United States Patent Application Publication	20250266225
Kind Code	A1
Publication Date	August 21, 2025
Inventor(s)	SATO; Taku et al.

SWITCH DEVICE

Abstract

Provided is a switch device including a phase-change material switch and a first series switch which is connected in series to the phase-change material switch and is normally on. In the phase-change material switch and the first series switch, between a first terminal and a second terminal of the switch device, the phase-change material switch may be connected to a side of the first terminal, and the first series switch may be connected to a side of the second terminal, and a control terminal of the first series switch may be connected to a terminal of the phase-change material switch on a side of the first terminal.

Inventors: **SATO; Taku (Tokyo, JP), YAMASHITA; Koji (Tokyo, JP)**

Applicant: **ADVANTEST CORPORATION** (Tokyo, JP)

Family ID: **1000008282277**

Appl. No.: **18/939391**

Filed: **November 06, 2024**

Foreign Application Priority Data

JP	2024-022448	Feb. 16, 2024

Publication Classification

Int. Cl.: **H01H37/72** (20060101)

U.S. Cl.:

CPC **H01H37/72** (20130101);

Background/Summary

[0001] The contents of the following patent application(s) are incorporated herein by reference: NO. 2024-022448 filed in JP on Feb. 16, 2024

BACKGROUND

1. Technical Field

[0002] The present invention relates to a switch device.

2. Related Art

[0003] Patent Document 1 describes that "FIG. 2 is a circuit diagram illustrating a configuration of a memory cell MM included in a memory array 1. In FIG. 2, the memory cell MM includes an N-channel MOS transistor 4 and a phase-change element 5. In the N-channel MOS transistor 4, a gate G receives a word line voltage VWL, a source S receives a source line voltage VSL, a substrate SUB (well, back gate) receives a well line voltage VMW, and a drain D is connected to one electrode of the phase-change element 5. Another electrode of the phase-change element 5 receives a bit line voltage VBL. The word line voltage VWL and the bit line voltage VBL are controlled by a write circuit 2 and a read circuit 3. Both the source line voltage VSL and the well voltage VMW are fixed to a ground voltage (0 V)." (paragraph 0010).

[0004] Patent Document 2 describes that "FIG. 1 shows a schematic configuration of a phase-change memory 7. A memory array (MARY) 10 is constituted by word lines WL0 to WLn, bit lines BL0 to BLk, and a plurality of memory cells 11 (M00 to Mnk) arranged at intersections of the word lines and the bit lines. Although various configurations of the memory cell 11 will be described in detail later, here, as an example, a configuration using a selection transistor CT as a selection element and a storage element PCR as a phase-change element using a phase-change material will be described. The memory cell 11 is constituted by connecting the selection transistor CT and the storage element PCR in series in a direction from the bit line to a feeder line of a ground voltage Vss." (paragraph 0049).

[0005] Patent Document 3 describes that "A phase-change memory cell 104*a* includes a phase-change element 106*a* and a TFET 108*a*. One end of the phase-change element 106*a* is electrically coupled to a bit line 112*a*, and another end of the phase-change element 106*a* is electrically coupled to the drain of the TFET 108*a*. The source of the TFET 108*a* is electrically coupled to a ground plate 114. The gate of the TFET 108*a* is electrically coupled to a word line 110*a*. A phase-change memory cell 104*b* includes a phase-change element 106*b* and a TFET 108*b*. One end of the phase-change element 106*b* is electrically coupled to the bit line 112*a*, and another end of the phase-change element 106*b* is electrically coupled to the drain of the TFET 108*b*. The source of the TFET 108*b* is electrically coupled to the ground plate 114." (paragraph 0017).

[0006] Patent Document 4 describes that "A schematic diagram of a memory system 100 according to an embodiment of the present invention is shown with reference to FIG. 1. The memory system 100 includes memory cells 102 in an array configuration. Each of the memory cells 102 includes a switch element 104, such as, for example, a metal-insulator-metal (MIM) switch cell or a phase-change switch cell, and a cell transistor 106, such as, for example, a junction field effect transistor (JFET)." (paragraph 0019), and "The switch element 104 includes a first side 114and a second side 116. The first side 114 is connected to one of the word lines 118, such as a word line 1 through a word line 1024, of the memory system 100, for example. The second side 116 is connected to the gate terminal 108 of the cell transistor 106." (paragraph 0021).

PRIOR ART DOCUMENTS

Patent Document

[0007] Patent Document 1: Japanese Patent Application Publication No. 2009-252253

[0008] Patent Document 2: International Publication No. 2010/004652

[0009] Patent Document 3: Japanese Patent Application Publication No. 2008-021970

[0010] Patent Document 4: Japanese translation publication of a PCT rout patent application No. 2009-538491

Non-Patent Document

[0011] Non-Patent Document 1: Tejinder Singh et al., "Reconfigurable PCM GeTe-based Latching 6-bit Digital Switched Capacitor Bank", 15th European Microwave Integrated Circuits Conference (EuMIC), Utrecht, Netherlands, pp. 93-96, January 2021

[0012] Non-Patent Document 2: Tejinder Singh et al., "Ultra-Compact Phase-Change GeTe-Based Scalable mmWave Latching Crossbar Switch Matrices", IEEE Transactions on Microwave Theory and Techniques, pp. 938-949, December 2021

Description

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] FIG. **1** shows a configuration of a switch device **10** according to the present embodiment.

[0014] FIG. **2** shows a configuration of a switch device **20** according to a modification of the present embodiment.

[0015] FIG. **3** shows a configuration of a capacitor bank **30** according to the present embodiment.

[0016] FIG. **4** shows a configuration of a switch matrix **40** according to the present embodiment.

DESCRIPTION OF EXEMPLARY EMBODIMENTS

[0017] Hereinafter, embodiments of the present invention will be described. However, the following embodiments are not for limiting the invention according to the claims. In addition, not all of the combinations of features described in the embodiments are essential to the solution of the invention.

[0018] A phase-change material (PCM) is a material capable of reversibly changing the phase between an amorphous phase having a high resistance and a low refractive index and a crystalline phase having a low resistance and a high refractive index through a heating and cooling cycle. Such a phase-change material is, for example, GeTe (germanium telluride) or Sb.sub.2Te.sub.3 (antimony telluride). In a switch using the phase-change material (also referred to as "phase-change material switch" and "PCM-SW"), the phase-change material is disposed between terminals, and the phase-change material can be switched between a high resistance state (off state) and a low resistance state (on state) by a heating/cooling cycle. The phase-change material switch is a non-volatile operating device and does not require power supply to maintain the on state and the off state.

[0019] Such a phase-change material switch is applied to a nonvolatile phase-change memory (see Patent Documents 1 to 4), a switched capacitor bank (see Non-Patent Document 1), a switch matrix (see Non-Patent Document 2), and the like. However, the phase-change material switch has a low withstand voltage between terminals of about 4 V as an example, and is difficult to be applied to applications requiring a high withstand voltage. In the present embodiment, it is possible to realize a switch device having a higher withstand voltage than a phase-change material switch alone by using the phase-change material switch.

[0020] FIG. **1** shows a configuration of a switch device **10** according to the present embodiment. The switch device **10** functions as a non-volatile switch that electrically connects or disconnects a first terminal P**1** and a second terminal P**2**. The switch device **10** includes a phase-change material switch **100**, a heater **110**, and a series switch **120**. The phase-change material switch **100** has a structure in which a channel of a phase-change material is disposed between terminals S**1** and S**2**. Here, the "channel" means a member that switches on and off (whether to allow or block current flow) between the terminals S**1** and S**2**.

[0021] The heater **110** is disposed near the channel of the phase-change material switch **100** and heats the phase-change material switch **100** when the phase-change material switch **100** is switched to be turned on or off. In the present embodiment, the heater **110** is formed of an electrothermal material such as tungsten. The heater **110** generates greater heat as the current flowing between terminals H**1** and H**2** increases.

[0022] The heater **110** changes the phase-change material from the crystalline phase to the amorphous phase by heating the phase-change material of the phase-change material switch **100** to a high temperature (in the case of a GeTe film, 700° C. as an example) equal to or higher than the melting point, and then stopping heating and quenching it. The heater **110** changes the phase-change material from the amorphous phase to the crystalline phase by thermally annealing the phase-change material of the phase-change material switch **100** at a relatively low temperature (in the case of a GeTe film, 200° C. as an example) equal to or higher than a crystallization temperature. A control device that controls the switching of the switch device **10** may change the phase state of the phase-change material as described above by controlling the current flowing between the terminals H**1** and H**2** of the heater **110**. Note that in the present embodiment, a configuration using an electric heater as the heater **110** is exemplified, but the heater **110** may heat the phase-change material switch **100** by another method such as light irradiation.

[0023] The series switch **120** is connected in series to the phase-change material switch **100**. The series switch **120** is a semiconductor switch element such as a metal oxide semiconductor field effect transistor (MOSFET) or an insulated gate bipolar transistor (IGBT). The series switch **120** may be a GaN-FET, a Si-MOSFET, a SiC-MOSFET, a SiC-IGBT, or the like. The series switch **120** includes a first main terminal, a second main terminal, and a control terminal that controls a connection state between the first main terminal and the second main terminal. When the series switch **120** is a MOSFET, a GaN FET, or the like, the series switch **120** has a drain and a source as the first main terminal and the second main terminal, and has a gate as the control terminal. When the series switch **120** is an IGBT, the series switch **120** has a collector and an emitter as the first main terminal and the second main terminal, and has a gate as the control terminal. In the present embodiment, for convenience of description, a case will be described in which the series switch **120** is a GaN-FET.

[0024] The series switch **120** is a normally-on switch. In the present embodiment, in the phase-change material switch **100** and the series switch **120**, between the first terminal P**1** and the second terminal P**2** of the switch device **10**, the phase-change material switch **100** is connected to the first terminal P**1** side, and the first series switch **120** is connected to the second terminal P**2** side. In the example of this drawing, the terminal S**1** of the phase-change material switch **100** is directly connected to the first terminal P**1**, a first main terminal T**1** (a source as an example) of the series switch **120** is directly connected to the terminal S**2** of the phase-change material switch **100**, and a second main terminal T**2** (a drain as an example) of the series switch **120** is directly connected to the second terminal P**2**. Alternatively, a passive component such as a resistor or an inductor may be provided in at least one of the following: between the first terminal P**1** and the terminal S**1**, between the terminal S**2** and the first main terminal T**1**, or between the second main terminal T**2** and the second main terminal P**2**.

[0025] A control terminal G of the series switch **120** is connected to the terminal S**1** of the phase-change material switch **100** on the first terminal P**1** side. In the example of this drawing, the control terminal G of the series switch **120** is directly connected to the terminal S**1** of the phase-change material switch **100**. Alternatively, a passive component such as a resistor or an inductor may be provided between the terminal S**1** and the control terminal G of the series switch **120**.

[0026] In the present embodiment, the series switch **120** may be designed to be turned off in response to the potential difference of the second terminal P**2** from the first terminal P**1** exceeding a first threshold. In this drawing, the series switch **120** is turned off when a potential difference between the control terminal G and the first main terminal T**1**, more specifically, a gate-source voltage (=the voltage of the control terminal G-the voltage of the first main terminal T**1**) is equal to or lower than a threshold voltage TH of the series switch **120**, and is turned on when the potential difference exceeds the threshold voltage TH. Since the series switch **120** is normally on, the threshold voltage TH is lower than 0.

[0027] As an example, in a case where the first terminal P**1** is 0 V, the threshold voltage TH of the series switch **120** is −2 V, and the withstand voltage of the phase-change material switch **100** is 4 V, the operation of the switch device **10** when the voltage of the second terminal P**2** rises from 0 V to 4 V or more after the phase-change material switch **100** is turned off will be described. When the phase-change material switch **100** is in the on state, both the control terminal G and the first main terminal T**1** of the series switch **120** are 0 V, and thus the gate-source voltage of the series switch **120** is 0 V, which is higher than the threshold voltage TH (−2 V), so that the series switch **120** is turned on. When the phase-change material switch **100** is turned off in this state, the series switch **120** maintains the on state.
[0028] When the voltage of the second terminal P**2** rises to near 2 V, the series switch **120** is turned on, so that the terminal T**1** rises to near 2 V. When the voltage at the second terminal P**2** reaches 2 V, the control terminal of the series switch **120** is at 0 V, the terminal T**1** is at 2 V, and the gate-source voltage of the series switch **120** is at −2 V, which is equal to or lower than the threshold voltage TH (−2 V), so that the series switch **120** is turned off. Thereafter, even when the voltage at the second terminal P**2** further rises to 4 V or more, the voltage at the terminal T**1** does not rise beyond 2 V since the series switch **120** is turned off. Therefore, the switch device **10** can limit the voltage applied to the phase-change material switch **100** to lower than the absolute value (2 V in this example) of the threshold voltage TH of the series switch **120**.
[0029] In this way, by setting the threshold voltage of the series switch **120** to −2 V, it is possible to make the series switch **120** turn off in response to the potential difference of the second terminal from the first terminal P**1** exceeding the first threshold of 2 V. Then, the switch device **10** is designed such that the first threshold is lower than the withstand voltage of the phase-change material switch **100**, whereby a switch having a high withstand voltage can be realized by using the phase-change material switch **100**. Note that in order to provide a sufficient margin for the withstand voltage, the first threshold may be ½ or less, ⅓ or less, ¼ or less, or the like of the withstand voltage of the phase-change material switch **100**.
[0030] Note that the withstand voltage of the series switch **120** may be higher than the withstand voltage of the phase-change material switch **100**. Accordingly, a withstand voltage exceeding twice the withstand voltage of the phase-change material switch **100** can be realized as the entire switch device **10**. The series switch **120** may be a high withstand voltage switch having a sufficiently high withstand voltage as compared to the phase-change material switch **100**. The withstand voltage of the series switch **120** may be, for example, 5 times or higher, 10 times or higher, 20 times or higher, 50 times or higher, or 100 times or higher the withstand voltage of the phase-change material switch **100**.
[0031] FIG. **2** shows a configuration of a switch device **20** according to a modification of the present embodiment. The switch device **20** shown in this drawing is a modification of the switch device **10** shown in FIG. **1**, and thus the description thereof will be omitted except for the following difference.
[0032] The switch device **20** has a function of protecting a phase-change material switch **200** from overvoltage not only when the potential of the second terminal P**2** is relatively higher than the potential of the first terminal P**1** but also when the potential of the second terminal P**2** is relatively lower than the potential of the first terminal P**1**. The switch device **20** includes a phase-change material switch **200**, a heater **210**, and series switches **220***a* to **220***b*.
[0033] The phase-change material switch **200** may have a function and a configuration similar to those of the phase-change material switch **100** shown in FIG. **1**. The heater **210** may have a function and a configuration similar to those of the heater **110** shown in FIG. **1**. The series switch **220***a* and the series switch **220***b* are normally-on switches. The series switch **220***a* and the series switch **220***b* are connected in series to the phase-change material switch **100** between the first terminal P**1** and the second terminal P**2** of the switch device **20**. The series switch **220***a* is an example of the “first series switch”, and is connected on the second terminal P**2** side with respect to

the phase-change material switch **200** between the first terminal P**1** and the second terminal P**2** of the switch device **20**. In the example of this drawing, a first main terminal T**1***a* (a source as an example) of the series switch **220***a* is directly connected to the terminal S**2** of the phase-change material switch **200**, and a second main terminal T**2***a* (a drain as an example) of the series switch **220***a* is directly connected to the second terminal P**2**. Instead of directly connecting these terminals, a passive component may be provided between the terminals.
[0034] The control terminal G of the series switch **220***a* is connected to the terminal S**1** of the phase-change material switch **200** on the first terminal P**1** side. In the example of this drawing, the control terminal G of the series switch **220***a* is directly connected to the terminal S**1** of the phase-change material switch **200**. The control terminal G of the series switch **220***a* may be directly connected to the first terminal P**1**. A passive component such as a resistor or an inductor may be provided between the terminal S**1** or the first terminal P**1** and the control terminal G of the series switch **220***a*.
[0035] The series switch **220***b* is an example of the “second series switch”, and is connected on the first terminal P**1** side with respect to the phase-change material switch **200** between the first terminal and the second terminal of the switch device **20**. In the example of this drawing, a first main terminal T**1***b* (a source as an example) of the series switch **220***b* is directly connected to the terminal S**2** of the phase-change material switch **200**, and a second main terminal T**2***b* (a drain as an example) of the series switch **220***b* is directly connected to the first terminal P**1**. Instead of directly connecting these terminals, a passive component may be provided between the terminals.
[0036] The control terminal G of the series switch **220***b* is connected to the terminal S**2** of the phase-change material switch **200** on the second terminal P**2** side. In the example of this drawing, the control terminal G of the series switch **220***b* is directly connected to the terminal S**2** of the phase-change material switch **200**. The control terminal G of the series switch **220***b* may be directly connected to the second terminal P**2**. A passive component such as a resistor or an inductor may be provided between the terminal S**2** or the second terminal P**2** and the control terminal G of the series switch **220***b*.
[0037] The series switch **220***a* and the series switch **220***b* may have functions and configurations similar to those of the series switch **120** shown in FIG. **1** except for the following points. Here, the series switch **220***b* may be designed to be turned off in response to the potential difference of the second terminal P**2** from the first terminal P**1** exceeding the first threshold similarly to the series switch **120** and the series switch **220***a*. Alternatively, the series switch **220***b* may be designed to be turned off in response to the potential difference of the second terminal P**2** from the first terminal P**1** exceeding a second threshold different from the first threshold. The second threshold may be determined so as to satisfy a constraint similar to the first threshold described with reference to FIG. **1**.
[0038] The operation of the switch device **20** shown in FIG. **2** can be described as follows based on the operation of the switch device **10** shown in FIG. **1**.
(1) When the Potential of the Second Terminal P**2** is Higher Than the Potential of the First Terminal P**1**
[0039] The control terminal G of the series switch **220***b* is connected to the second terminal P**2** via the series switch **220***a*. Therefore, when the voltage of the first terminal P**1** is equal to or lower than the voltage of the second terminal P**2**, the voltage of the control terminal G of the series switch **220***b* becomes equal to or higher than the voltage of the first main terminal T**1***b* of the series switch **220***b*. Thus, the gate-source voltage of the series switch **220***b* becomes higher than the threshold voltage TH (a negative value such as −2 V), so that the series switch **220***b* is turned on.
[0040] Therefore, when the potential of the second terminal P**2** is higher than the potential of the first terminal P**1**, the switch device **20** can be regarded as a circuit equivalent to the switch device **10**, and similarly to the switch device **10**, the voltage applied to the phase-change material switch **200** can be limited to lower than the absolute value of the threshold voltage TH of the series switch

220*a*.

(2) When the Potential of the First Terminal P**1** is Higher Than the Potential of the Second Terminal P**2**

[0041] The control terminal G of the series switch **220***a* is connected to the first terminal P**1** via the series switch **220***b*. Therefore, when the voltage of the second terminal P**2** is equal to or lower than the voltage of the first terminal P**1**, the voltage of the control terminal G of the series switch **220***a* becomes equal to or higher than the voltage of the first main terminal T**1***a* of the series switch **220***a*. Thus, the gate-source voltage of the series switch **220***a* becomes higher than the threshold voltage TH (a negative value such as −2 V), so that the series switch **220***a* is turned on.

[0042] Therefore, when the potential of the first terminal P**1** is higher than the potential of the second terminal P**2**, the switch device **20** can be regarded as a circuit equivalent to a circuit in which the first terminal P**1** and the second terminal P**2** in the switch device **10** shown in FIG. **1** are reversed, and similarly to the switch device **10**, the voltage applied to the phase-change material switch **200** can be limited to lower than the absolute value of the threshold voltage TH of the series switch **220***b*.

[0043] FIG. **3** shows a configuration of a capacitor bank **30** according to the present embodiment. The capacitor bank **30** according to the present embodiment outputs a signal input from an input terminal IN from an output terminal OUT. The capacitor bank **30** allows the capacitance of the capacitor added to the signal line between the input terminal IN and the output terminal OUT to be variable.

[0044] The capacitor bank **30** includes a plurality of switch devices **310***a* to **310***h* and a plurality of capacitors **320***a* to **320***h*. The switch device **310***a* and the capacitor **320***a* are connected between the signal line and a power supply potential VCC. Similarly, the switch device **310***b* and the capacitor **320***b*, the switch device **310***c* and the capacitor **320***c*, and the switch device **310***d* and the capacitor **320***d* are connected between the signal line and the power supply potential VCC. The switch device **310***e* and the capacitor **320***e* are connected between the signal line and a ground potential GND. Similarly, the switch device **310***f* and the capacitor **320***f*, the switch device **310***g* and the capacitor **320***g*, and the switch device **310***h* and the capacitor **320***h* are connected between the signal line and the ground potential GND. Note that the capacitor bank **30** may include a different number of capacitors and switch devices from the example of this drawing.

[0045] Each of the switch devices **310***a* to **310***h* may be the switch device **10** shown in FIG. **1** or the switch device **20** shown in FIG. **2**. When the switch device **10** shown in FIG. **1** is used as the switch devices **310***a* to **310***d*, the second terminal P**2** of the switch device **10** is set to the power supply potential VCC side. When the switch device **10** shown in FIG. **1** is used as the switch devices **310***e* to **310***h*, the second terminal P**2** of the switch device **10** is set to the signal line side.

[0046] The capacitors **320***a* to **320***h* may have the same capacitance or different capacitances. In addition, each set of the capacitor **320***a* and the capacitor **320***e*, the capacitor **320***b* and the capacitor **320***f*, the capacitor **320***c* and the capacitor **320***g*, and the capacitor **320***d* and the capacitor **320***h* may have the same capacitance, and different sets may have different capacitances.

[0047] According to the capacitor bank **30** shown in this drawing, it is possible to allow the capacitance added to the signal line to be varied by changing the number or combination of switches to be turned on among the switch devices **310***a* to **310***h*. In addition, by using the switch device **10** or the switch device **20** as the switch devices **310***a* to **310***h*, the phase-change material switch **100** or the phase-change material switch **200** can be protected even when the amplitude of the signal flowing through the signal line is large.

[0048] FIG. **4** shows a configuration of a switch matrix **40** according to the present embodiment. The switch matrix **40** according to the present embodiment can switch a connection form between a plurality of input terminals IN**0** to IN**3** and a plurality of output terminals OUT**0** to OUT**3**.

[0049] The switch matrix **40** includes the plurality of input terminals IN**0** to IN**3**, the plurality of output terminals OUT**0** to OUT**3**, and a plurality of switch devices **410-00** to **410-33** (also referred to as a “switch device **410**”). Each of the plurality of switch devices **410** is provided between each of the plurality of input terminals IN**0** to IN**3** and each of the plurality of output terminals OUT**0** to OUT**3**. Each switch device **410** may be the switch device **10** shown in FIG. **1** or the switch device **20** shown in FIG. **2**. Note that in the switch matrix **40**, at least one of the number of input terminals or the number of output terminals may be different from that in the example of this drawing, and accordingly, the number of switch devices **410** may also be different.

[0050] The switch device **410-00** is connected between the output terminal OUT**0** and the input terminal IN**0**, the switch device **410-10** is connected between the output terminal OUT**0** and the input terminal IN**1**, the switch device **410-20** is connected between the output terminal OUT**0** and the input terminal IN**2**, and the switch device **410-30** is connected between the output terminal OUT**0** and the input terminal IN**3**. In the switch matrix **40**, the output terminal OUT**0** can be electrically connected to the input terminal IN**0** by turning on the switch device **410-00** and turning off the other switch devices **410**, the output terminal OUT**0** can be electrically connected to the input terminal IN**1** by turning on the switch device **410-10** and turning off the other switch devices **410**, the output terminal OUT**0** can be electrically connected to the input terminal IN**2** by turning on the switch device **410-20** and turning off the other switch devices **410**, and the output terminal OUT**0** can be electrically connected to the input terminal IN**3** by turning on the switch device **410-30** and turning off the other switch devices **410**. Similarly for the other output terminals OUT**1** to OUT**3**, the switch matrix **40** can switch which input terminal the output terminal is electrically connected to by selectively turning on the switch device **410** connected to the output terminal. Note that, although the input terminal and the output terminal are illustrated in the example of this drawing for convenience of description, the switch matrix **40** may exchange electrical signals bidirectionally between the terminals IN**0** to IN**3** and the terminals OUT**0** to OUT**3**.

[0051] While the present invention has been described above by using the embodiments, the technical scope of the present invention is not limited to the scope of the above-described embodiments. It is apparent to persons skilled in the art that various alterations or improvements can be made to the above-described embodiments. It is also apparent from description of the claims that the embodiments to which such modifications or improvements are made may be included in the technical scope of the present invention.

[0052] It should be noted that each process of the operations, procedures, steps, stages, and the like performed by the apparatus, system, program, and method shown in the claims, specification, or drawings can be executed in any order as long as the order is not indicated by “prior to”, “before”, or the like and as long as the output from a previous process is not used in a later process. Even if the operation flow is described using phrases such as “first” or “next” for the sake of convenience in the claims, specification, or drawings, it does not necessarily mean that the process must be performed in this order.

EXPLANATION OF REFERENCES

[0053] **10**: switch device; **20**: switch device; **30**: capacitor bank; **40**: switch matrix; **100**: phase-change material switch; **110**: heater; **120**: series switch; **200**: phase-change material switch; **210**: heater; **220**: series switch; **310***a* to **310***h*: switch device; **320***a* to **320***h*: capacitor; **410-00** to **410-33**: switch device.

Claims

1. A switch device comprising: a phase-change material switch; and a first series switch which is connected in series to the phase-change material switch and is normally on.

2. The switch device according to claim 1, wherein in the phase-change material switch and the first series switch, between a first terminal and a second terminal of the switch device, the phase-change material switch is connected on a side of the first terminal, and the first series switch is connected on a side of the second terminal, and a control terminal of the first series switch is

connected to a terminal of the phase-change material switch on a side of the first terminal.
3. The switch device according to claim 2, further comprising: a second series switch which is connected in series to the phase-change material switch and is normally on, wherein between the first terminal and the second terminal of the switch device, the second series switch is connected on a side of the first terminal with respect to the phase-change material switch, and a control terminal of the second series switch is connected to a terminal of the phase-change material switch on a side of the second terminal.
4. The switch device according to claim 2, wherein the first series switch is turned off in response to a potential difference of the second terminal from the first terminal exceeding a first threshold.
5. The switch device according to claim 3, wherein the first series switch is turned off in response to a potential difference of the second terminal from the first terminal exceeding a first threshold.
6. The switch device according to claim 4, wherein the first threshold is lower than a withstand voltage of the phase-change material switch.
7. The switch device according to claim 5, wherein the first threshold is lower than a withstand voltage of the phase-change material switch.
8. The switch device according to claim 3, wherein the second series switch is turned off in response to a potential difference of the first terminal from the second terminal exceeding a second threshold.
9. The switch device according to claim 4, wherein a withstand voltage of the first series switch is higher than a withstand voltage of the phase-change material switch.
10. The switch device according to claim 5, wherein a withstand voltage of the first series switch is higher than a withstand voltage of the phase-change material switch.
11. The switch device according to claim 6, wherein a withstand voltage of the first series switch is ten times or higher a withstand voltage of the phase-change material switch.