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(54) **POWER SUPPLY APPARATUS, IMAGE FORMING APPARATUS, AND POWER SUPPLY CONTROL METHOD**

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(57) **ABSTRACT**

A power supply apparatus comprises: a first power supply line; a second power supply line; a connection unit connecting the first and second power supply line and capable of operating in either a first operation mode in which power transmission between the first and second power supply lines is possible or a second operation mode in which power transmission is not possible; an electric discharge unit connected to the second power supply line and capable of operating in either a third operation mode in which a voltage of the second power supply line is dropped or a fourth operation mode in which the voltage is not dropped; a voltage monitoring unit to monitor the voltage of the second power supply line; and a control unit to control operation of the connection unit and the electric discharge unit.

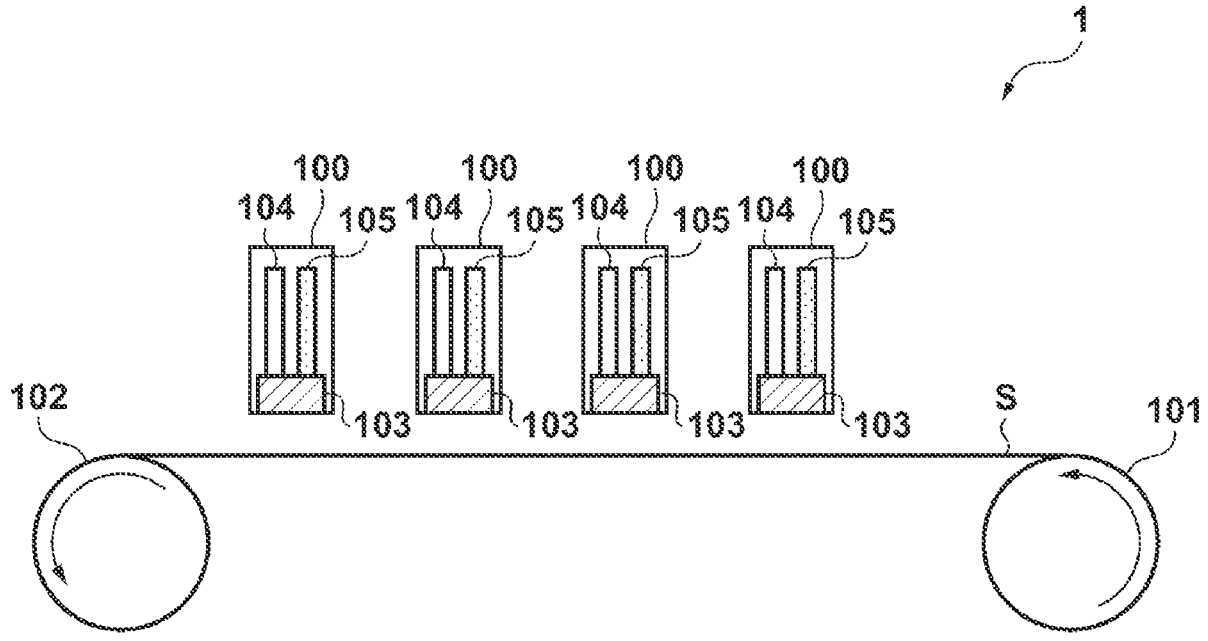
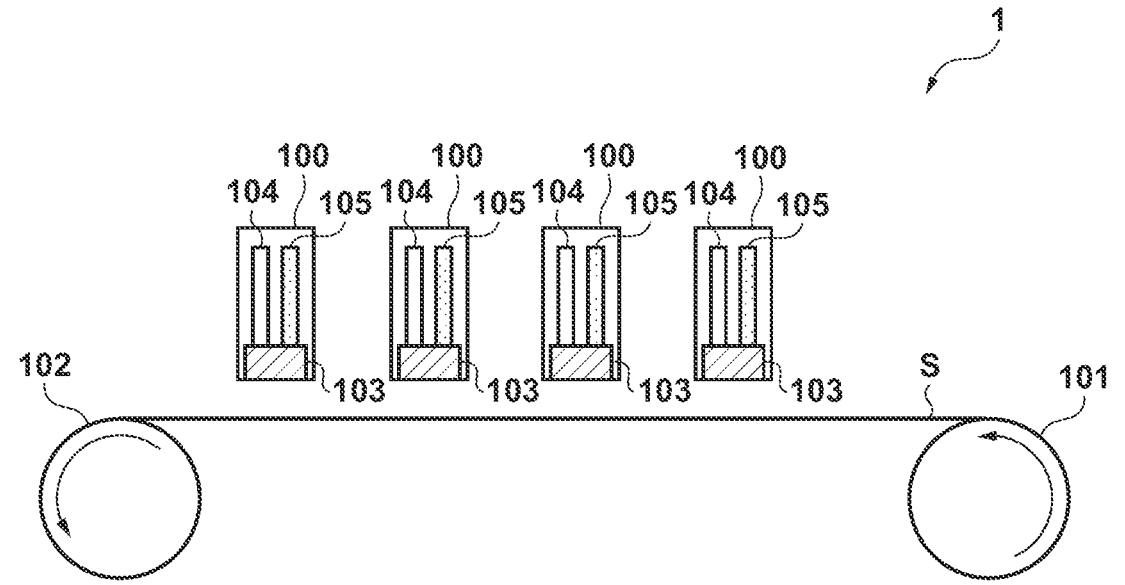


FIG. 1



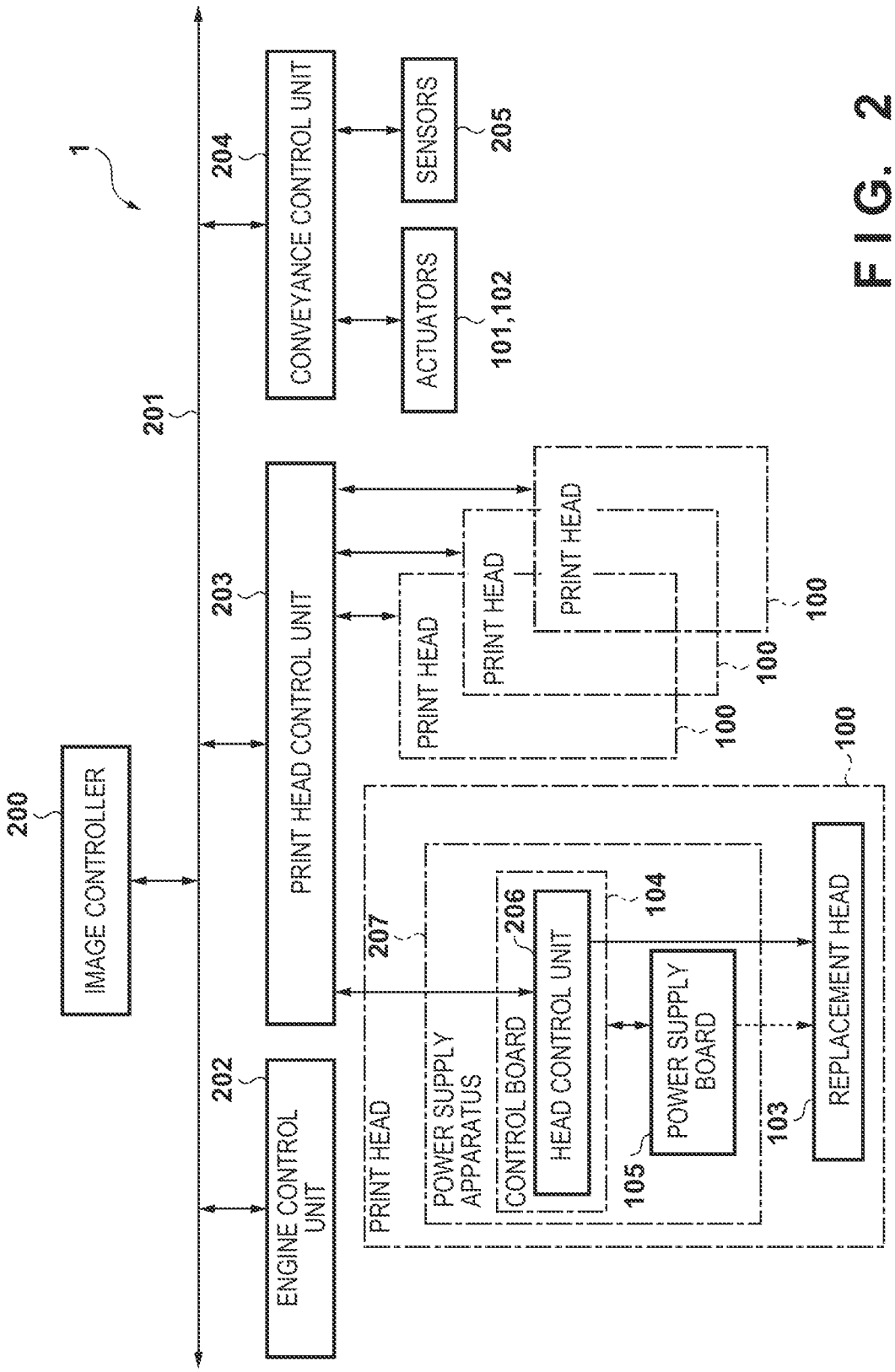

1
200
IMAGE CONTROLLER
201
202
ENGINE CONTROL UNIT
203
PRINT HEAD CONTROL UNIT
204
CONVEYANCE CONTROL UNIT
205
SENSORS
101,102
ACTUATORS
PRINT HEAD
PRINT HEAD
PRINT HEAD
100
100
100
100
PRINT HEAD
207
POWER SUPPLY APPARATUS
CONTROL BOARD
206
HEAD CONTROL UNIT
104
105
POWER SUPPLY BOARD
103
REPLACEMENT HEAD

FIG. 2

FIG. 3

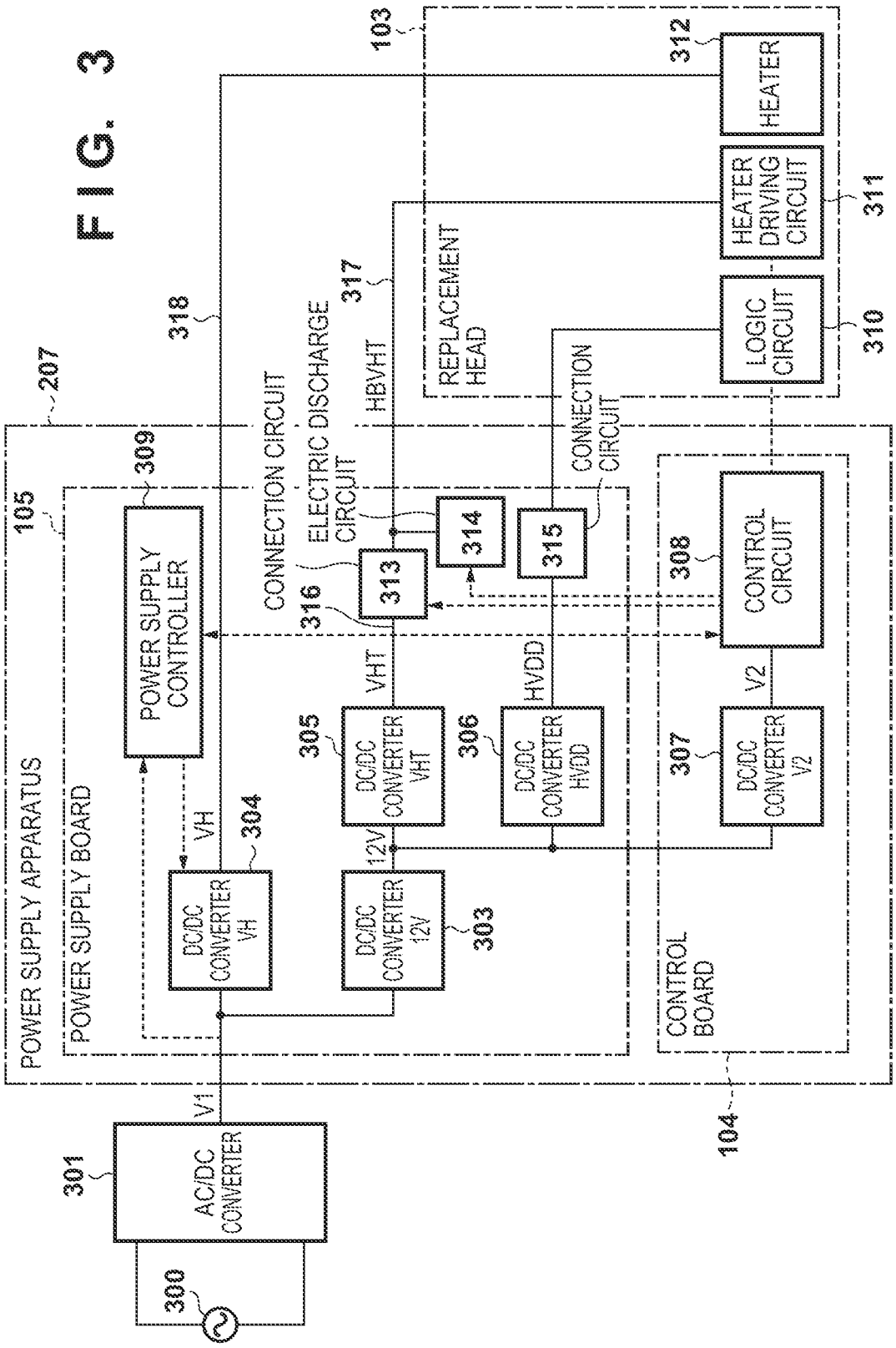

300
301
AC/DC CONVERTER
V1
104
POWER SUPPLY APPARATUS
207
POWER SUPPLY BOARD
105
CONTROL BOARD
DC/DC CONVERTER VH
304
DC/DC CONVERTER 12V
303
DC/DC CONVERTER VHT
305
DC/DC CONVERTER HVDD
306
DC/DC CONVERTER V2
307
VH
12V
VHT
HVDD
V2
POWER SUPPLY CONTROLLER
309
CONNECTION CIRCUIT
318
ELECTRIC DISCHARGE CIRCUIT
316
313
314
315
317
HBVHT
CONNECTION CIRCUIT
308
CONTROL CIRCUIT
REPLACEMENT HEAD
103
LOGIC CIRCUIT
310
HEATER DRIVING CIRCUIT
311
HEATER
312

FIG. 4

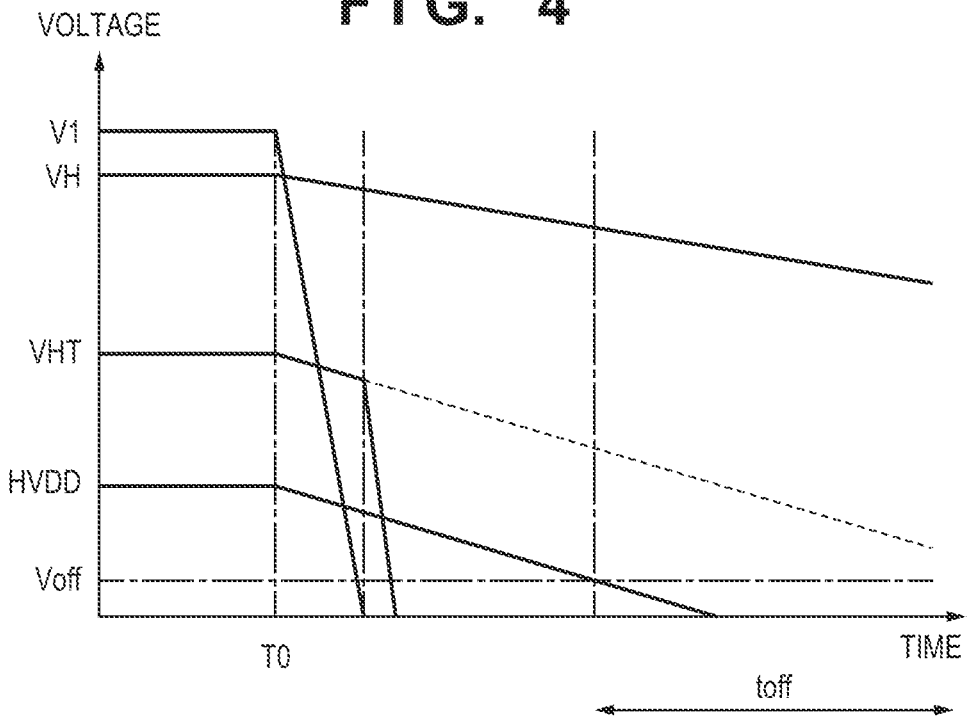


FIG. 5

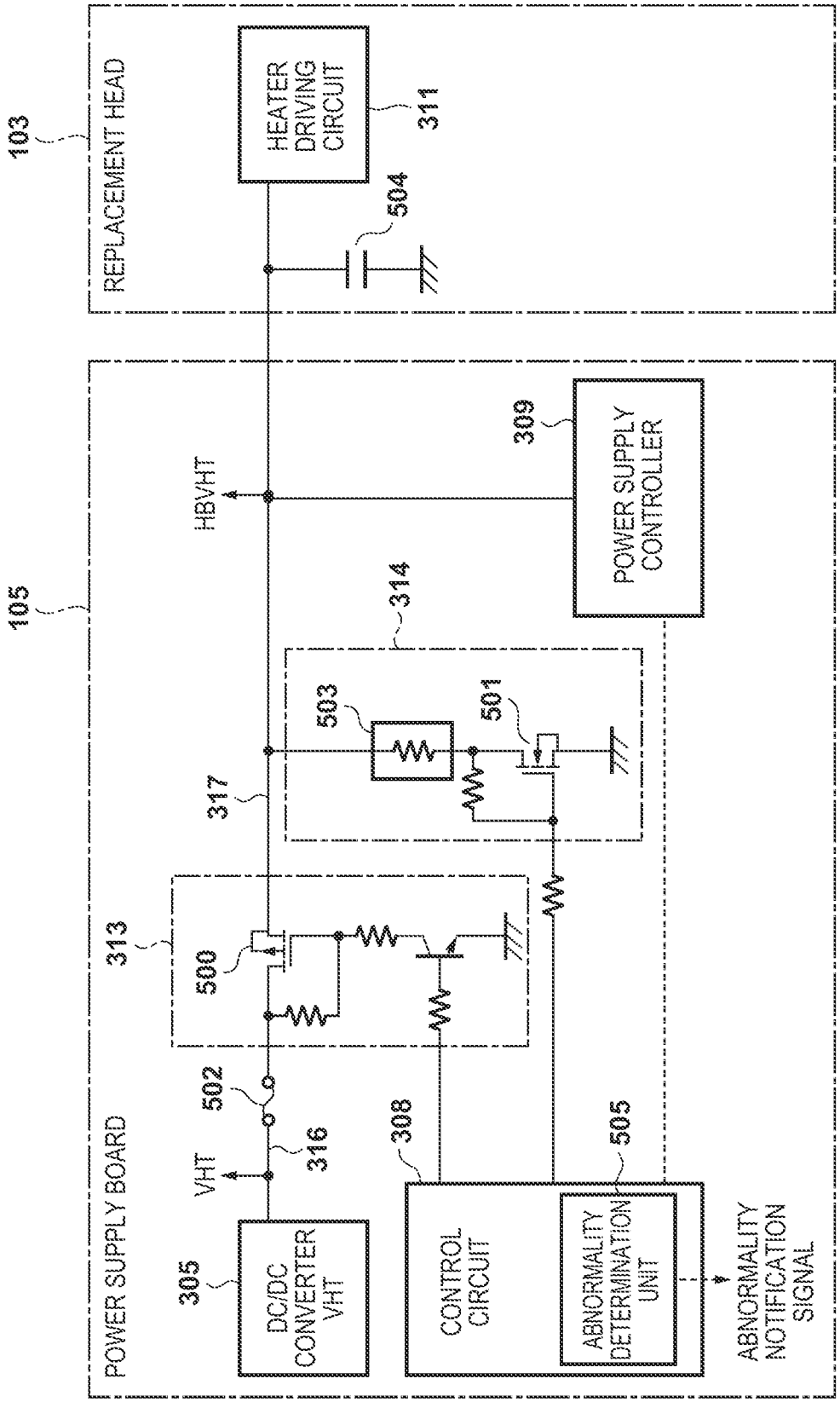
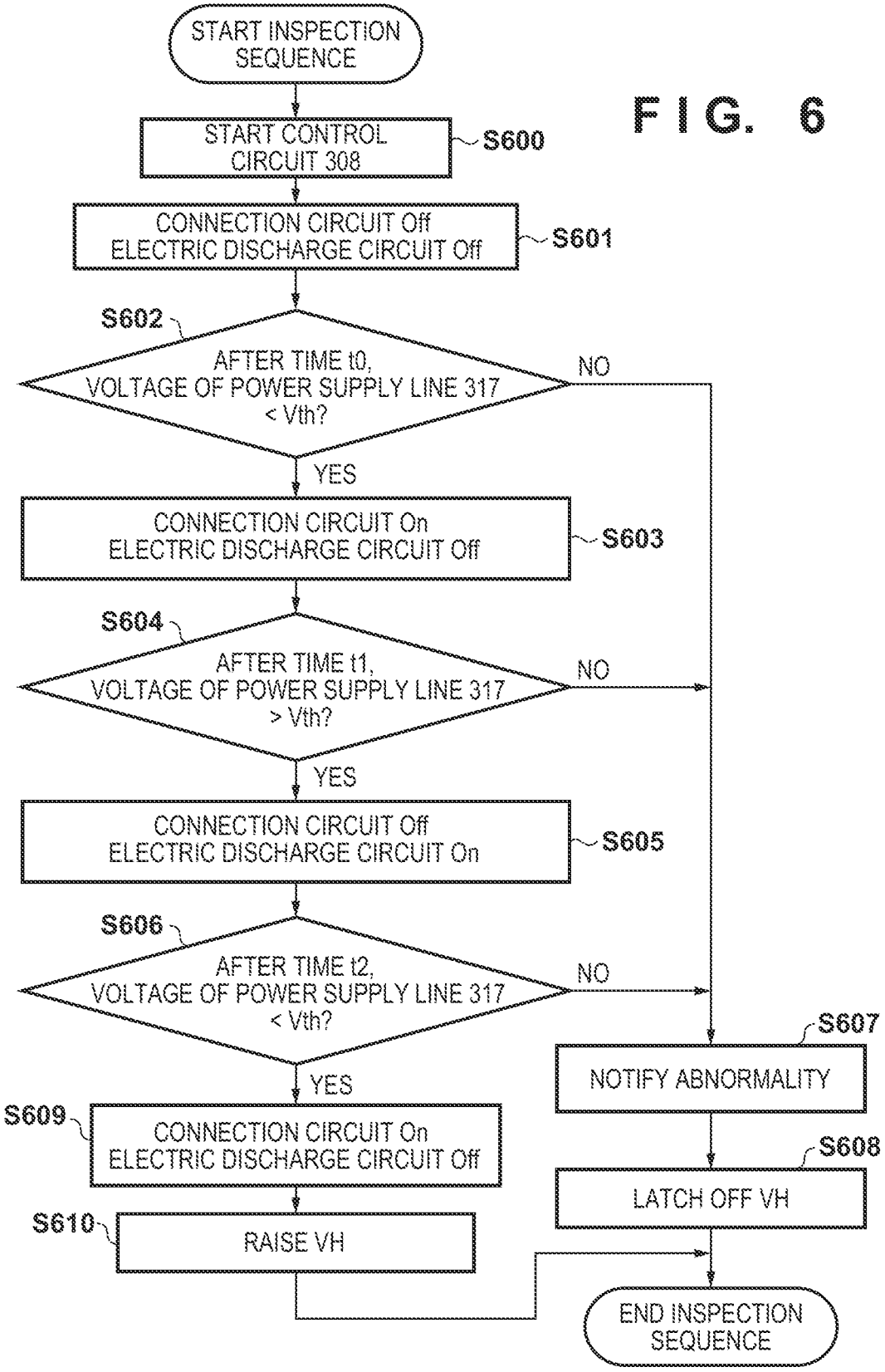

103
REPLACEMENT HEAD
HEATER DRIVING CIRCUIT
311
504
105
POWER SUPPLY BOARD
HBVHT
309
POWER SUPPLY CONTROLLER
314
503
501
317
313
500
502
VHT
316
308
505
305
DC/DC CONVERTER VHT
CONTROL CIRCUIT
ABNORMALITY DETERMINATION UNIT
ABNORMALITY NOTIFICATION SIGNAL

FIG. 6


START INSPECTION SEQUENCE
START CONTROL CIRCUIT 308
S600
CONNECTION CIRCUIT Off
ELECTRIC DISCHARGE CIRCUIT Off
S601
S602
AFTER TIME t0, VOLTAGE OF POWER SUPPLY LINE 317 < Vth?
NO
YES
CONNECTION CIRCUIT On
ELECTRIC DISCHARGE CIRCUIT Off
S603
S604
AFTER TIME t1, VOLTAGE OF POWER SUPPLY LINE 317 > Vth?
NO
YES
CONNECTION CIRCUIT Off
ELECTRIC DISCHARGE CIRCUIT On
S605
S606
AFTER TIME t2, VOLTAGE OF POWER SUPPLY LINE 317 < Vth?
NO
YES
S607
NOTIFY ABNORMALITY
S608
LATCH OFF VH
S609
CONNECTION CIRCUIT On
ELECTRIC DISCHARGE CIRCUIT Off
S610
RAISE VH
END INSPECTION SEQUENCE

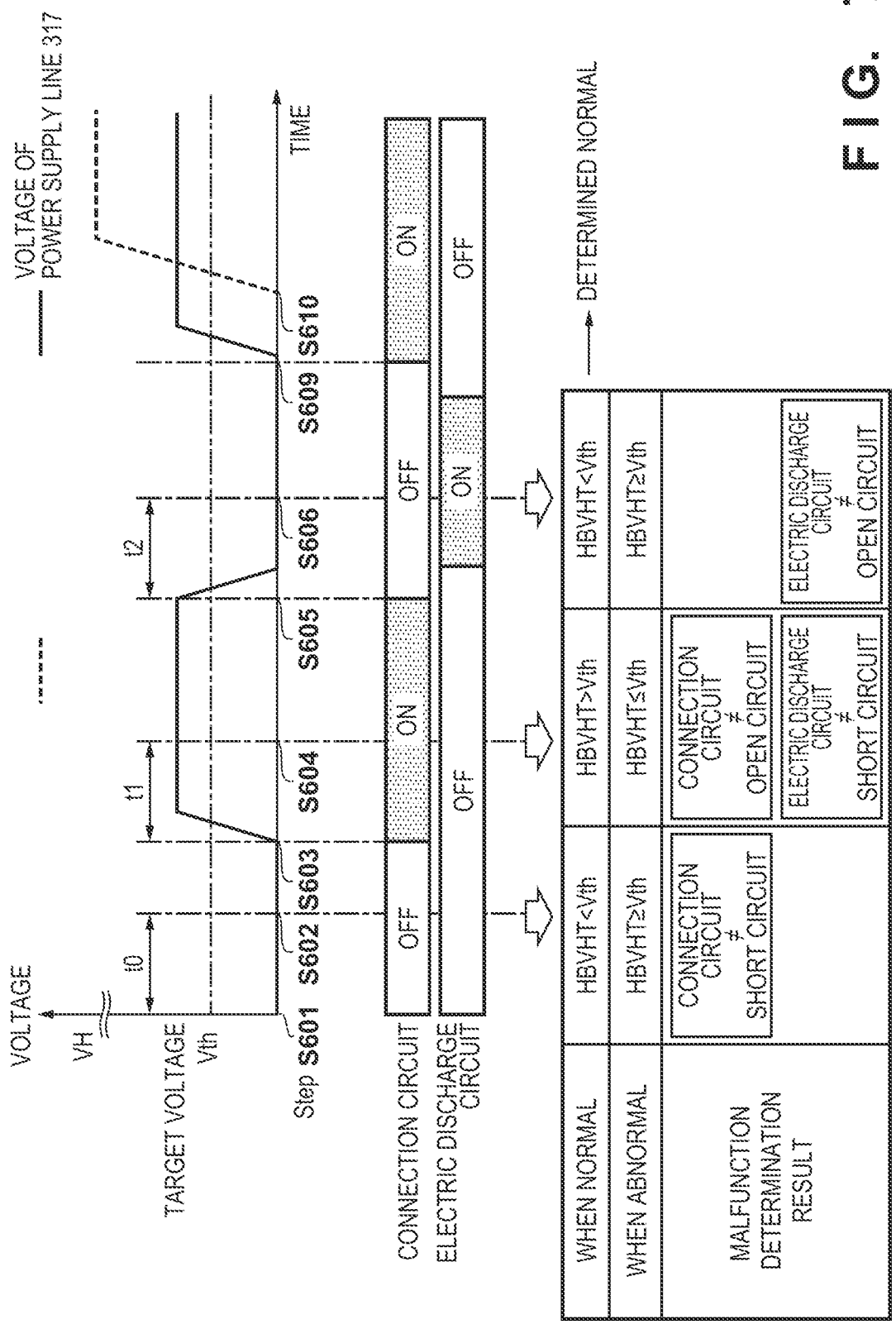

VOLTAGE
VH
t0
t1
t2
TARGET VOLTAGE
Vth
VOLTAGE OF POWER SUPPLY LINE 317
TIME
Step S601 S602 S603 S604 S605 S606 S609 S610
CONNECTION CIRCUIT OFF ON OFF ON
ELECTRIC DISCHARGE CIRCUIT OFF ON OFF
DETERMINED NORMAL
WHEN NORMAL HBVHT<Vth HBVHT>Vth HBVHT<Vth
WHEN ABNORMAL HBVHT≥Vth HBVHT≤Vth HBVHT≥Vth
MALFUNCTION DETERMINATION RESULT
CONNECTION CIRCUIT ≠ SHORT CIRCUIT
CONNECTION CIRCUIT ≠ OPEN CIRCUIT
ELECTRIC DISCHARGE CIRCUIT ≠ SHORT CIRCUIT
ELECTRIC DISCHARGE CIRCUIT ≠ OPEN CIRCUIT

FIG. 7

FIG. 8

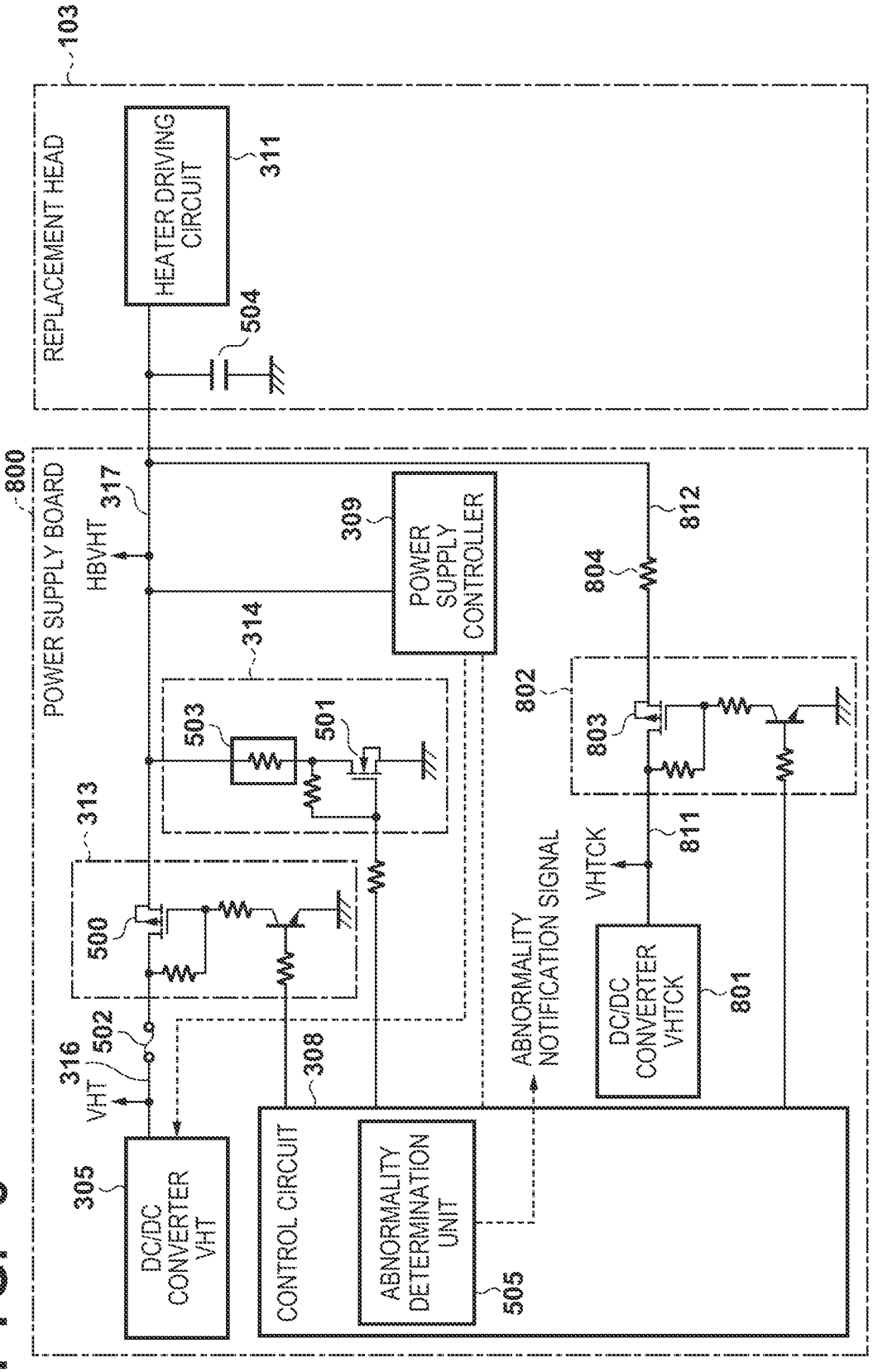

103
REPLACEMENT HEAD
HEATER DRIVING CIRCUIT
311
504
800
POWER SUPPLY BOARD
317
HBVHT
309
POWER SUPPLY CONTROLLER
812
804
314
503
501
802
803
313
500
VHTCK
811
316
502
VHT
308
ABNORMALITY NOTIFICATION SIGNAL
DC/DC CONVERTER VHTCK
801
305
DC/DC CONVERTER VHT
CONTROL CIRCUIT
ABNORMALITY DETERMINATION UNIT
505

FIG. 9A

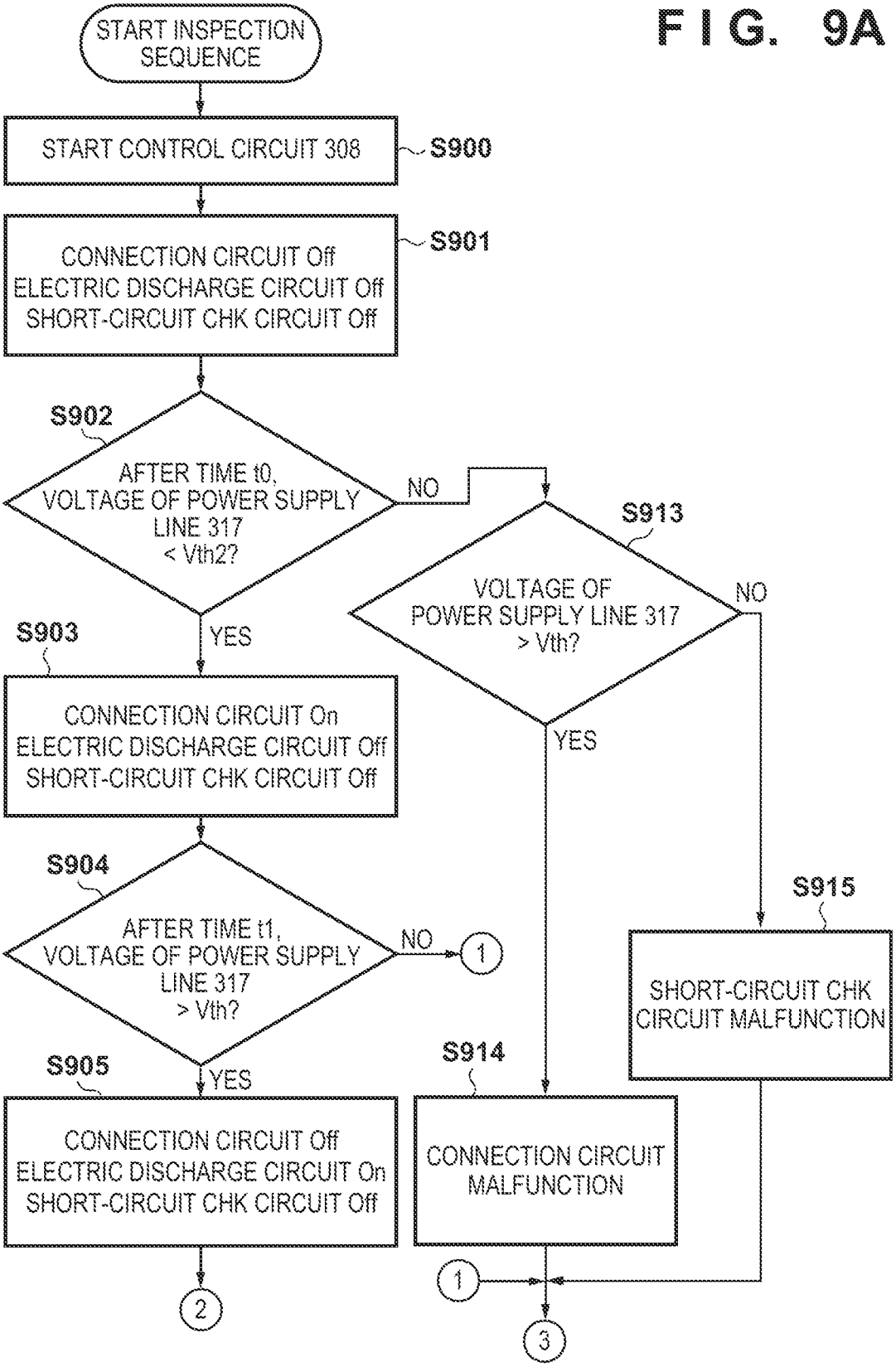
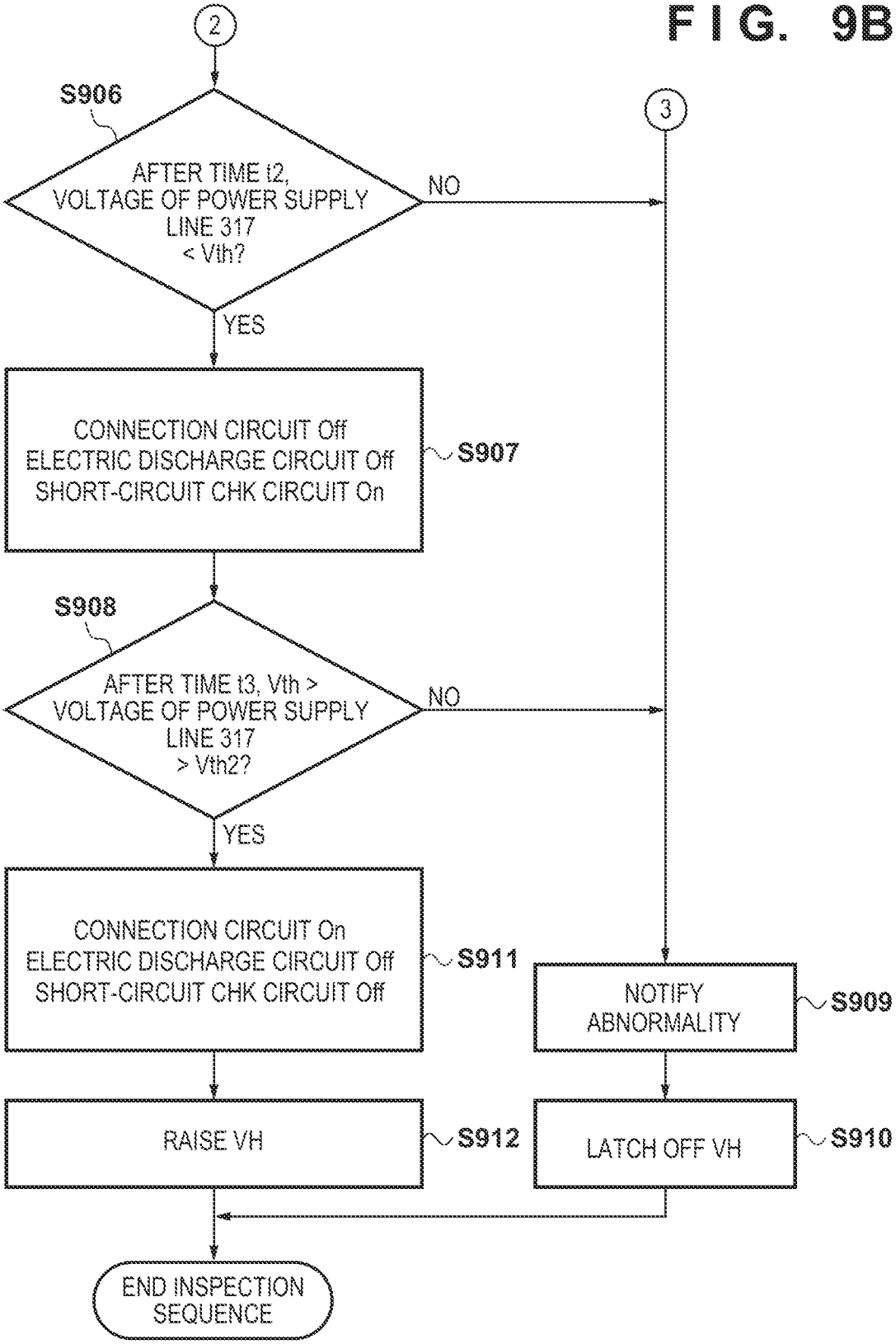

START INSPECTION SEQUENCE
START CONTROL CIRCUIT 308
S900
CONNECTION CIRCUIT Off
ELECTRIC DISCHARGE CIRCUIT Off
SHORT-CIRCUIT CHK CIRCUIT Off
S901
S902
AFTER TIME t0, VOLTAGE OF POWER SUPPLY LINE 317 < Vth2?
NO
YES
S913
VOLTAGE OF POWER SUPPLY LINE 317 > Vth?
NO
YES
S903
CONNECTION CIRCUIT On
ELECTRIC DISCHARGE CIRCUIT Off
SHORT-CIRCUIT CHK CIRCUIT Off
S904
AFTER TIME t1, VOLTAGE OF POWER SUPPLY LINE 317 > Vth?
NO
1
S915
SHORT-CIRCUIT CHK CIRCUIT MALFUNCTION
S905
YES
S914
CONNECTION CIRCUIT Off
ELECTRIC DISCHARGE CIRCUIT On
SHORT-CIRCUIT CHK CIRCUIT Off
CONNECTION CIRCUIT MALFUNCTION
2
1
3

FIG. 9B


2
S906
AFTER TIME t2, VOLTAGE OF POWER SUPPLY LINE 317 < Vth?
NO
3
YES
CONNECTION CIRCUIT Off
ELECTRIC DISCHARGE CIRCUIT Off
SHORT-CIRCUIT CHK CIRCUIT On
S907
S908
AFTER TIME t3, Vth > VOLTAGE OF POWER SUPPLY LINE 317 > Vth2?
NO
YES
CONNECTION CIRCUIT On
ELECTRIC DISCHARGE CIRCUIT Off
SHORT-CIRCUIT CHK CIRCUIT Off
S911
NOTIFY ABNORMALITY
S909
RAISE VH
S912
LATCH OFF VH
S910
END INSPECTION SEQUENCE

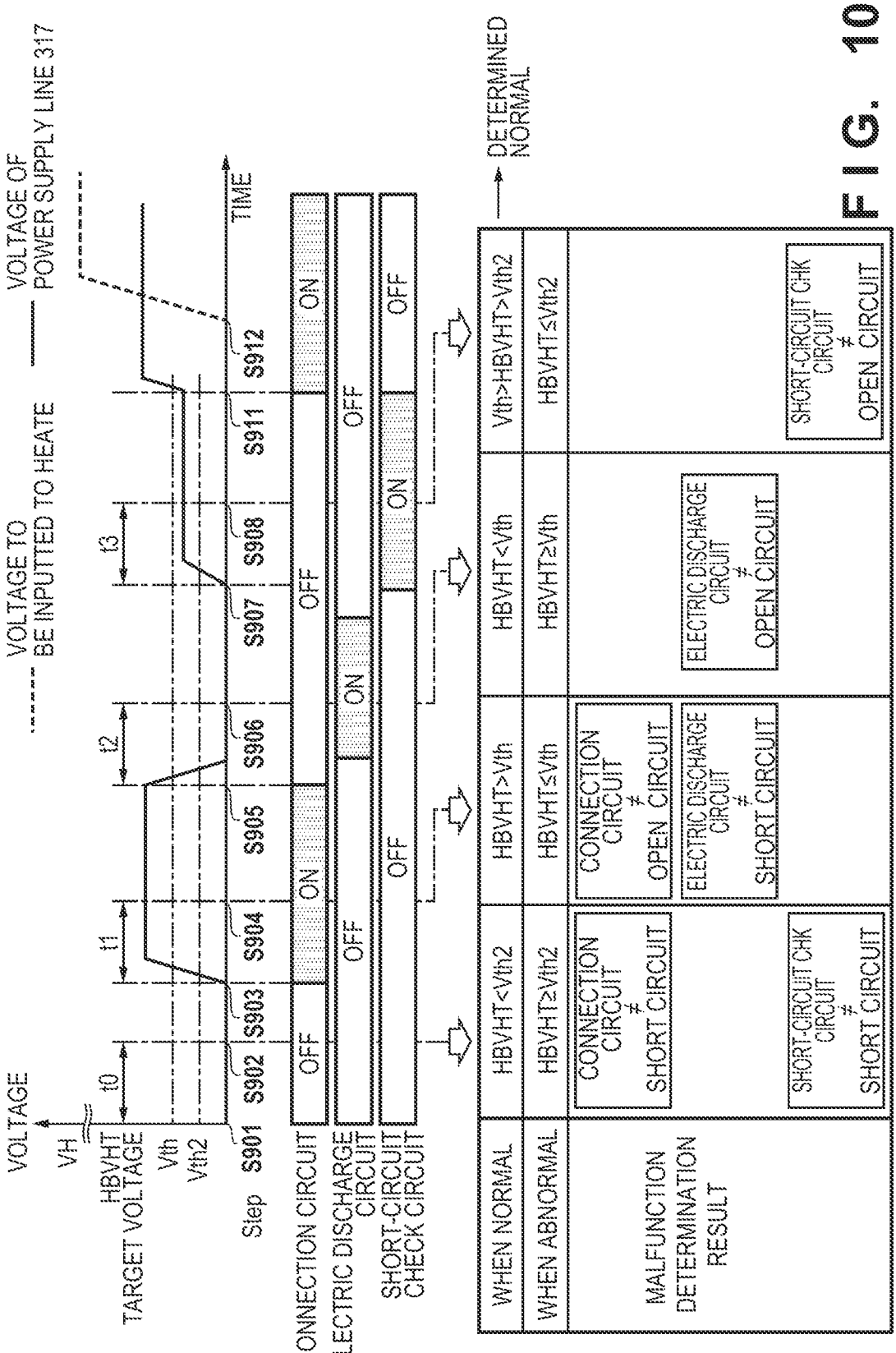

VOLTAGE
VH
HBVHT
TARGET VOLTAGE
Vth
Vth2
t0
t1
t2
t3
VOLTAGE TO BE INPUTTED TO HEATE
VOLTAGE OF POWER SUPPLY LINE 317
TIME
Step
S901
S902
S903
S904
S905
S906
S907
S908
S911
S912
CONNECTION CIRCUIT
ELECTRIC DISCHARGE CIRCUIT
SHORT-CIRCUIT CHECK CIRCUIT
OFF
ON
OFF
ON
OFF
ON
OFF
ON
OFF
DETERMINED NORMAL
WHEN NORMAL
HBVHT<Vth2
HBVHT>Vth
HBVHT<Vth
Vth>HBVHT>Vth2
WHEN ABNORMAL
HBVHT≥Vth2
HBVHT≤Vth
HBVHT≥Vth
HBVHT≤Vth2
MALFUNCTION DETERMINATION RESULT
CONNECTION CIRCUIT ≠ SHORT CIRCUIT
CONNECTION CIRCUIT ≠ OPEN CIRCUIT
ELECTRIC DISCHARGE CIRCUIT ≠ SHORT CIRCUIT
ELECTRIC DISCHARGE CIRCUIT ≠ OPEN CIRCUIT
SHORT-CIRCUIT CHK CIRCUIT ≠ SHORT CIRCUIT
SHORT-CIRCUIT CHK CIRCUIT ≠ OPEN CIRCUIT

FIG. 10

POWER SUPPLY APPARATUS, IMAGE FORMING APPARATUS, AND POWER SUPPLY CONTROL METHOD

BACKGROUND OF THE INVENTION

Field of the Invention

[0001] The present invention relates to a power supply apparatus including a connection circuit and an electric discharge circuit, an image forming apparatus, and a power supply control method.

Description of the Related Art

[0002] Conventionally, thermal-head-type inkjet printing apparatuses have a power supply unit that supplies power to heaters that are mounted on a print head, which is an ink discharge unit, and a control circuit that controls the heaters. Japanese Patent Laid-Open No. 2016-224561 discloses a configuration in which an electric relay circuit is connected between a power supply unit and a print head and power is supplied. Japanese Patent Laid-Open No. 63-77757 discloses a configuration in which, in a condition in which the supply voltage is unstable due to a power failure or the like, in order to prevent a print head from being damaged due to excessive power being supplied to the print head, a power supply for driving the print head is discharged based on a reset signal.

[0003] In such power supply apparatuses for supplying power to an external apparatus, there are cases where unintended power is supplied to the external apparatus due to malfunctioning of circuit elements, such as an electric relay circuit and an electric discharge circuit. In such cases, there is a problem that a malfunction of a power supply apparatus may cause a malfunction of an external apparatus to which power is supplied by the power supply apparatus.

SUMMARY OF THE INVENTION

[0004] The present invention has been made in view of the above-described problems, and a purpose thereof is to, when a power supply apparatus malfunctions, prevent inappropriate power from being supplied to an external apparatus to which power is supplied by the power supply apparatus.

[0005] A power supply apparatus according to the present invention for solving the above-described problems comprises: a first power supply line to which power is supplied from a power supply unit; a second power supply line connected to an external apparatus; a connection unit connecting the first power supply line and the second power supply line and configured to be capable of operating in either a first operation mode in which power transmission from the first power supply line to the second power supply line is possible or a second operation mode in which power transmission is not possible; an electric discharge unit connected to the second power supply line and configured to be capable of operating in either a third operation mode in which a voltage of the second power supply line is dropped or a fourth operation mode in which the voltage is not dropped; a voltage monitoring unit configured to monitor the voltage of the second power supply line; and a control unit configured to control operation of the connection unit and the electric discharge unit, wherein the control unit decides whether to supply power to the second power supply line based on a control state of the connection unit and the electric discharge unit and the voltage of the second power supply line monitored by the voltage monitoring unit.

[0006] It is possible to, when a power supply apparatus malfunctions, prevent inappropriate power from being supplied to an external apparatus to which power is supplied by the power supply apparatus.

[0007] Further features of the present invention will become apparent from the following description of exemplary embodiments (with reference to the attached drawings).

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] FIG. **1** is a configuration diagram of a printing apparatus according to a first embodiment.

[0009] FIG. **2** is a block diagram of the printing apparatus according to the first embodiment.

[0010] FIG. **3** is a block diagram of a print head according to the first embodiment.

[0011] FIG. **4** is a diagram for explaining the operation of an electric discharge circuit according to the first embodiment.

[0012] FIG. **5** is a configuration diagram of a power supply board according to the first embodiment.

[0013] FIG. **6** is a flowchart for explaining an inspection sequence according to the first embodiment.

[0014] FIG. **7** is a diagram illustrating the operation of a power supply at the time of an inspection sequence according to the first embodiment.

[0015] FIG. **8** is a configuration diagram of the power supply board according to a second embodiment.

[0016] FIGS. **9**A and **9**B are flowcharts for explaining an inspection sequence according to the second embodiment.

[0017] FIG. **10** is a diagram illustrating the operation of the power supply at the time of an inspection sequence according to the second embodiment.

DESCRIPTION OF THE EMBODIMENTS

[0018] Hereinafter, embodiments will be described in detail with reference to the attached drawings. Note, the following embodiments are not intended to limit the scope of the claimed invention. Multiple features are described in the embodiments, but limitation is not made to an invention that requires all such features, and multiple such features may be combined as appropriate.

[0019] Furthermore, in the attached drawings, the same reference numerals are given to the same or similar configurations, and redundant description thereof is omitted.

First Embodiment

[0020] FIG. **1** is a configuration diagram of a printing apparatus **1** according to the present embodiment. The printing apparatus **1** is an example of an image forming apparatus and includes a first conveyance unit **101**, a second conveyance unit **102**, and one or more print heads **100**.

[0021] The first conveyance unit **101** and the second conveyance unit **102** are examples of a conveyance apparatus for conveying a sheet S, which is a sheet-like printing medium, and the sheet S is conveyed by the second conveyance unit **102** winding the sheet S after it has been conveyed by the first conveyance unit **101**. The sheet S is, for example, roll-shaped paper (rolled paper), cloth, a plastic film, or the like. An image is formed on the conveyed sheet

S, which is a printing medium, by the print heads **100** performing print processing from above onto the sheet S.

[0022] Regarding the print heads **100**, a plurality of print heads are arranged along a conveyance direction following a conveyance path. In the present embodiment, the print heads include four line-type print heads, which correspond to four colors, black (Bk), yellow (Y), magenta (M), and cyan (C). The number of colors and the number of print heads **100** are not limited to four. The respective colors of ink are each supplied to the print head **100** from an ink tank (not illustrated) via an ink tube. The print head **100** includes a replacement head **103** in which heaters, nozzles, and the like are provided, a control board **104**, and a power supply board **105**, which are electrically connected to each other.

[0023] A plurality of nozzles and corresponding heaters are provided in the print head **100**, and ink is discharged by an electric signal from a print control unit, which will be described later. The replacement head **103** can be attached to and detached from the control board **104**, the power supply board **105**, and the ink tank (not illustrated) and can be replaced. The replacement head **103** may be a head unit that cannot be replaced.

[0024] FIG. **2** is a control block diagram of the printing apparatus **1**. An image controller **200** performs image processing for converting data, which is a source of an image to be printed, to data to be handled by a print head control unit **203**. The data on which image processing has been performed by the image controller **200** is transmitted to the print head control unit **203** via a communication interface (I/F) **201**. The print head **100** is arranged in the printing apparatus **1** for each color as described above and is controlled by the print head control unit **203**.

[0025] An engine control unit **202** controls the entire engine in the printing apparatus **1**. A conveyance control unit **204** controls actuators included in the first conveyance unit **101** and the second conveyance unit **102** illustrated in FIG. **1**. In addition, a printing medium conveyance timing may be controlled based on data obtained from a sensor **205**.

[0026] The print head control unit **203** generates a control signal for controlling the print heads **100** based on image data obtained from the image controller **200**. In addition, the print head control unit **203**, for example, adjusts discharge timings between the plurality of print heads **100**.

[0027] The print head **100** includes a power supply apparatus **207** and the replacement head **103**, and the power supply apparatus **207** includes the control board **104** and the power supply board **105**, which have been illustrated in FIG. **1**. The power supply apparatus **207** is an example of a power supply apparatus according to the present embodiment, and the replacement head **103** is an example of an external apparatus to which power is supplied by the power supply apparatus.

[0028] The control board **104** includes a replacement head control unit **206** and controls the power supply board and the replacement head **103** based on a control signal received from the print head control unit **203**. The replacement head control unit **206** converts data that has been decompressed in the print head control unit **203** into data that corresponds to an array of nozzles of the head and transmits the data to the replacement head **103**.

[0029] FIG. **3** is a block diagram for explaining a configuration of a power supply system for supplying power to the replacement head **103** by controlling a power supply circuit on the power supply board **105**. In FIG. **3**, solid lines that connect the blocks indicate power supply lines that are used for transmitting and receiving power, and dotted lines indicate signal lines that are used for transmitting and receiving control signals.

[0030] An AC power supply **300** and an AC/DC converter **301** are arranged in the printing apparatus **1**. The AC power supply **300** supplies, via the AC/DC converter **301**, voltage V**1** DC power to DC/DC converters **303** and **304** of the power supply board **105** provided in each print head **100** of the printing apparatus **1**.

[0031] <Power Supply Board>

[0032] The DC/DC converter **303** provides voltage **12** VDC power to DC/DC converters **305** and **306** of the power supply board **105** and to a DC/DC converter **307** of the control board **104**.

[0033] The DC/DC converter **305** generates, from the power that has been supplied from the DC/DC converter **303**, voltage VHT DC power to be supplied to a heater driving circuit **311** of the replacement head **103**. The voltage VHT DC power outputted from the DC/DC converter **305** is supplied to a connection circuit **313** via a power supply line **316** (first power supply line). The power supplied to the connection circuit **313** is converted into a voltage HBVHT and is supplied to the heater driving circuit **311** via a power supply line **317** (second power supply line).

[0034] The DC/DC converter **306** generates, from the power that has been supplied from the DC/DC converter **303**, voltage HVDD DC power to be supplied to a logic circuit **310** of the replacement head **103**. Regarding the voltage HVDD DC power outputted from the DC/DC converter **306**, the voltage is converted by a connection circuit **315** and the power is inputted into the logic circuit **310** of the replacement head **103**.

[0035] The DC/DC converter **304** provides the voltage VH DC power to a heater **312** of the replacement head **103** of the print head **100** via a power supply line **318** (third power supply line).

[0036] A power supply controller **309** can control whether the DC/DC converter **304** is on/off and change the power supply voltage VH outputted by the DC/DC converter **304**. In addition, by monitoring the power supply voltage V**1**, which is inputted from the AC/DC converter **301** to the DC/DC converter **304**, the power supply controller **309** can detect a power failure and the turning off of the power supply.

[0037] Regarding the connection circuits **313** and **315**, it is possible to adopt electric relay elements, which include solid state electric relays and mechanical electric relay switches. The connection circuits **313** and **315** are controlled by a control circuit **308**, and the connection operation is switched on/off according to an ink discharge operation sequence. In the following description, a mode in which the connection circuit **313** makes a connection so as to transmit the power supplied from the DC/DC converter **305** to the heater driving circuit **311** is set as a first operation mode (on state), and a mode in which no power is transmitted is set as a second operation mode (off state). Similarly, a mode in which the connection circuit **315** allows transmission of power supplied from the DC/DC converter **306** to the logic circuit **310** is set as a first operation mode (on state), and a mode in which power is not transmitted is set as a second operation mode (off state). The connection circuits **313** and **315** can control the timings at which the power outputted from the DC/DC converters **305** and **306** is supplied to the

heater driving circuit **311** and the logic circuit **310**. For example, when the printing apparatus **1** is started, the control circuit **308** performs control so as to start supplying power to the logic circuit **310**, the heater driving circuit **311**, and the heater **312** in that order.

[0038] An electric discharge circuit **314**, which is controlled by the control circuit **308**, is connected to the second power supply line **317**, which is connected from the connection circuit **313** to the heater driving circuit **311**. The operation of the electric discharge circuit **314** will be described later with reference to FIG. **4**.

[0039] <Control Board>

[0040] The DC/DC converter **307** generates voltage V**2** DC power to be supplied to the control circuit **308** of the control board **104**. In addition, the DC/DC converter **307** may supply power whose voltage is different from V**2** depending on the devices that are used in the control circuit **308** or the other devices that are mounted on the control board **104**. For example, power of a different voltage may be supplied by a logic power supply, an analog power supply, and the like.

[0041] The control circuit **308** is a control unit, such as a microcontroller, and realizes control of the power supply apparatus **207** including the control processing of FIG. **6**, which will be described later, by executing a program stored in a memory (not illustrated). The control circuit **308** generates a timing signal that allows determination of ink discharge of the print head **100** according to image data (not illustrated) that has been inputted from outside the print head **100** and inputs a control signal to the logic circuit **310**.

[0042] The description will be given assuming that the voltage of each power supply line is V**1**>VH>VHT>HVDD V**2**.

[0043] <Replacement Head>

[0044] For a plurality of ink nozzles (not illustrated) mounted on the print head **100**, a plurality of heaters **312** and heater driving circuits **311** are provided; however, in FIG. **3**, one of each is illustrated. The logic circuit **310** selects a heater to drive from a plurality of heaters **312** based on a control signal from the control circuit **308**. The heater driving circuit **311** receives an on/off signal from the logic circuit **310** and drives a double-diffused MOSFET (DMOS) of the heater **312**. The heater driving circuit **311** also converts the voltage level of a signal of the logic circuit **310**, which has been generated using the voltage HVDD as a reference, to the voltage VHT for driving the DMOS. Thus, the heater **312** of the replacement head **103** generates heat, and ink is discharged.

[0045] The operation of the electric discharge circuit **314** will be described with reference to FIG. **4**. In order to cause a large amount of current to flow to the heater **312**, a capacitor is connected, on the replacement head **103** side, to the power supply line **318** for supplying the voltage VH power, and low impedance is realized. Meanwhile, the larger the capacitance of the capacitor, the slower the discharge of the charge accumulated in the capacitor. Therefore, when, at time TO, the operation of the AC/DC converter **301** for supplying the voltage V**1** stops due to a power failure or the like, the drop of voltage is slower for the voltage of the power supply line **318** for supplying the voltage VH than that of the power supply lines for supplying the voltages HVDD and HBVHT. In the present embodiment, the power supply controller **309** monitors the voltage of the power outputted by the AC/DC converter **301** and, by detecting that the output voltage has dropped below a threshold, can determine a power failure.

[0046] Here, in a period toff in which the voltage of the power supply line for supplying the voltage HVDD is smaller than a minimum voltage Voff, which is necessary for the operation of the logic circuit **310**, the operation of the logic circuit **310** becomes unstable, and the output of the logic circuit **310** may become unstable. Therefore, there are cases where, in the period toff, the logic circuit **310** outputs a signal that turns on the heater driving circuit **311**. Here, if the voltage of the second power supply line **317** for supplying power to the heater driving circuit **311** remains as the dashed line, when a signal for turning on the heater driving circuit **311** is outputted from the logic circuit **310**, there are cases where the heater driving circuit **311** unintendedly drives the heater **312**. As a result, ink is discharged from the replacement head **103**, resulting in a possibility that the print head **100** may malfunction.

[0047] Therefore, the power supply apparatus **207** according to the present embodiment includes the electric discharge circuit **314** for discharging charge accumulated in the power supply line **317** for supplying power to the heater driving circuit **311** before the voltage supplied to the logic circuit **310** falls below Voff.

[0048] The electric discharge circuit **314** can operate in a third operation mode (on state) in which it operates so as to reduce the voltage of the power supply line **317** and a fourth operation mode (off state) in which it operates so as not to reduce the voltage of the power supply line **317**. At the time of power failure, by operating in the third operation mode and reducing the voltage of the heater driving circuit **311** in the period toff in which the output of the logic circuit **310** becomes unstable, the electric discharge circuit **314** can prevent the heater **312** from being driven. It is possible to prevent the operation of the heater **312** by discharging the power supply line **318** for supplying the voltage VH rather than the power supply line **317** for supplying the voltage HBVHT. However, the amount of charge accumulated in the power supply line **318** for supplying the voltage VH is greater than that of the power supply line **317** for supplying the voltage VHT; thus, when connecting an electric discharge circuit to the power supply line **318**, the capacitance of the circuit device necessary for electric discharge needs to be increased. Therefore, in the present embodiment, the voltage of the power supply line **317** for supplying the voltage HBVHT power for which the capacitance of the circuit device necessary for electric discharge is small is reduced.

[0049] FIG. **5** is a diagram for explaining the structures of the connection circuit **313** and the electric discharge circuit **314** in the power supply board **105** according to the present embodiment. The output voltage VHT power of the first power supply line **316**, which connects the DC/DC converter **305** and the connection circuit **313** is supplied to the second power supply line **317** via a field-effect transistor (FET) **500**, which is a switch unit of the connection circuit **313**, at the voltage HBVHT. The voltage HBVHT power supplied from the second power supply line **317** is a power for driving the heater, and a capacitive load **504** is connected to the second power supply line **317**, which connects the connection circuit **313** and the heater driving circuit **311**. In addition the electric discharge circuit **314**, which is configured by an FET **501** and a thermistor **503**, is connected to the

second power supply line **317** and limits the amount of current by converting the electric discharge current into temperature using a thermistor **503**, which includes a positive temperature coefficient (PTC) thermistor. The power supply controller **309** communicates with the control circuit **308**, monitors the voltage of the second power supply line **317**, and transmits the monitored voltage value to the control circuit **308** as voltage monitoring information. The control circuit **308** includes an abnormality determination unit **505**, analyzes the voltage monitoring information obtained from the power supply controller, and determines whether at least one of the connection circuit **313** and the electric discharge circuit **314** is abnormal based on the voltage value of the power supply line **317**. When the abnormality determination unit **505** determines that there is an abnormality in at least one of the connection circuit **313** and the electric discharge circuit **314**, the control circuit **308** decides not to supply power to the second power supply line **317** and outputs an abnormality notification signal to outside of the print head **100**. When it is determined that there is no abnormality in the connection circuit **313** and the electric discharge circuit **314**, the control circuit **308** decides to supply power to the second power supply line **317**. The control circuit **308** can also switch the operation state (on/off) of the connection circuit **313** and the electric discharge circuit **314**.

[0050] In a first operation mode of the connection circuit **313**, current flows from the first power supply line **316** to the second power supply line **317** by the control circuit **308** applying (turning on) a voltage greater than or equal to a gate threshold between the gate and source of the FET **500** of the connection circuit **313**. In the second operation mode, the control circuit **308** prevents current from flowing from the first power supply line **316** to the second power supply line **317** by not applying a voltage greater than the gate threshold between the gate and source of the FET **500** of the connection circuit **313**.

[0051] In the third operation mode, the control circuit **308** reduces the voltage of the power supply line **317** by causing the charge accumulated in the power supply line **317** to flow to the ground via the electric discharge circuit **314** by applying (turning on) a voltage greater than the gate threshold between the gate and source of the FET **501** of the electric discharge circuit **314**. In the fourth operation mode, the control circuit **308** prevents the voltage of the power supply line **317** from decreasing by not applying a voltage greater than or equal to the gate threshold between the gate and source of the FET **501**.

[0052] The control circuit **308** may, for example, perform exclusive control, such as when operating the connection circuit **313** in an on state, operating the electric discharge circuit **314** in an off state. As a result, it is possible to prevent excessive current from flowing from the DC/DC converter **305** to the ground via the connection circuit **313** and the electric discharge circuit **314**. A fuse **502**, which is provided in the first power supply line **316**, is a fuse element for protecting the replacement head **103** by opening the first power supply line **316** when a predetermined amount or more of current flows into the first power supply line **316** such that excessive current does not flow to the replacement head **103**.

[0053] As described in FIGS. **4** and **5**, due to a malfunction or the like of semiconductors, which are switch elements of the connection circuit **313** and the electric discharge circuit **314**, in the power supply board **105**, the power supply board **105** may not function properly. In such a case, current unintendedly flows across the replacement head **103**, and the replacement head **103** may be caused to malfunction. By there being malfunction locations in addition to the power supply board **105** in this way, the number of malfunctioning components to be replaced increases and the difficulty of identifying the malfunction locations increases; thus, the cost of repair may increase. Therefore, in the power supply board **105**, it is necessary to detect that an abnormality is occurring in at least one of the connection circuit **313** and the electric discharge circuit **314** (at least one of the connection circuit **313** and the electric discharge circuit **314** is malfunctioning) and operate so as not to cause unintended current to flow across the replacement head **103**.

[0054] A power supply control sequence for detecting a malfunction of the connection circuit **313** and the electric discharge circuit **314** according to the present embodiment will be described with reference to FIGS. **6** and **7**. FIG. **6** is a flowchart for explaining an example of processing that is performed in an inspection sequence. FIG. **7** is a diagram for explaining a change in the voltage of the second power supply line **317**, which changes according to the processing of the flowchart illustrated in FIG. **6**. The respective processing steps of FIG. **7** denote the timings at which the processes referenced by the reference numerals of FIG. **6** are performed.

[0055] A reference voltage Vth is a voltage threshold for determining whether the power supply board **105** is normal and is used to perform abnormality determination processing in the abnormality determination unit **505**. Part of the determination in the abnormality determination unit **505** is illustrated in the lower part of FIG. **7**.

[0056] The processing sequence indicated in FIG. **6** is executed by the power supply apparatus **207** in a process for starting the print head **100**. In step S**600**, the control circuit **308** is started by power being supplied from the AC/DC converter **301** to the DC/DC converters **304** and **307** and the voltage V**2** power being supplied to the control circuit **308**.

[0057] In step S**601**, the control circuit **308** operates the connection circuit **313** and the electric discharge circuit **314** in an off state. That is, the control circuit **308** operates the connection circuit **313** in the second operation mode and operates the electric discharge circuit **314** in the fourth operation mode. Here, based on a condition that, after time t**0** has elapsed, the voltage of the power supply line **317** is below a voltage threshold Vth (Yin step S**602**), the control circuit **308** determines that the operation in a control state in which the connection circuit **313** and the electric discharge circuit **314** are in an off state is normal. Based on a condition that the voltage of the power supply line **317** is greater than or equal to the voltage threshold Vth (N in step S**602**), the control circuit **308** determines that the connection circuit **313** is short-circuit malfunctioning and advances the processing to step S**607**.

[0058] In step S**603**, the control circuit **308** sets the connection circuit **313** to be in an on state (first operation mode) and sets the electric discharge circuit **314** to be in an off state (fourth operation mode). Here, if, after time t**1** has elapsed, the voltage of the power supply line **317** exceeds a voltage threshold Vth (Y in step S**604**), the control circuit **308** determines that the operation in a control state in which the connection circuit **313** is in an on state and the electric discharge circuit **314** is in an off state is normal and advances the processing to step S**605**. Based on a condition that the

voltage of the second power supply line **317** is less than or equal to the voltage threshold Vth (N in step S**604**), the control circuit **308** determines that the connection circuit **313** is in an open-circuit state (open-circuit malfunction) or the electric discharge circuit **314** is in a short-circuit state (short-circuit malfunction) and advances the processing to step S**607**.

[0059] In step S**605**, the control circuit **308** operates the connection circuit **313** to be in an off state (second operation mode) and operates the electric discharge circuit **314** to be in an on state (third operation mode). Here, if, after time t**2** has elapsed, the voltage of the power supply line **317** is below the voltage threshold Vth (Y in step S**606**), the control circuit **308** determines that the operation in a control state in which the connection circuit **313** is in an off state and the electric discharge circuit **314** is in an on state is normal and advances the processing to step S**609**. Based on a condition that the voltage of the second power supply line **317** is greater than or equal to the voltage threshold Vth (N in step S**606**), the control circuit **308** determines that there is a possibility that the electric discharge circuit **314** is open-circuit malfunctioning in which it is in an open-circuit state and is unable to perform electric discharge and advances the processing to step S**607**.

[0060] In step S**607**, the control circuit **308** transmits an abnormality notification signal for notifying that an abnormality has occurred in at least one of the connection circuit **313** and the electric discharge circuit **314**. For example, the abnormality determination unit **505** may notify the user that an abnormality has occurred via an output interface (not illustrated), such as a display or a light emitting diode (LED) included in the printing apparatus **1**. In one example, the control circuit **308** may transmit an abnormality notification signal that includes a type indicating what abnormality has occurred. For example, when it is determined in step S**602** that the voltage of the second power supply line **317** is greater than or equal to the voltage threshold, the control circuit **308** may control an abnormality notification signal so as to display, on a display (not illustrated) of the printing apparatus **1**, a message that includes information indicating the possibility of a short-circuit malfunction of the connection circuit **313**. Similarly, when the voltage of the power supply line **317** is less than or equal to the voltage threshold in step S**604**, an abnormality notification signal may be controlled so as to display, on the display (not illustrated) of the printing apparatus **1**, a message that includes information indicating the possibility of an open-circuit malfunction of the connection circuit **313** or a short-circuit malfunction of the electric discharge circuit **314**. Similarly, when it is determined in step S**606** that the voltage of the second power supply line **317** is greater than or equal to the voltage threshold, an abnormality notification signal may be controlled so as to display, on a display (not illustrated) of the printing apparatus **1**, a message that includes information indicating the possibility of an open-circuit malfunction of the electric discharge circuit **314**. Alternatively, a different LED may be lit depending on the type of abnormality that may have occurred.

[0061] In step S**608**, even if the voltage of the first power supply line **316** for supplying the voltage VHT and the voltage of the power supply line for supplying the voltage HVDD are raised, the control circuit **308** does not supply the voltage VH to the heater **312** and performs an abnormal termination via the power supply controller **309**. For example, in step S**608**, the power supply controller **309** may be controlled so as not to supply power from the DC/DC converter **303** to the heater **312**. The control circuit **308** may execute a control operation such that the connection circuit **313** operates in an off state (second operation mode) and the electric discharge circuit **314** operates in an on state (third operation mode) regardless of the possibility of malfunction. That is, in step S**608**, by not supplying power to at least one of the heater **312** and the heater driving circuit **311**, inappropriate supply of power to the replacement head **103** and malfunction of the replacement head **103** are prevented.

[0062] The control circuit **308** sets, in step S**609**, the connection circuit **313** to be in an on state and the electric discharge circuit **314** to be in an off state; raises, in step S**610**, the voltage of the power supply line **318** for supplying the voltage VH; and then performs a normal termination of the inspection sequence illustrated in FIG. **6**. When switching the on/off states of the connection circuit **313** and the electric discharge circuit **314**, the switch may be executed while providing a period in which both the connection circuit **313** and the electric discharge circuit **314** operate in an off state as illustrated in FIG. **7**. As a result, due to the difference in the control timings, the power transmission by the connection circuit **313** and electric discharge by the electric discharge circuit **314** are performed at the same time, and it is possible to prevent excessive current from flowing.

[0063] As described above, the control circuit **308** according to the present embodiment determines whether at least one of the connection circuit **313** and the electric discharge circuit **314** is malfunctioning based on a control state of the connection circuit **313** and the electric discharge circuit **314** and the voltage of the power supply line to which the electric discharge circuit **314** is connected. Then, when it is determined that either is malfunctioning (an abnormality has occurred), the control circuit **308** decides not to supply power to the print head **100**. As a result, even if a circuit malfunction is occurring, the operation of the printing apparatus **1** can be stopped without inducing a malfunction of the print head **100**. As a result, it is possible to restore the printing apparatus **1** simply by replacing the power supply board **105** or the power supply apparatus **207**; thus, it is possible to reduce the number of malfunction locations and reduce the hassle and the cost of repair.

Second Embodiment

[0064] In the present embodiment, a configuration in which, in the power supply board of the first embodiment, a circuit for performing electric replay from another power supply is further connected to the power supply line for supplying the voltage HBVHT will be described. The same reference numerals will be used for configurations, functions, and processes that are similar to the first embodiment, and descriptions thereof will be omitted.

[0065] A power supply board **800** according to the present embodiment will be described with reference to FIG. **8**. The power supply board **800** according to the present embodiment includes a DC/DC converter **801**, and a power supply line (fourth power supply line) **811** for supplying a voltage VHTCK is connected to the DC/DC converter **801**. A power supply line (fifth power supply line) **812**, which includes a current limiting resistor **804**, is connected to the fourth power supply line **811** via a connection circuit **802**, which is configured by an FET **803** and the like, and the fifth power

supply line **812** is connected to the second power supply line **317**. The connection circuit **802**, which relays the voltage VHTCK power supplied by the DC/DC converter **801**, is a short-circuit check circuit (short-circuit CHK circuit) provided for confirming a short circuit in the replacement head **103**. The connection circuit **802** is configured similarly to the connection circuit **313** and controlled by the control circuit **308**, and on/off of the connection operation can be switched. In the following description, a mode in which the connection circuit **802** makes a connection so as to transmit the power supplied from the DC/DC converter **801** to the fifth power supply line **812** is set as a first operation mode (on state), and a mode in which power is not transmitted is set as a second operation mode (off state). By limiting current by operating the connection circuit **313** in an off state and operating the connection circuit **802** in an on state so as not to cause the replacement head **103** to malfunction at the time of inspection and by monitoring the voltage, it is possible to confirm a short circuit in the replacement head **103**. The present embodiment describes an inspection sequence for distinguishing a malfunction of the connection circuit **802** and a malfunction of the connection circuit **313** and the electric discharge circuit **314**, which are inspected in the first embodiment.

[0066] A power supply control sequence according to the present embodiment will be described with reference to FIGS. **9**A, **9**B, and **10**. FIGS. **9**A and **9**B are flowcharts for explaining a power supply control method of performing inspection for determining whether the operation of the power supply apparatus **207** according to the present embodiment is abnormal and controlling power supply. FIG. **10** is a diagram illustrating a change in the voltage of the second power supply line **317** for supplying the voltage HBVHT according to the flowchart of FIGS. **9**A and **9**B. In the present embodiment, by setting the voltage value of the short-circuit check circuit to be different from the voltage HBVHT and comparing the voltage value with a voltage threshold Vth**2** for abnormal determination, it is determined whether the short-circuit check circuit is abnormal. According to this, it is possible to distinguish between a malfunction of the connection circuit **313** and a malfunction of the connection circuit **802** at the time of malfunction determination.

[0067] In step S**901**, the control circuit **308** operates the connection circuit **313**, the electric discharge circuit **314**, and the connection circuit **802** in an off state. In step S**902**, the control circuit **308** determines whether, when time t**0** has elapsed, the voltage of the power supply line **317** is less than the second voltage threshold Vth**2**. If it is determined that the voltage of the power supply line **317** is less than the second voltage threshold Vth**2** (Yin step S**902**), the control circuit **308** determines that the operation in an off state is normal for the connection circuit **313**, the electric discharge circuit **314**, and the connection circuit **802** and advances the processing to step S**903**. If it is determined that the voltage of the power supply line **317** is greater than or equal to the second voltage threshold Vth**2** (N in step S**902**), the control circuit **308** determines that the connection circuit **313** or **802** is short-circuit malfunctioning and advances the processing to step S**913**.

[0068] In step S**913**, the control circuit **308** determines whether the voltage of the second power supply line **317** is greater than the first voltage threshold Vth. If it is determined that the voltage of the second power supply line **317** is greater than the first voltage threshold Vth (Y in step S**913**), the control circuit **308** determines that the connection circuit **313** is short-circuit malfunctioning (step S**914**). If it is determined that the voltage of the second power supply line **317** is less than or equal to the first voltage threshold Vth (N in step S**913**), the control circuit **308** determines that the connection circuit **802** is short-circuit malfunctioning (step S**915**).

[0069] The processing of step S**903** to step S**906** is similar to that of step S**603** to step S**606** of FIG. **6** except that the connection circuit **802** operates in an off state; thus, description will be omitted.

[0070] In step S**907**, the control circuit **308** operates the connection circuit **313** and the electric discharge circuit **314** in an off state and the connection circuit **802** in an on state. In step S**908**, the control circuit **308** determines whether, when time t**3** has elapsed, the voltage of the power supply line **317** is greater than the second voltage threshold Vth**2** and less than the first voltage threshold Vth. If it is determined that the voltage of the power supply line **317** is higher than the second voltage threshold Vth**2** and lower than the first voltage threshold Vth (Y in step S**908**), the control circuit **308** determines that the operation in which the connection circuit **313** and the electric discharge circuit **314** are in an off state and of the connection circuit **802** is in the on state is normal. If it is determined that the voltage of the second power supply line **317** is less than or equal to the second voltage threshold Vth**2** or greater than or equal to the first voltage threshold (N in step S**908**), the control circuit **308** determines that the connection circuit **802** is open-circuit malfunctioning and advances the processing to step S**909**.

[0071] In step S**911**, the control circuit **308** starts the connection circuit **313** in an on state and the electric discharge circuit **314** and the connection circuit **802** in an off state and supplies power from the second power supply line **317** to the heater driving circuit **311**. Then, in step S**912**, the control circuit **308** raises the voltage of the third power supply line **318** and supplies power to the heater **312**. Steps S**909** and S**910** are similar to steps S**607** and S**608** of FIG. **6**; thus, description will be omitted.

[0072] As described above, in the present embodiment, a condition for when the short-circuit check circuit is to be on/off is added to the first embodiment, and in step S**907**, only the connection circuit **802**, which is the short-circuit check circuit, is turned on. Then, in step S**908**, based on a condition that Vth>the voltage of the second power supply line **317**>Vth**2**, it is determined that the connection circuits **313** and **802** and the electric discharge circuit **314** are normal. Then, when it is determined that the connection circuits **313** and **802** and the electric discharge circuit **314** are normal, the control circuit **308** decides to supply power to the heater driving circuit **311** and the heater **312**. In addition, when it is determined that at least one of the connection circuits **313** and **802** and the electric discharge circuit **314** is abnormal, the control circuit **308** performs control so as not to supply power to the heater **312**. Alternatively, when it is determined that at least one of the connection circuits **313** and **802** and the electric discharge circuit **314** is abnormal, the control circuit **308** performs control so as not to supply power to the heater driving circuit **311**.

[0073] As described above, even if there are a plurality of connection circuits for supplying power to an external

apparatus, the printing apparatus **1** according to the present embodiment can detect a malfunction. In addition, it is possible to identify the malfunction location by making the voltages of supplied power different.

OTHER EMBODIMENTS

[0074] Regarding the processing of steps S**601**, S**603** and S**605** indicated in FIG. **6** and steps S**901**, S**903**, S**905** and S**907** indicated in FIGS. **9**A and **9**B, their order can be changed arbitrarily.

[0075] Embodiment(s) of the present invention can also be realized by a computer of a system or apparatus that reads out and executes computer executable instructions (e.g., one or more programs) recorded on a storage medium (which may also be referred to more fully as a 'non-transitory computer-readable storage medium') to perform the functions of one or more of the above-described embodiment(s) and/or that includes one or more circuits (e.g., application specific integrated circuit (ASIC)) for performing the functions of one or more of the above-described embodiment(s), and by a method performed by the computer of the system or apparatus by, for example, reading out and executing the computer executable instructions from the storage medium to perform the functions of one or more of the above-described embodiment(s) and/or controlling the one or more circuits to perform the functions of one or more of the above-described embodiment(s). The computer may comprise one or more processors (e.g., central processing unit (CPU), micro processing unit (MPU)) and may include a network of separate computers or separate processors to read out and execute the computer executable instructions. The computer executable instructions may be provided to the computer, for example, from a network or the storage medium. The storage medium may include, for example, one or more of a hard disk, a random-access memory (RAM), a read only memory (ROM), a storage of distributed computing systems, an optical disk (such as a compact disc (CD), digital versatile disc (DVD), or Blu-ray Disc (BD)™), a flash memory device, a memory card, and the like.

[0076] While the present invention has been described with reference to exemplary embodiments, it is to be understood that the invention is not limited to the disclosed exemplary embodiments. The scope of the following claims is to be accorded the broadest interpretation so as to encompass all such modifications and equivalent structures and functions.

[0077] This application claims the benefit of Japanese Patent Application No. 2022-127323, filed Aug. 9, 2022 hereby incorporated by reference herein in its entirety.

What is claimed is:

1. A power supply apparatus comprising:

a first power supply line to which power is supplied from a power supply unit;

a second power supply line connected to an external apparatus;

a connection unit connecting the first power supply line and the second power supply line and configured to be capable of operating in either a first operation mode in which power transmission from the first power supply line to the second power supply line is possible or a second operation mode in which power transmission is not possible;

an electric discharge unit connected to the second power supply line and configured to be capable of operating in either a third operation mode in which a voltage of the second power supply line is dropped or a fourth operation mode in which the voltage is not dropped;

a voltage monitoring unit configured to monitor the voltage of the second power supply line; and

a control unit configured to control operation of the connection unit and the electric discharge unit,

wherein the control unit decides whether to supply power to the second power supply line based on a control state of the connection unit and the electric discharge unit and the voltage of the second power supply line monitored by the voltage monitoring unit.

2. The power supply apparatus according to claim **1**, wherein in a case where the control unit controls the connection unit to operate in the second operation mode and the electric discharge unit to operate in the fourth operation mode, the control unit does not supply power to the second power supply line based on a condition that the voltage of the second power supply line is greater than or equal to a threshold.

3. The power supply apparatus according to claim **1**, wherein in a case where the control unit controls the connection unit to operate in the first operation mode and controls the electric discharge unit to operate in the fourth operation mode, the control unit does not supply power to the second power supply line based on a condition that the voltage of the second power supply line is less than or equal to a threshold.

4. The power supply apparatus according to claim **3**, wherein in a case where a first time has elapsed after switching operation of the connection unit to the first operation mode and switching operation of the electric discharge unit to the fourth operation mode, the control unit does not supply power to the second power supply line based on a condition that the voltage of the second power supply line is less than or equal to the threshold.

5. The power supply apparatus according to claim **1**, wherein in a case where the control unit controls the connection unit to operate in the second operation mode and the electric discharge unit to operate in the third operation mode, the control unit does not supply power to the second power supply line based on a condition that the voltage of the second power supply line is greater than or equal to a threshold.

6. The power supply apparatus according to claim **5**, wherein in a case where a second time has elapsed after switching operation of the connection unit to the second operation mode and switching operation of the electric discharge unit to the third operation mode, the control unit does not supply power to the second power supply line based on a condition that the voltage of the second power supply line is greater than or equal to the threshold.

7. The power supply apparatus according to claim **1**, wherein in a case where the control unit controls the connection unit to operate in the second operation mode and the electric discharge unit to operate in the fourth operation mode, the control unit supplies power to the second power supply line based on a condition that the voltage of the second power supply line is less than a threshold.

8. The power supply apparatus according to claim **1**, wherein in a case where the control unit controls the connection unit to operate in the first operation mode and the electric discharge unit to operate in the fourth operation mode, the control unit supplies power to the second power

supply line based on a condition that the voltage of the second power supply line is greater than a threshold.

9. The power supply apparatus according to claim **8**, wherein in a case where a first time has elapsed after switching operation of the connection unit to the first operation mode and switching operation of the electric discharge unit to the fourth operation mode, the control unit supplies power to the second power supply line based on a condition that the voltage of the second power supply line is greater than the threshold.

10. The power supply apparatus according to claim **1**, wherein in a case where the control unit controls the connection unit to operate in the second operation mode and the electric discharge unit to operate in the third operation mode, the control unit supplies power to the second power supply line based on a condition that the voltage of the second power supply line is less than a threshold.

11. The power supply apparatus according to claim **10**, wherein in a case where a second time has elapsed after switching operation of the connection unit to the second operation mode and switching operation of the electric discharge unit to the third operation mode, the control unit supplies power to the second power supply line based on a condition that the voltage of the second power supply line is less than the threshold.

12. The power supply apparatus according to claim **1**, further comprising: a notification unit configured to, in a case where the control unit decides not to supply power to the second power supply line, notifies an abnormality.

13. The power supply apparatus according to claim **1**, wherein the control unit controls operation of the connection unit and the electric discharge unit such that, while the connection unit is operating in the first operation mode, the electric discharge unit does not operate in the third operation mode.

14. The power supply apparatus according to claim **1**, wherein

the external apparatus includes a heater configured to discharge ink using heat and a heater driving circuit configured to drive the heater, and

the second power supply line supplies power to the heater driving circuit.

15. The power supply apparatus according to claim **14**, further comprising:

a third power supply line configured to supply power to the heater,

wherein in a case where the control unit decides not to supply power to the second power supply line, the control unit performs control so as to stop supply of power from the third power supply line to the heater.

16. The power supply apparatus according to claim **1**, wherein the first power supply line includes a fuse element configured to provide protection such that current that is greater than or equal to a predetermined amount does not flow to the second power supply line.

17. An image forming apparatus comprising:

the power supply apparatus according to claim **1**,

wherein the external apparatus is a head including a heater configured to discharge ink using heat and a heater driving circuit configured to drive the heater,

wherein the second power supply line supplies power to the heater driving circuit, and

wherein the head forms an image on a printing medium by discharging ink using heat.

18. The image forming apparatus according to claim **17**,

wherein the power supply apparatus further comprises a third power supply line configured to supply power to the heater, and

wherein in a case where the control unit decides not to supply power to the second power supply line, the control unit performs control so as to stop supply of power from the third power supply line to the heater.

19. A power supply control method executed by a power supply apparatus, the apparatus comprising:

a first power supply line to which power is supplied from a power supply unit;

a second power supply line connected to an external apparatus;

a connection unit connecting the first power supply line and the second power supply line and configured to be capable of operating in either a first operation mode in which power transmission from the first power supply line to the second power supply line is possible or a second operation mode in which power transmission is not possible;

an electric discharge unit connected to the second power supply line and configured to be capable of operating in either a third operation mode in which a voltage of the second power supply line is dropped or a fourth operation mode in which the voltage is not dropped;

a voltage monitoring unit configured to monitor the voltage of the second power supply line; and

a control unit configured to control operation of the connection unit and the electric discharge unit, and

the method comprising:

deciding whether to supply power to the second power supply line based on a control state of the connection unit and the electric discharge unit according to the control unit and the voltage of the second power supply line monitored by the voltage monitoring unit.

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