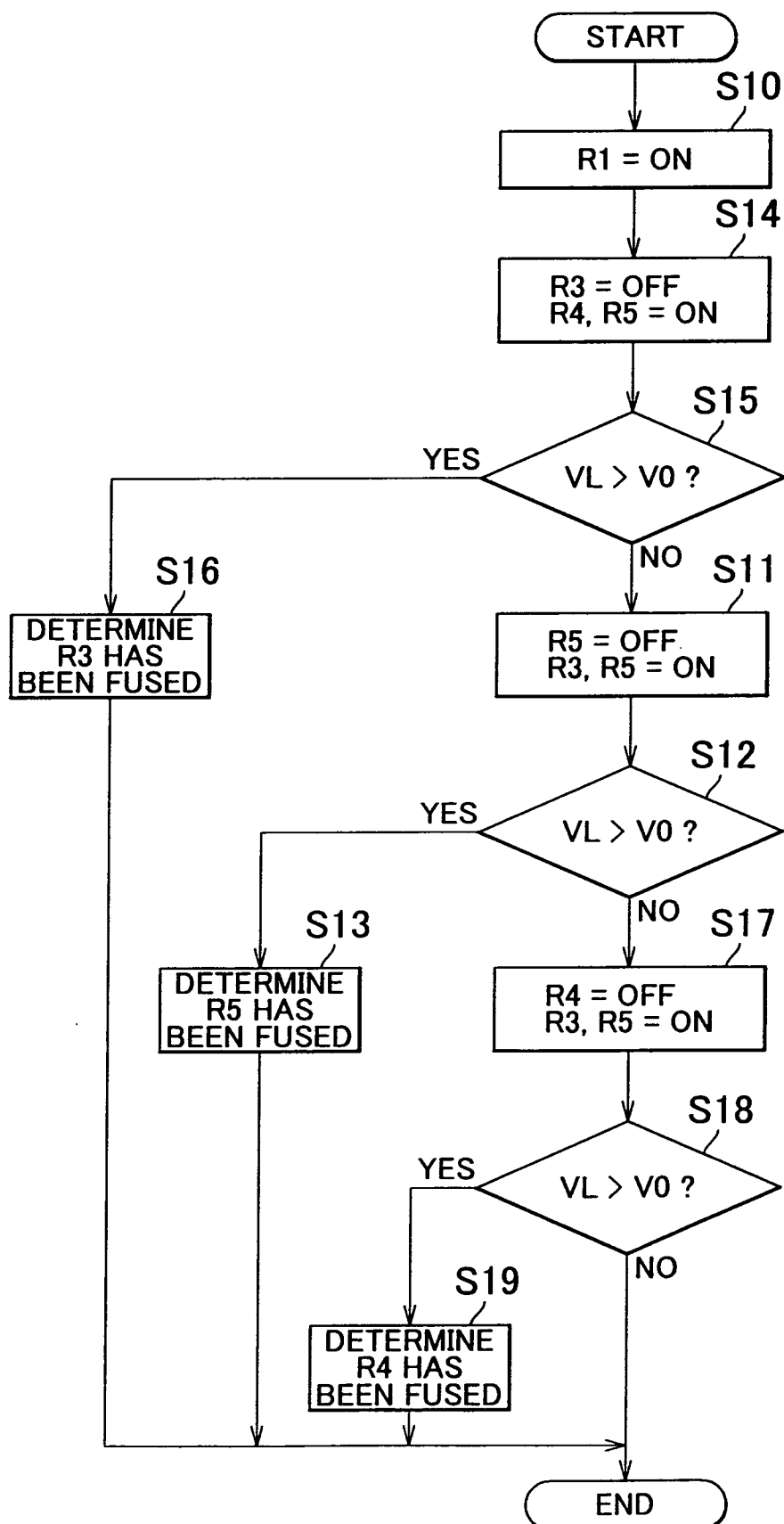


FIG. 7

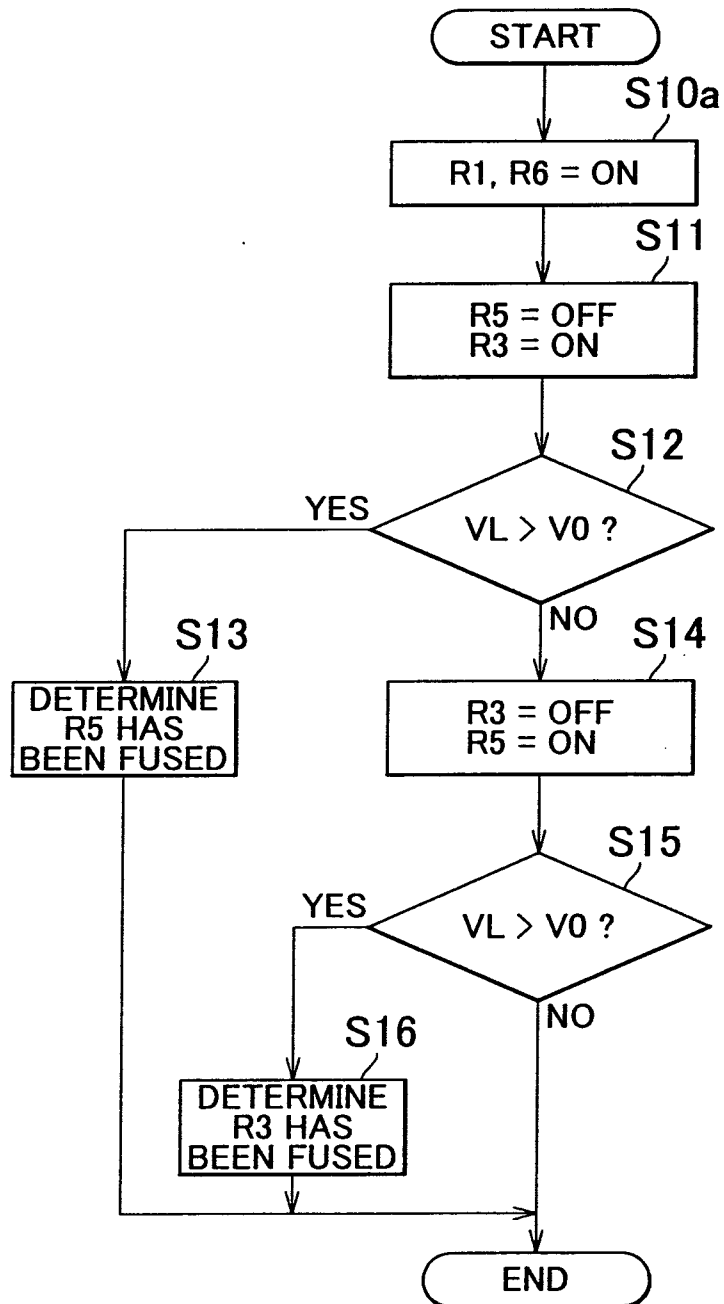


FIG. 8

