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(54) GAS SENSOR

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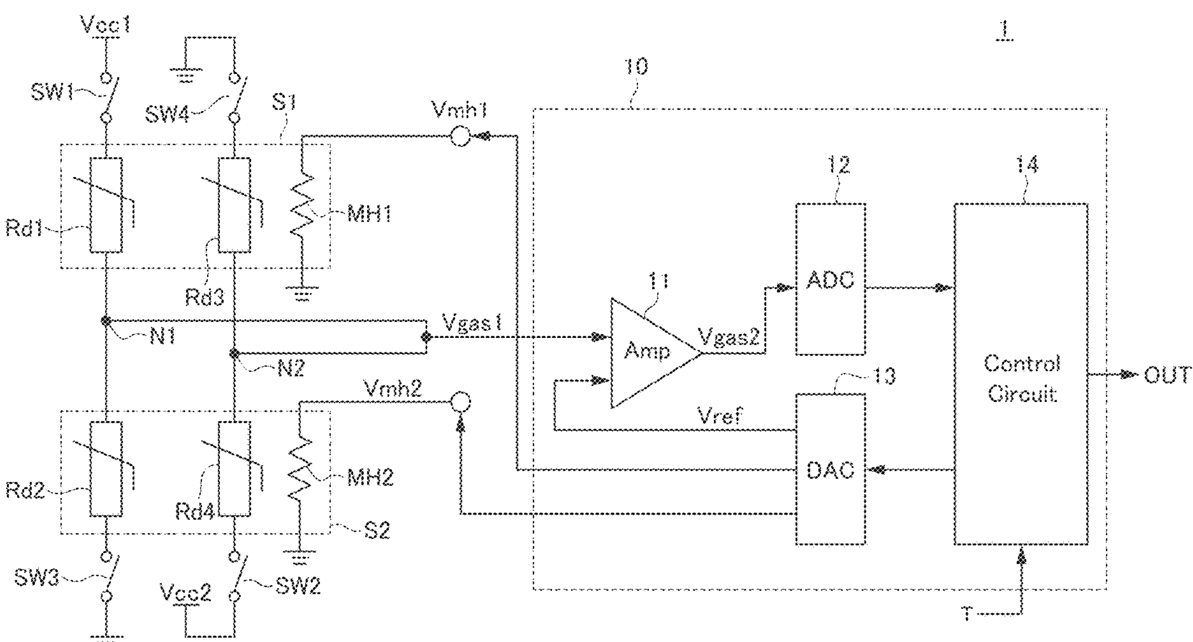
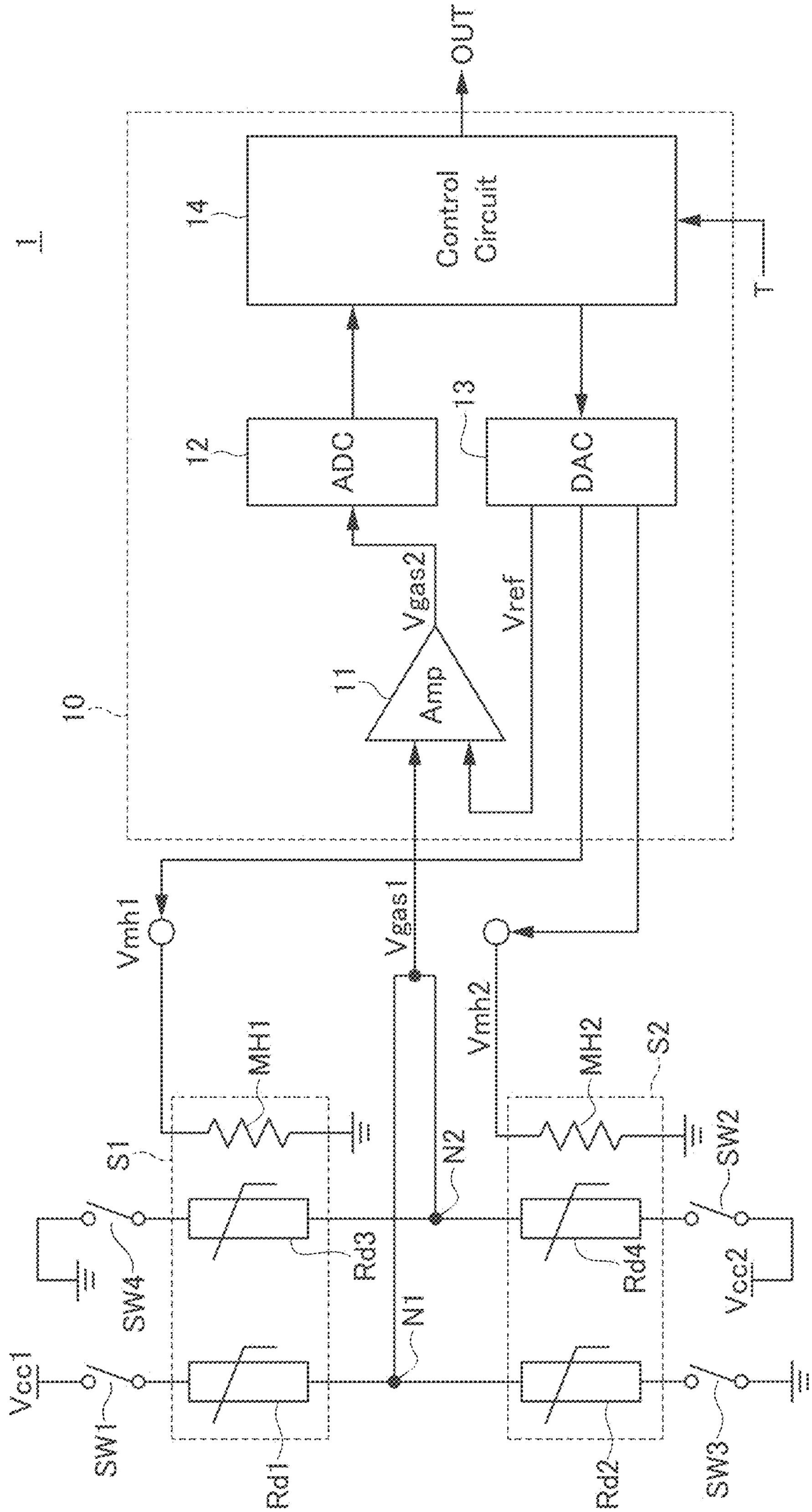
(57) **ABSTRACT**

Disclosed herein is a gas sensor that includes: first and second temperature-sensitive elements connected in series; third and fourth temperature-sensitive elements connected in series; and signal processing circuit configured to detect a first detection voltage appearing at a first node in a first period during which the first and third temperature-sensitive elements are heated to a first temperature range and the second and fourth temperature-sensitive elements are heated to a second temperature range, detect a second detection voltage appearing at a second node in a second period during which the first and third temperature-sensitive elements are heated to the second temperature range and the second and fourth temperature-sensitive elements are heated to the first temperature range, and calculate a concentration of a gas to be detected based on the first detection voltage and the second detection voltage.





1
OUT
14
Control Circuit
T
12
ADC
13
DAC
10
11
Amp
Vgas2
Vref
Vmh1
Vgas1
Vmh2
MH1
MH2
S1
S2
N1
N2
SW1
SW2
SW3
SW4
Vcc1
Vcc2
Rd1
Rd2
Rd3
Rd4

FIG. 1

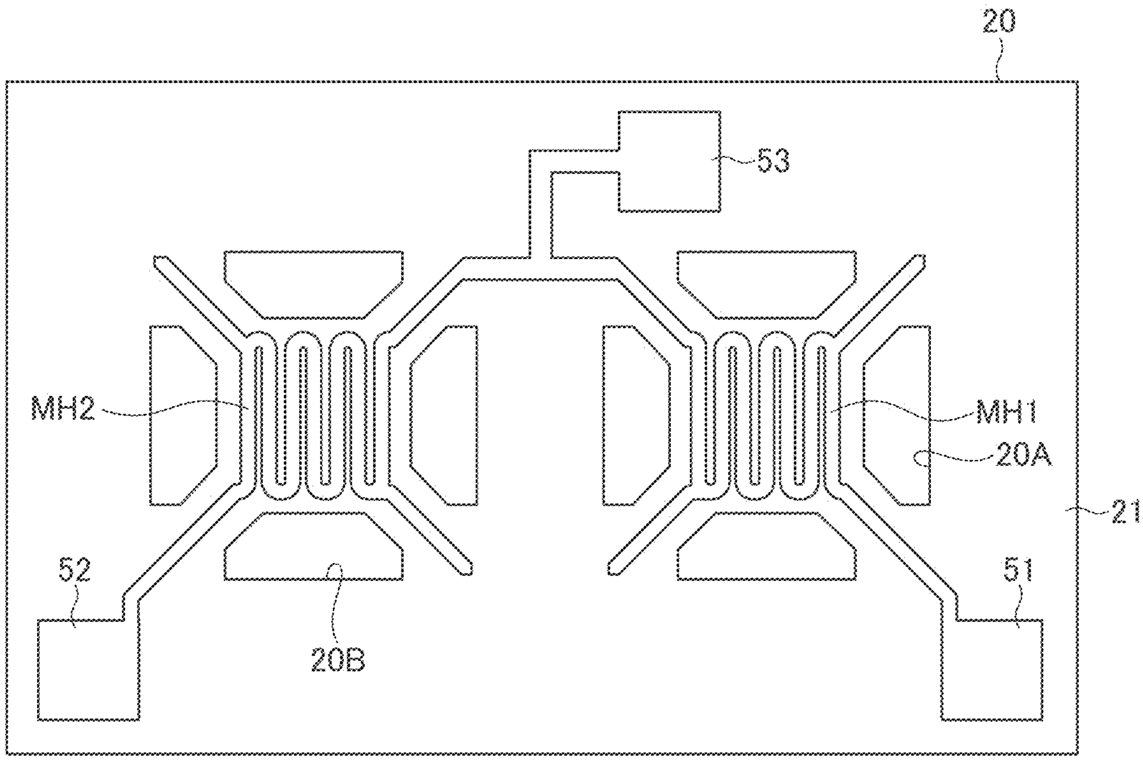


FIG. 2

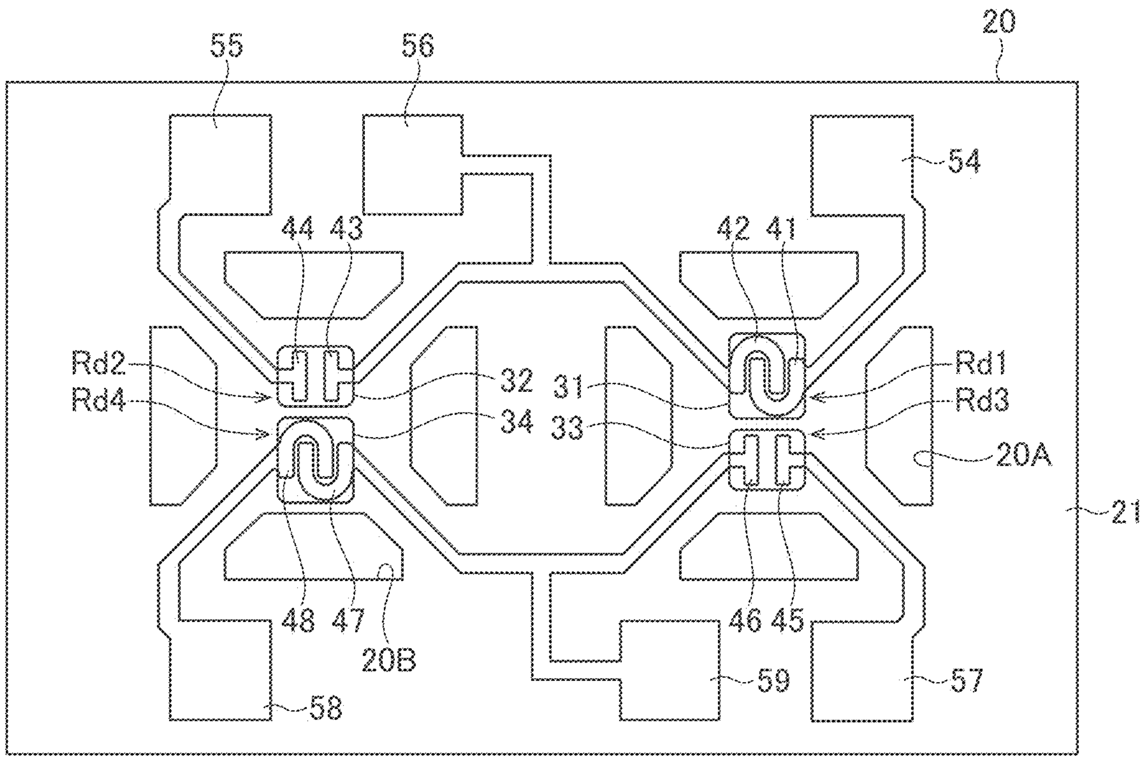

20
55
56
54
44 43
42 41
Rd2
Rd4
32
34
31
33
Rd1
Rd3
20A
21
48 47
46 45
20B
58
59
57

FIG. 3

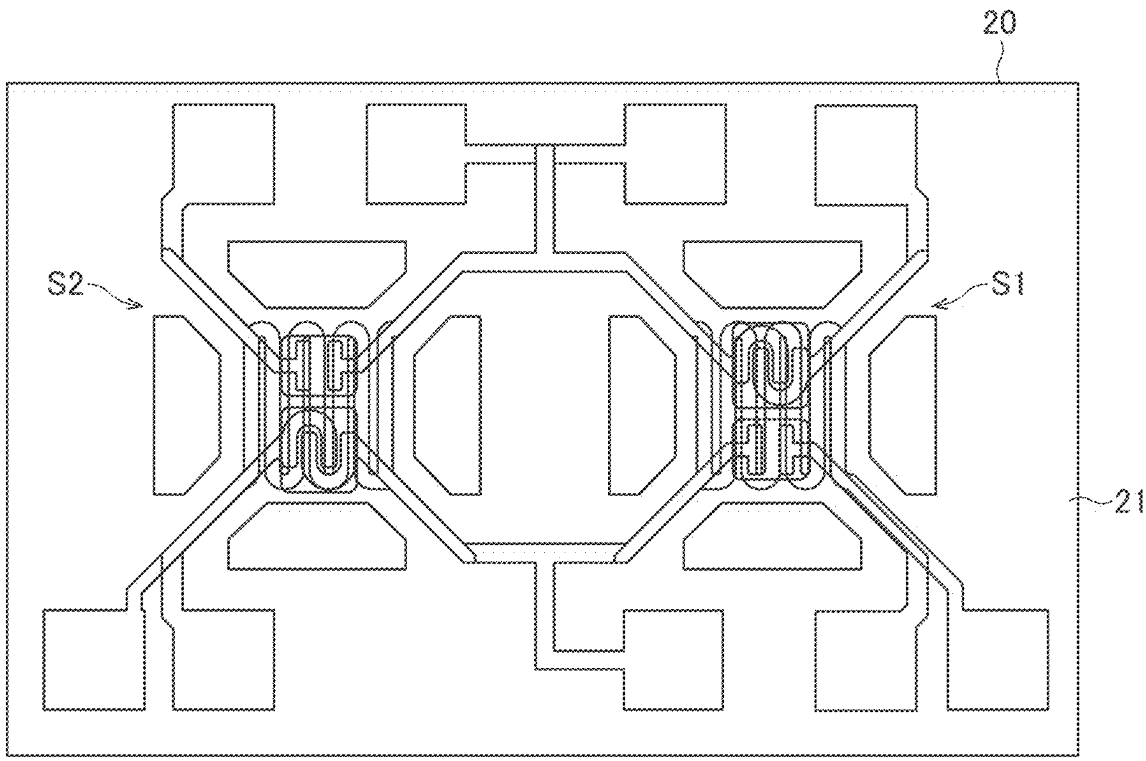


FIG. 4

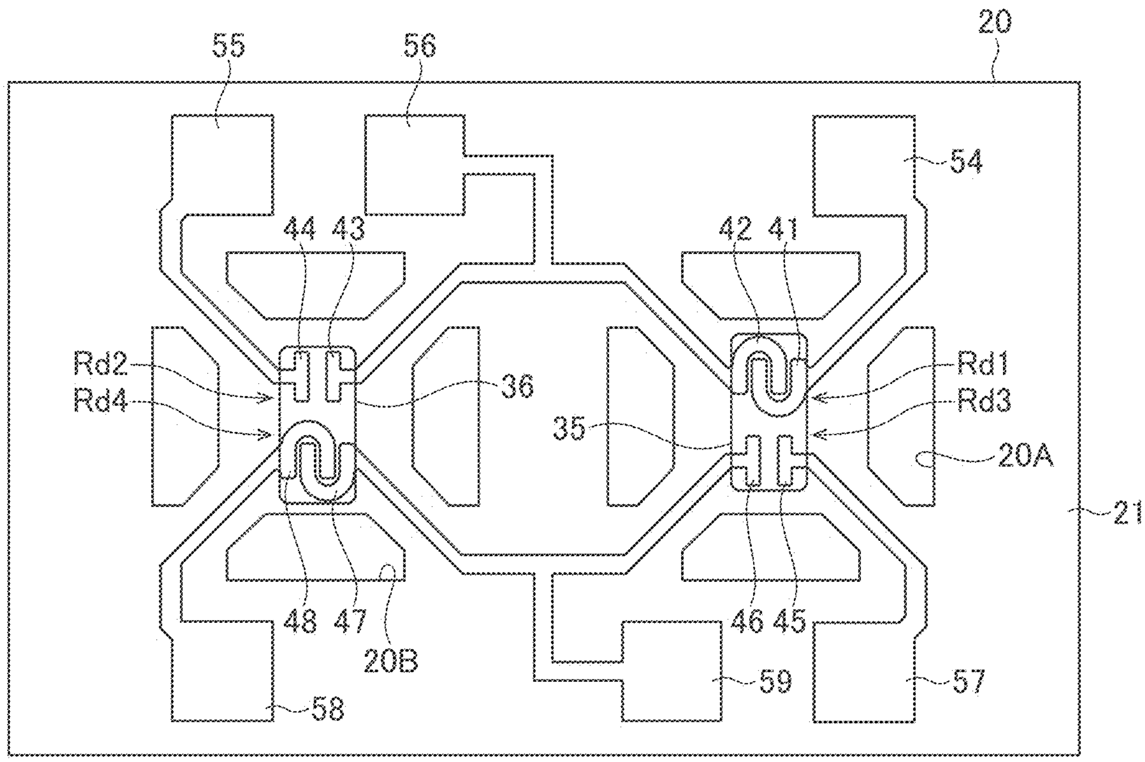

20
55
56
54
44 43
42 41
Rd2
Rd4
36
Rd1
Rd3
35
20A
21
48 47
46 45
20B
59
57
58

FIG. 5

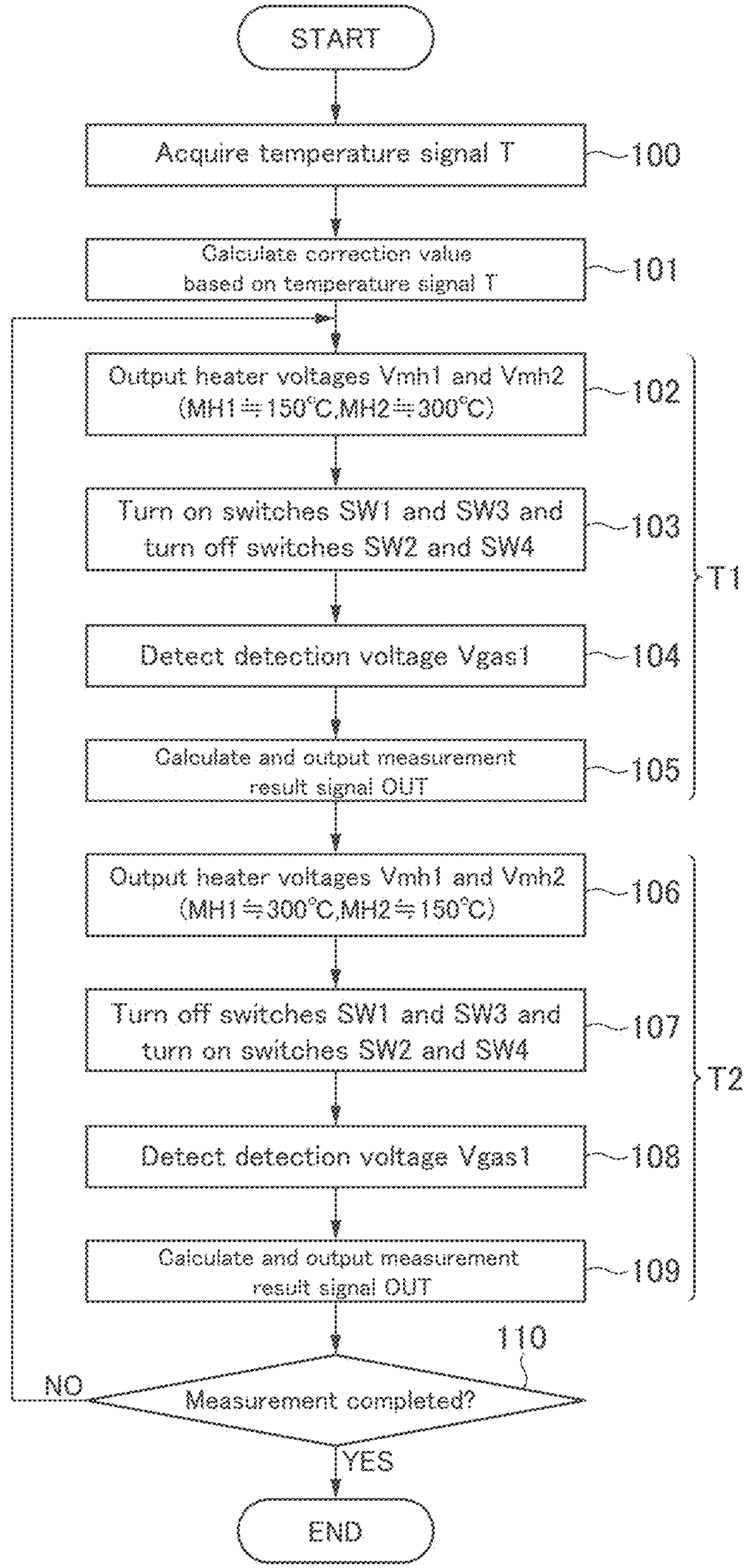

START
Acquire temperature signal T
100
Calculate correction value based on temperature signal T
101
Output heater voltages Vmh1 and Vmh2 (MH1≒150℃,MH2≒300℃)
102
Turn on switches SW1 and SW3 and turn off switches SW2 and SW4
103
T1
Detect detection voltage Vgas1
104
Calculate and output measurement result signal OUT
105
Output heater voltages Vmh1 and Vmh2 (MH1≒300℃,MH2≒150℃)
106
Turn off switches SW1 and SW3 and turn on switches SW2 and SW4
107
T2
Detect detection voltage Vgas1
108
Calculate and output measurement result signal OUT
109
110
NO
Measurement completed?
YES
END

FIG. 6

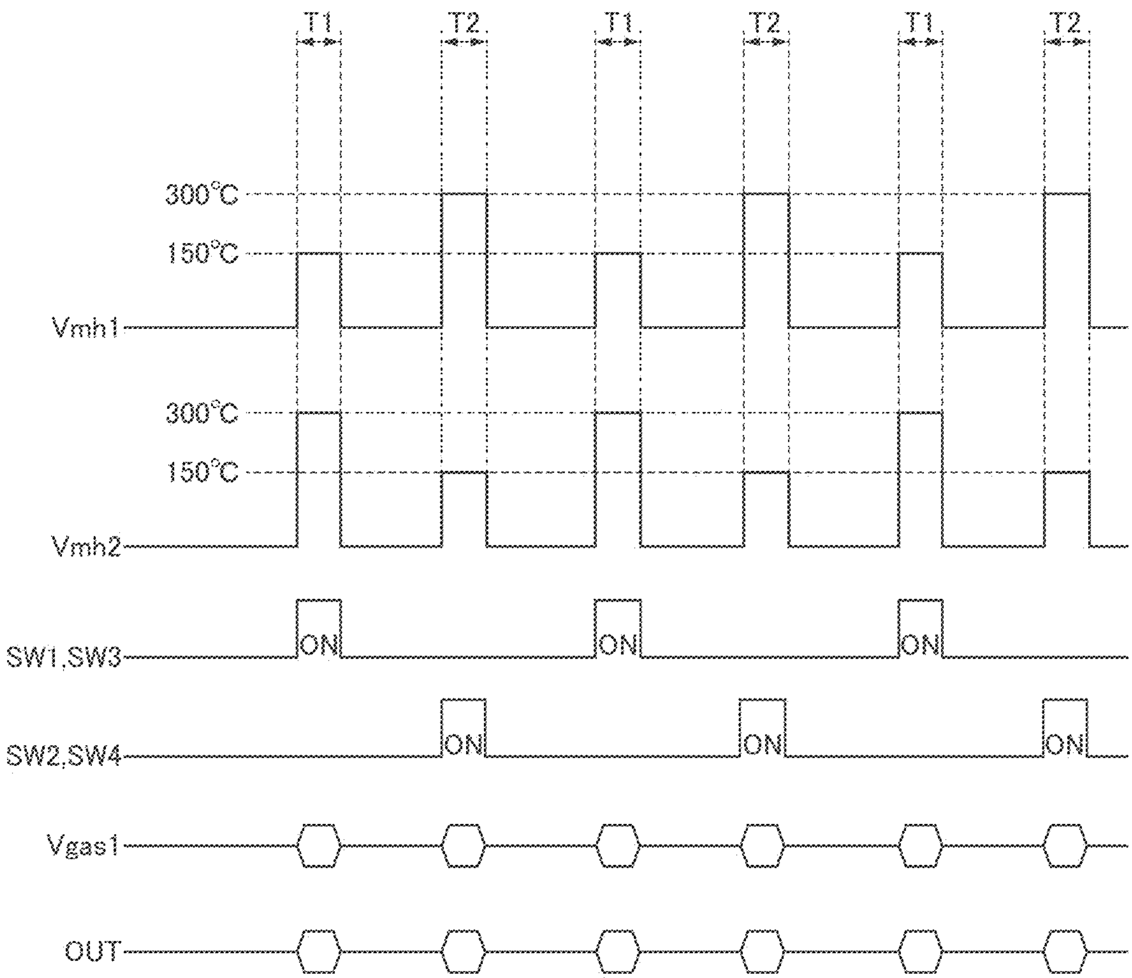

T1
T2
T1
T2
T1
T2
300°C
150°C
Vmh1
300°C
150°C
Vmh2
SW1,SW3
ON
SW2,SW4
ON
Vgas1
OUT

FIG. 7

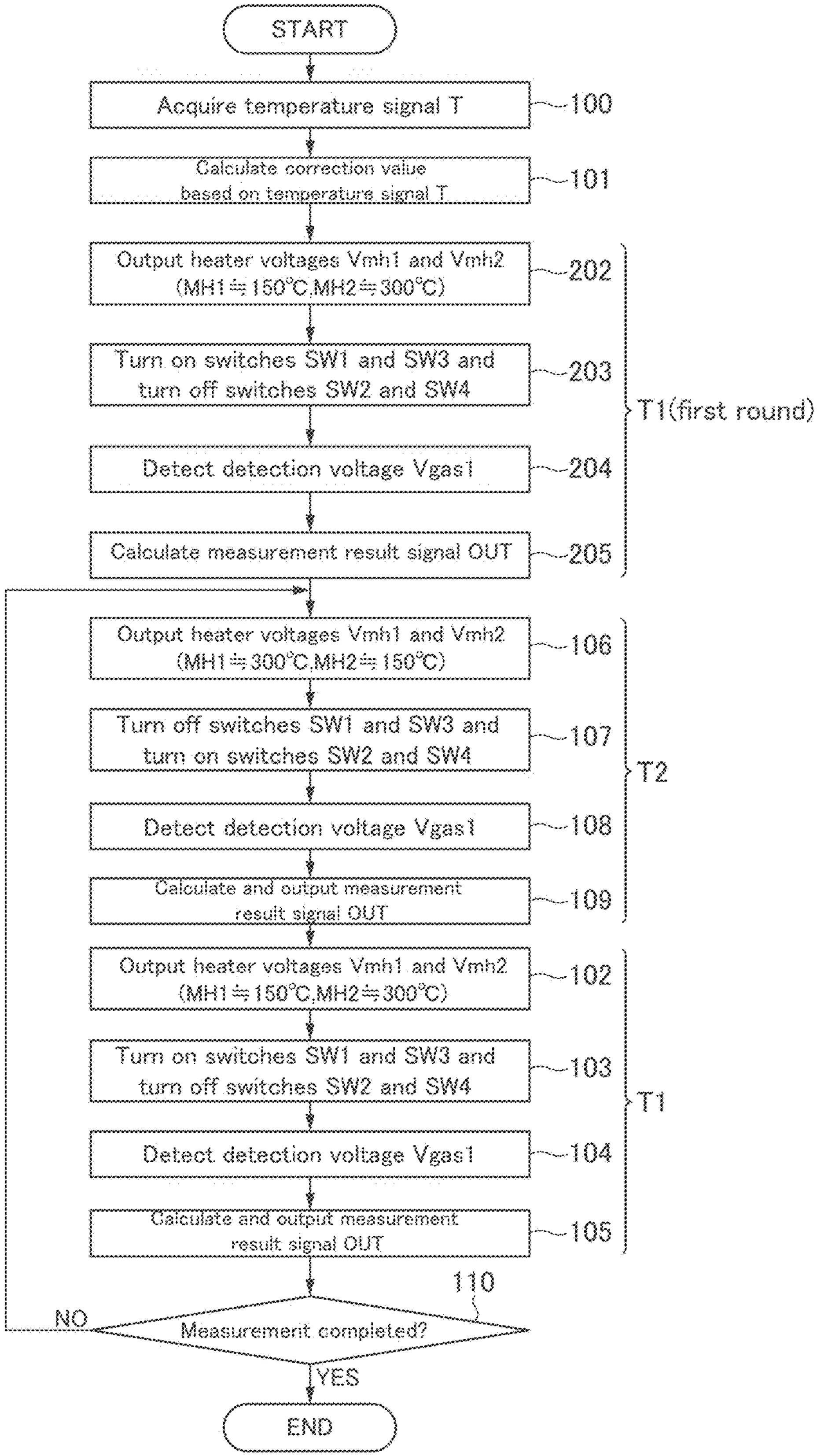

START
Acquire temperature signal T
100
Calculate correction value based on temperature signal T
101
Output heater voltages Vmh1 and Vmh2 (MH1≒150℃,MH2≒300℃)
202
Turn on switches SW1 and SW3 and turn off switches SW2 and SW4
203
Detect detection voltage Vgas1
204
Calculate measurement result signal OUT
205
T1(first round)
Output heater voltages Vmh1 and Vmh2 (MH1≒300℃,MH2≒150℃)
106
Turn off switches SW1 and SW3 and turn on switches SW2 and SW4
107
Detect detection voltage Vgas1
108
Calculate and output measurement result signal OUT
109
T2
Output heater voltages Vmh1 and Vmh2 (MH1≒150℃,MH2≒300℃)
102
Turn on switches SW1 and SW3 and turn off switches SW2 and SW4
103
Detect detection voltage Vgas1
104
Calculate and output measurement result signal OUT
105
T1
110
Measurement completed?
NO
YES
END

FIG. 8

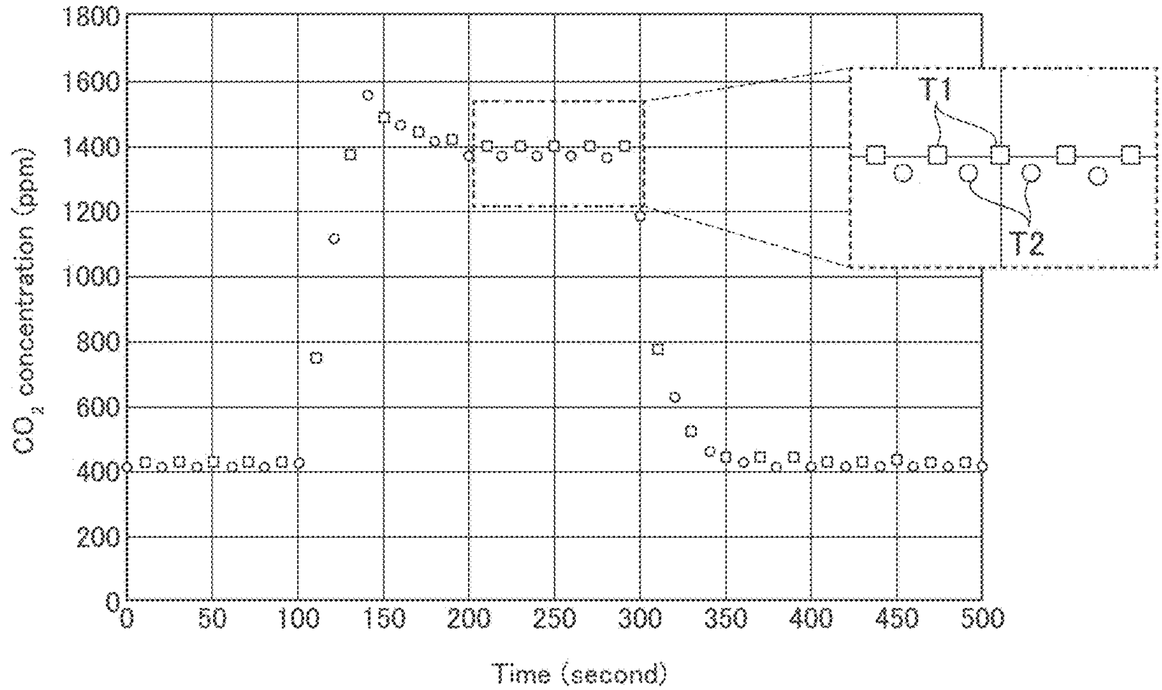

1800
1600
1400
1200
1000
800
600
400
200
0
0
50
100
150
200
250
300
350
400
450
500
CO_2 concentration (ppm)
Time (second)
T1
T2

FIG. 9A

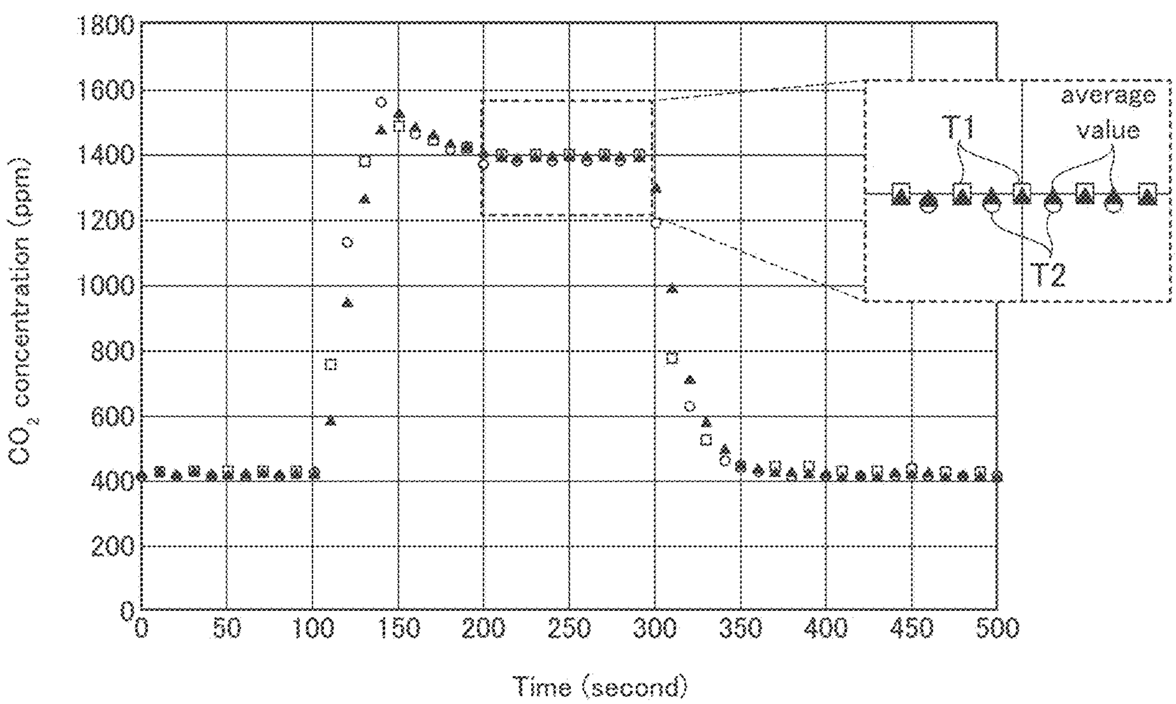

1800
1600
1400
1200
1000
800
600
400
200
0
0
50
100
150
200
250
300
350
400
450
500
CO_2 concentration (ppm)
Time (second)
average value
T1
T2

FIG. 9B

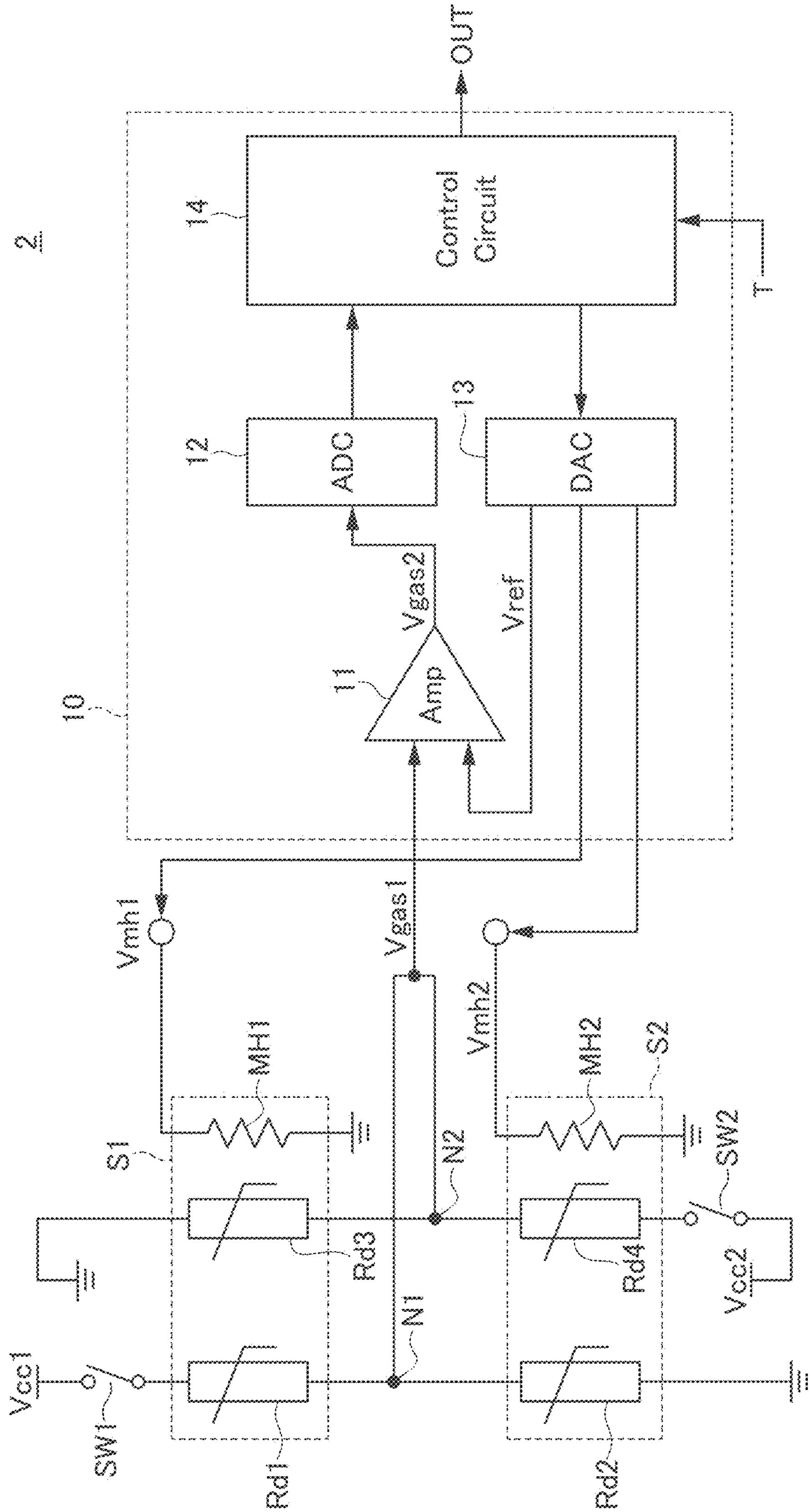

2
OUT
14
Control
Circuit
T
12
ADC
13
DAC
10
11
Amp
Vgas2
Vref
Vgas1
Vmh1
Vmh2
MH1
MH2
S1
S2
N1
N2
Rd1
Rd2
Rd3
Rd4
SW1
SW2
Vcc1
Vcc2

FIG. 10

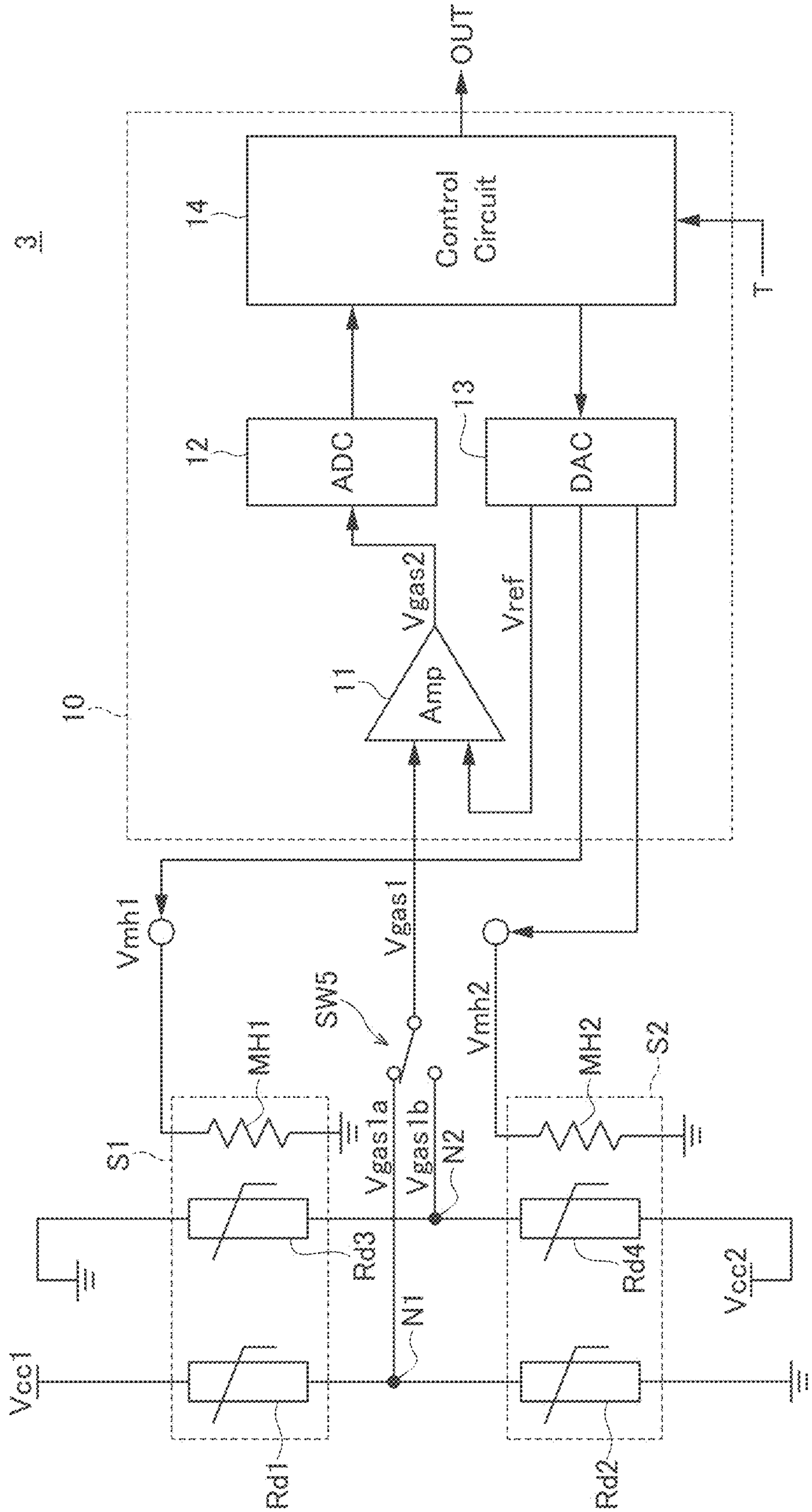

3
OUT
10
14
Control Circuit
T
12
ADC
13
DAC
11
Amp
Vgas2
Vref
Vmh1
Vgas1
SW5
Vmh2
MH1
MH2
S1
S2
Vgas1a
Vgas1b
N2
N1
Rd3
Rd4
Vcc1
Vcc2
Rd1
Rd2

FIG. 11

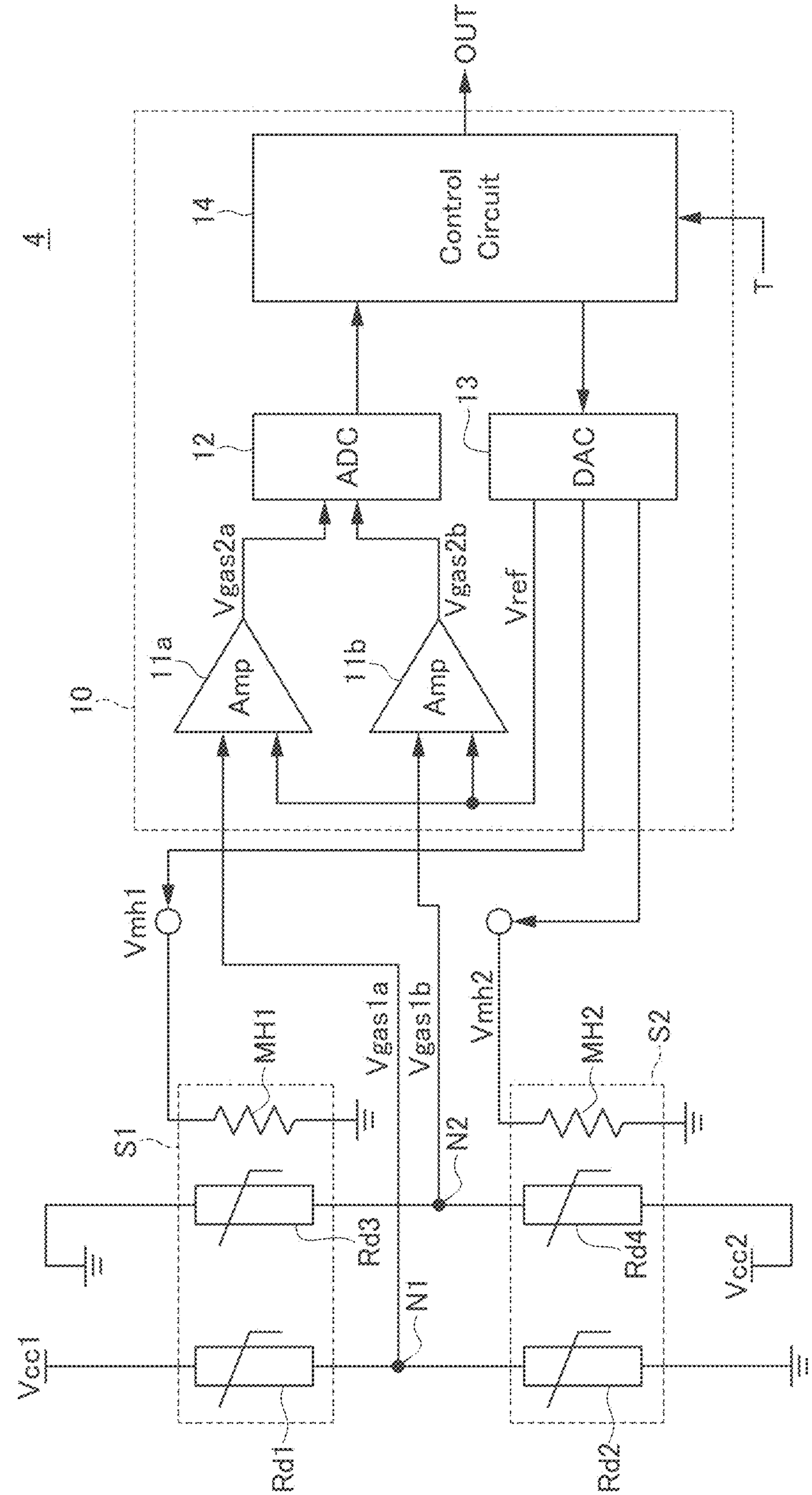

4
OUT
14
Control Circuit
T
12
ADC
13
DAC
10
11a
Amp
11b
Amp
Vgas2a
Vgas2b
Vref
Vmh1
Vmh2
Vgas1a
Vgas1b
MH1
MH2
S1
S2
N1
N2
Rd1
Rd2
Rd3
Rd4
Vcc1
Vcc2

FIG. 12

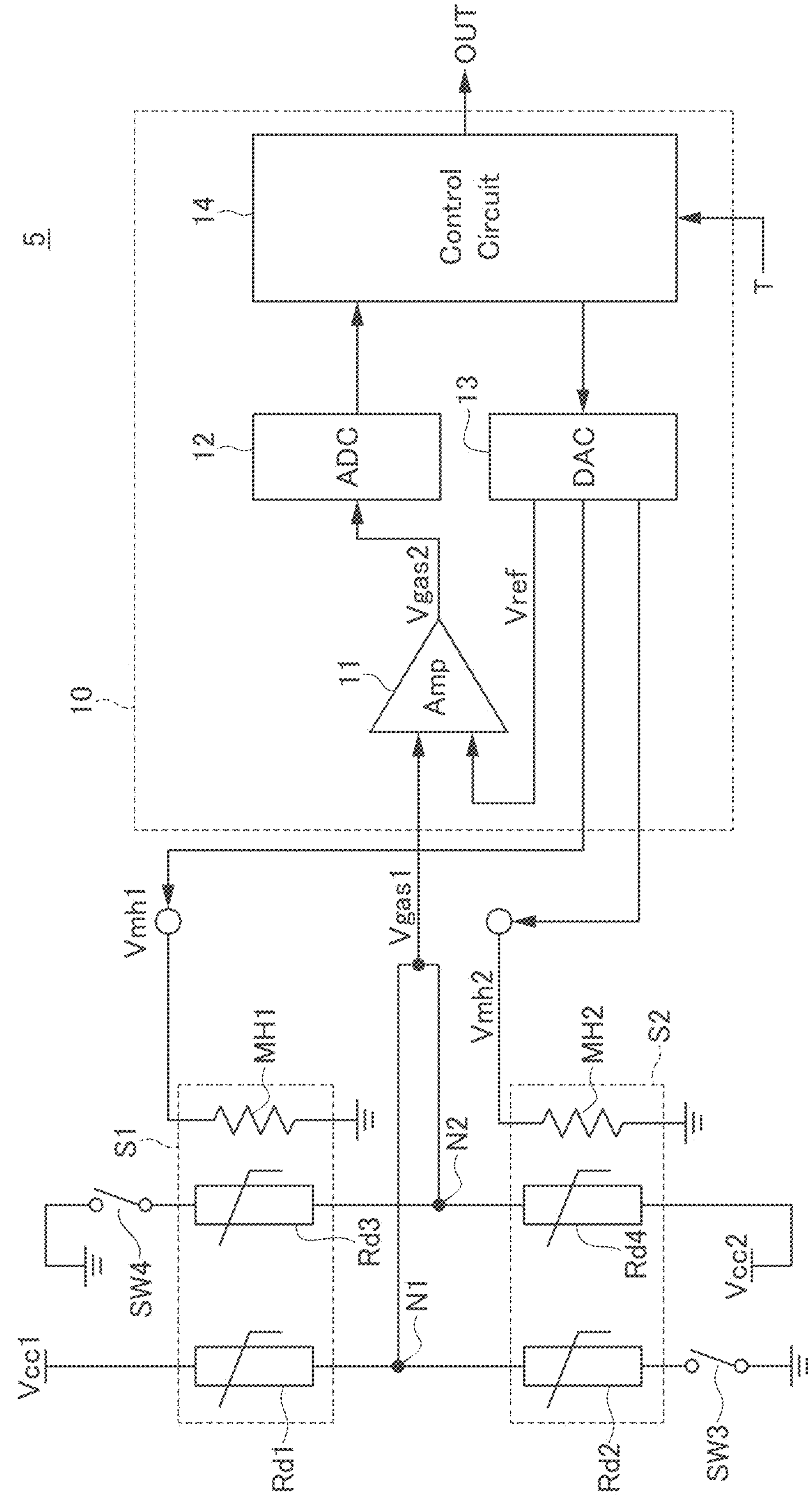

5
OUT
10
14
Control Circuit
T
12
ADC
13
DAC
11
Amp
Vgas2
Vref
Vgas1
Vmh1
Vmh2
MH1
MH2
S1
S2
SW4
SW3
Rd1
Rd2
Rd3
Rd4
N1
N2
Vcc1
Vcc2

FIG. 13

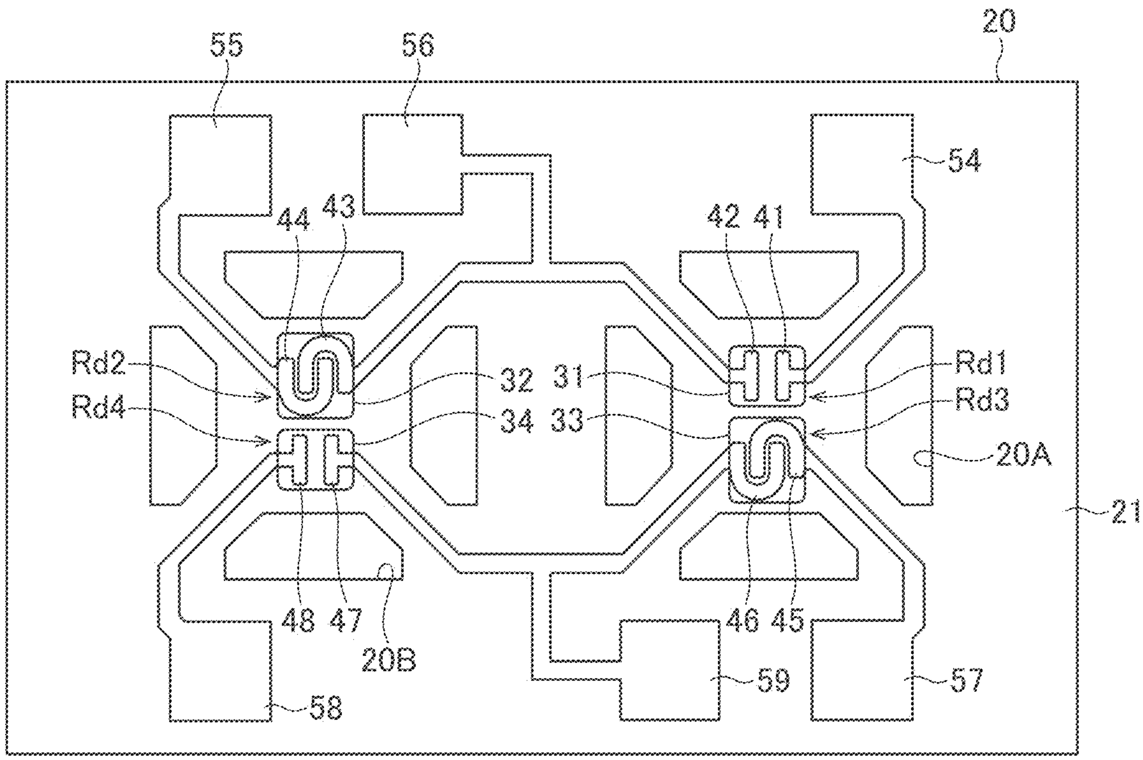

20
55
56
54
44
43
42
41
Rd2
32
31
Rd1
Rd4
34
33
Rd3
20A
21
48
47
46
45
20B
59
57
58

FIG. 14

GAS SENSOR

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims the benefit of Japanese Patent Application No. 2024-020015, filed on Feb. 14, 2024, the entire disclosure of which is incorporated by reference herein.

BACKGROUND OF THE ART

Field of the Art

[0002] The present disclosure relates to a gas sensor and, more particularly, to a gas sensor provided with a temperature-sensitive element such as a thermistor.

Description of Related Art

[0003] International Publication WO 2020/031517 discloses a gas sensor provided with two series-connected thermistors. The gas sensor described in this document heats first and second thermistors to first and second temperature ranges, respectively, during a first period and heats the first and second thermistors to the second and first temperature ranges, respectively, during a second period to make thermal histories of the two thermistors coincide with each other.

[0004] However, the gas sensor described in the above document cannot detect the concentration of a gas to be detected in the second period.

SUMMARY

[0005] The present disclosure describes a technology for increasing a period during which a gas sensor provided with a temperature-sensitive element such as a thermistor can detect the concentration of a gas to be detected.

[0006] A gas sensor according to an aspect of the present disclosure includes: a first series circuit including a first temperature-sensitive element and a second temperature-sensitive element connected in series; a second series circuit including a third temperature-sensitive element and a fourth temperature-sensitive element connected in series; a first power supply circuit configured to apply voltage to the first series circuit; a second power supply circuit configured to apply voltage to the second series circuit; and a signal processing circuit. The signal processing circuit is configured to: detect a first detection voltage appearing at a first node at which the first temperature-sensitive element and the second temperature-sensitive element are connected in a first period during which the first temperature-sensitive element and a third temperature-sensitive element are heated to a first temperature range and the second temperature-sensitive element and the fourth temperature-sensitive element are heated to a second temperature range; detect a second detection voltage appearing at a second node at which the third temperature-sensitive element and the fourth temperature-sensitive element are connected in a second period during which the first temperature-sensitive element and the third temperature-sensitive element are heated to the second temperature range and the second temperature-sensitive and element the fourth temperature-sensitive element are heated to the first temperature range; and calculate a concentration of a gas to be detected based on the first detection voltage and the second detection voltage.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] The above features and advantages of the present disclosure will be more apparent from the following description of some embodiments taken in conjunction with the accompanying drawings, in which:

[0008] FIG. **1** is a circuit diagram illustrating the configuration of a gas sensor **1** according to a first embodiment of the technology according to the present disclosure;

[0009] FIG. **2** is a schematic plan view for explaining the device structure of the heater resistors MH**1** and MH**2** of the sensor parts S**1** and S**2**;

[0010] FIG. **3** is a schematic plan view for explaining the device structure of the thermistors Rd**1** to Rd**4** of the sensor parts S**1** and S**2**;

[0011] FIG. **4** is a schematic superimposed plan view of FIGS. **2** and **3** for explaining the device structure of the sensor parts S**1** and S**2**;

[0012] FIG. **5** is a schematic plan view for explaining a modification of the device structure of the thermistors Rd**1** to Rd**4** of the sensor parts S**1** and S**2**;

[0013] FIG. **6** is a flowchart for explaining the operation of the gas sensor **1**;

[0014] FIG. **7** is a timing chart for explaining the operation of the gas sensor **1**;

[0015] FIG. **8** is a flowchart for explaining the operation of the gas sensor **1** according to a modification;

[0016] FIG. **9**A is a graph showing a change in the measurement result signal OUT obtained when there is an offset between the detection voltage Vgas**1** appearing at a node N**1** and the detection voltage Vgas**1** appearing at a node N**2**;

[0017] FIG. **9**B is a graph showing a change in the average value of the measurement result signal OUT obtained in a measurement at a certain point in time and the measurement result signal OUT obtained in the measurement immediately prior to that;

[0018] FIG. **10** is a circuit diagram illustrating the configuration of a gas sensor **2** according to a second embodiment of the technology according to the present disclosure;

[0019] FIG. **11** is a circuit diagram illustrating the configuration of a gas sensor **3** according to a third embodiment of the technology according to the present disclosure;

[0020] FIG. **12** is a circuit diagram illustrating the configuration of a gas sensor **4** according to a fourth embodiment of the technology according to the present disclosure;

[0021] FIG. **13** is a circuit diagram illustrating the configuration of a gas sensor **5** according to a fifth embodiment of the technology according to the present disclosure; and

[0022] FIG. **14** is a schematic plan view for explaining the device structure of the thermistors Rd**1** to Rd**4** of the sensor parts S**1** and S**2** in the gas sensor **5**.

DETAILED DESCRIPTION OF THE EMBODIMENTS

[0023] Some embodiments of the present disclosure will be explained below in detail with reference to the accompanying drawings.

First Embodiment

[0024] FIG. **1** is a circuit diagram illustrating the configuration of a gas sensor **1** according to a first embodiment of the technology according to the present disclosure.

[0025] As illustrated in FIG. 1, the gas sensor 1 according to the first embodiment has sensor parts S1 and S2 and a signal processing circuit 10. Although not particularly limited, the gas sensor 1 according to the present embodiment is a heat-conduction type gas sensor for detecting the concentration of CO_2 gas in the atmosphere.

[0026] The sensor part S1 includes thermistors Rd1, Rd3 and a heater resistor MH1. The sensor part S2 includes thermistors Rd2, Rd4 and a heater resistor MH2. The thermistors Rd1 to Rd4 all have a negative temperature coefficient of resistance. The thermistors Rd1 and Rd2 are connected in series to constitute a first series circuit. The thermistors Rd3 and Rd4 are connected in series to constitute a second series circuit. One end of the thermistor Rd1 and one end of the thermistor Rd2 are short-circuited by a node N1. One end of the thermistor Rd3 and one end of the thermistor Rd4 are short-circuited by a node N2. In the example illustrated in FIG. 1, the nodes N1 and N2 are short-circuited.

[0027] The other end of the thermistor Rd1 is connected, through a switch SW1, to a line to which a power supply voltage Vcc1 is supplied. The other end of the thermistor Rd2 is connected to a ground line through a switch SW3. The other end of the thermistor Rd3 is connected to a ground line through a switch SW4. The other end of the thermistor Rd4 is connected, through a switch SW2, to a line to which a power supply voltage Vcc2 is supplied. The power supply voltages Vcc1 and Vcc2 may have the same level. The switches SW1, SW3, the line to which the power supply voltage Vcc1 is supplied, and the ground line constitute a first power supply circuit that applies voltage to the first series circuit constituted by the thermistors Rd1 and Rd2. The switches SW2, SW4, the line to which the power supply voltage Vcc2 is supplied, and the ground line constitute a second power supply circuit that applies voltage to the second series circuit constituted by the thermistors Rd3 and Rd4. In the first series circuit, the connection relation of the thermistors Rd1 and Rd2 to the power supply voltage Vcc1 and ground line may be reversed. That is, the other end of the thermistor Rd1 may be connected to the ground line through the switch SW1, and the other end of the thermistor Rd2 may be connected, through the switch SW3, to the line to which the power supply voltage Vcc1 is supplied. Similarly, in the second series circuit, the connection relation of the thermistors Rd3 and Rd4 to the power supply voltage Vcc2 and ground line may be reversed. That is, the other end of the thermistor Rd3 may be connected, through the switch SW4, to the line to which the power supply voltage Vcc2 is supplied, and the other end of the thermistor Rd4 may be connected to the ground line through the switch SW2.

[0028] The resistance values of the thermistors Rd1 and Rd4 each serving as a temperature-sensitive element for detection are designed so as to fall within a first resistance range when the thermistors Rd1 and Rd4 are heated to a first temperature range (e.g., about 150° C.). The first temperature range is, for example, a predetermined temperature range included in the range of 100° C. or more and 230° C. or less, for example, a temperature range about 150° C. The resistance values of the thermistors Rd2 and Rd3 each serving as a temperature-sensitive element for reference are designed so as to fall within a second resistance range when the thermistors Rd2 and Rd3 are heated to a second temperature range (e.g., about 300° C.). The second temperature range is, for example, a predetermined temperature range included in the range of 250° C. or more and 450° C. or less, for example, a temperature range about 300° C. In the specification, the "temperature range" has a temperature width of, for example, within 1° C. For example, a temperature range about 150° C. may be a range of 149.5° C. or more and 150.5° C. or less. Also, for example, a temperature range about 300° C. may be a range of 299.5° C. or more and 300.5° C. or less. In the present embodiment, the second temperature range is set higher than the first temperature range. The first and second resistance ranges may partially overlap each other or may completely coincide with each other. When the first and second resistance ranges partially overlap each other or completely coincide with each other, it is possible to bring the level of a detection voltage Vgas1 appearing at the nodes N1 and N2 close to Vcc1/2 or Vcc2/2, achieving a wide dynamic range. The detection voltage Vgas1 appearing at the nodes N1 and N2 is supplied to the signal processing circuit 10.

[0029] When CO_2 gas is present in the measuring atmosphere in a state where the thermistors Rd1 and Rd4 as the temperature-sensitive element for detection is heated to around 150° C., heat dissipation characteristics of the thermistors Rd1 and Rd4 change according to the concentration of the CO_2 gas. This change appears as a change in the temperatures of the thermistors Rd1 and Rd4, i.e., the resistance values thereof. Specifically, CO_2 gas is lower in heat dissipation than air, so that the temperatures of the thermistors Rd1 and Rd4 increase as the concentration of CO_2 gas becomes high. Thus, for example, assuming that heating is performed so that temperatures of the thermistors Rd1 and Rd4 become 150° C. when CO_2 gas concentration in the measuring atmosphere is the same as CO_2 average concentration in the atmosphere, the temperatures of the thermistors Rd1 and Rd4 exceed 150° C. when CO_2 gas concentration in the measuring atmosphere is higher than CO_2 average concentration in the atmosphere. As a result, the resistance values of the thermistors Rd1 and Rd4 lower as compared with when CO_2 gas concentration in the measuring atmosphere assumes CO_2 average concentration in the atmosphere.

[0030] On the other hand, when CO_2 gas is present in the measuring atmosphere in a state where the thermistors Rd2 and Rd3 as the thermosensitive element for reference is heated to around 300° C., heat dissipation characteristics of the thermistor Rd2 and RD3 hardly change according to the concentration thereof, and the temperatures of the thermistors Rd2 and Rd3 also hardly change. Accordingly, a change in the resistance values of the thermistors Rd1 and Rd3 heated to around 300° C. according to the CO_2 gas concentration is sufficiently smaller than a change in the resistance values of the thermistors Rd1 and Rd4 heated to around 150° C. according to the CO_2 gas concentration and may be imperceptible. As a result, when the thermistors Rd1 and Rd2 are heated to around 150° C. and 300° C., respectively, the detection voltage Vgas1 corresponding to the concentration of CO_2 gas in the measuring atmosphere appears at the node N1. Similarly, when the thermistors Rd4 and Rd3 are heated to around 150° C. and 300° C., respectively, the detection voltage Vgas1 corresponding to the concentration of CO_2 gas in the measuring atmosphere appears at the node N2. Even when another gas, in which there is no significant difference between heat dissipation characteristics exhibited when the thermistors Rd1 to Rd4 are heated to around 150° C. and heat dissipation characteristics exhibited when the thermistors Rd**1** to Rd**4** are heated to around 300° C., is contained in the measuring atmosphere, the concentration of this gas has little influence on the detection voltage Vgas**1**. Thus, it is possible to selectively detect the concentration of CO_2 gas.

[0031] The signal processing circuit **10** has an amplifier **11**, an AD converter (ADC) **12**, a DA converter (DAC) **13**, and a control circuit **14**. The amplifier **11** compares the detection voltage Vgas**1** and a reference voltage Vref to generate an amplified detection voltage Vgas**2**. The amplifier **11** is a differential amplifier, for example, and amplifies a difference between the detection voltage Vgas**1** and the reference voltage Vref to generate and output the detection voltage Vgas**2**. The detection voltage Vgas**2** is input to the AD converter **12**. The AD converter **12** AD-converts the detection voltage Vgas**2** into a digital detection voltage Vgas**2** and supplies the digital detection voltage Vgas**2** to the control circuit **14**.

[0032] The control circuit **14** supplies various control parameters to the DA converter **13** in the form of digital values. The DA converter **13** D-A coverts the digital control parameters to generate heater voltages Vmh**1** and Vmh**2** and a reference voltage Vref. The heater voltage Vmh**1** is applied to the heater resistor MH**1** to heat the thermistors Rd**1** and Rd**3**. The heater voltage Vmh**2** is applied to the heater resistor MH**2** to heat the thermistors Rd**2** and Rd**4**. The reference voltage Vref is supplied to the amplifier **11**.

[0033] FIGS. **2** to **4** are schematic plan views for explaining the device structure of the sensor parts S**1** and S**2**. FIG. **2** illustrates a portion corresponding to the heater resistors MH**1** and and MH**2**, FIG. **3** illustrates a portion corresponding to the thermistors Rd**1** to Rd**4**, and FIG. **4** is a superimposed view of FIGS. **2** and **3**.

[0034] As illustrated in FIGS. **2** to **4**, the sensor parts S**1** and S**2** include a substrate **20**, an insulating film **21** formed on the surface of the substrate **20**, the heater resistors MH**1** and MH**2** provided on the insulating film **21**, thermistor films **31** and **33** formed so as to overlap the heater resistor MH**1**, thermistor films **32** and **34** formed so as to overlap the heater resistor MH**2**, a pair of counter electrodes **41** and **42** contacting the thermistor film **31**, a pair of counter electrodes **43** and **44** contacting the thermistor film **32**, a pair of counter electrodes **45** and **46** contacting the thermistor film **33**, and a pair of counter electrodes **47** and **48** contacting the thermistor film **34**. A first portion of the thermistor film **31** that is positioned between the pair of counter electrodes **41** and **42** and the counter electrodes **41** and **42** constitute the thermistor Rd**1**. A first portion of the thermistor film **32** that is positioned between the pair of counter electrodes **43** and **44** and the counter electrodes **43** and **44** constitute the thermistor Rd**2**. A first portion of the thermistor r film **33** that is positioned between the pair of counter electrodes **45** and **46** and the counter electrodes **45** and **46** constitute the thermistor Rd**3**. A first portion of the thermistor film **34** that is positioned between the pair of counter electrodes **47** and **48** and the counter electrodes **47** and **48** constitute the thermistor Rd**4**.

[0035] The substrate **20** is not particularly limited in material as long as it has adequate mechanical strength and is suitable for fine processing such as etching. Examples of the material of the substrate **20** include a silicon single crystal substrate, a sapphire single crystal substrate, a ceramic substrate, a quartz substrate, and a glass substrate. The substrate **20** and insulating film **21** are removed at notches **20**A and **20**B, and cavities are formed Further, the substrate **20** is removed in an area there. surrounded by the notches **20**A and that surrounded by the notches **20**B, and the heater resistors KH**1** and MH**2** and thermistors Rd**1** to Rd**4** are supported by the thin insulating film **21** in these areas. Such a membrane structure can suppress conduction of heat from the heater resistors MH**1** and MH**2** to the substrate **20**.

[0036] The heater resistors MH**1** and MH**2** are each made of a conductive substance and may be made of a metal material having a comparatively high melting point, such as molybdenum (Mo), platinum (Pt), gold (Au), tungsten (W), tantalum (Ta), palladium (Pd), iridium (Ir), nickel (Ni), chrome (Cr), or an alloy containing two or more of them. As illustrated in FIG. **2**, one end of the heater resistor MH**1** is connected to a terminal electrode **51**, and the other end thereof is connected to a terminal electrode **53**. One end of the heater resistor MH**2** is connected to a terminal electrode **52**, and the other end thereof is connected to the terminal electrode **53**. The heater resistors MH**1** and MH**2** may each have a meander shape.

[0037] The thermistor films **31** to **34** are each made of a material having a negative temperature coefficient of resistance, such as a composite metal oxide, amorphous silicon, polysilicon, or germanium. The counter electrodes **41** and **42** contacting the thermistor film **31** are connected to terminal electrodes **54** and **56**, respectively. As a result, the terminal electrodes **54** and **56** are connected to each other through the thermistor film **31** positioned between the counter electrodes **41** and **42**. The counter electrodes **43** and **44** contacting the thermistor film **32** are connected to terminal electrodes **56** and **55**, respectively. As a result, the terminal electrodes **55** and **56** are connected to each other through the thermistor film **32** positioned between the counter electrodes **43** and **44**. The counter electrodes **45** and **46** contacting the thermistor film **33** are connected to terminal electrodes **57** and **59**, respectively. As a result, the terminal electrodes **57** and **59** are connected to each other through the thermistor film **33** positioned between the counter electrodes **45** and **46**. The counter electrodes **47** and **48** contacting the thermistor film **34** are connected to terminal electrodes **59** and **58**, respectively. As a result, the terminal electrodes **58** and **59** are connected to each other through the thermistor film **34** positioned between the counter electrodes **47** and **48**.

[0038] The terminal electrode **54** is connected, through the switch SW**1**, to the line to which the power supply voltage Vcc**1** is supplied. The terminal electrode **55** is connected to the ground line through the switch SW**3**. The terminal electrode **58** is connected, through the switch SW**2**, to the line to which the power supply voltage Vcc**2** is supplied. The terminal electrode **57** is connected to the ground line through the switch SW**4**. The switches SW**1** to SW**4** may constitute a part of the signal processing circuit **10**. The terminal electrode **56** constitutes the node N**1**. The terminal electrode **59** constitutes the node N**2**.

[0039] As illustrated in FIG. **3**, the counter electrodes **41** and **42** (also counter electrodes **47** and **48**) are so shaped as to be engaged with each other in a comb-like shape, while the counter electrodes **43** and **44** (also counter electrodes **45** and **46**) are so shaped as to linearly face each other. As a result, the opposing length between the counter electrodes **41** and **42** (also counter electrodes **47** and **48**) is longer than the opposing length between the counter electrodes **43** and **44** (also counter electrodes and **45** and **46**). Further, the inter-electrode distance (opposing width) between the counter electrodes **41** and **42** (also counter electrodes **47** and **48**) is smaller than the inter-electrode distance (opposing width) between the counter electrodes **43** and **44** (also counter electrodes **45** and **46**). Thus, when the thermistor films **31** to **34** having substantially the same resistivity are heated to substantially the same temperature, the resistance value of the thermistor film **31** positioned between the counter electrodes **41** and **42** and that of the thermistor film **34** positioned between the counter electrodes **47** and **48** become lower than the resistance value of the thermistor film **32** positioned between the counter electrodes **43** and **44** and that of the thermistor film **33** positioned between the counter electrodes **45** and **46**. The reason for this is as follows. As described above, the resistance values of the thermistors Rd**1** and Rd**4** as the temperature-sensitive element for detection are designed to fall within the first resistance range when the thermistors Rd**1** and Rd**4** are heated to about 150° C., while the resistance values of the thermistors Rd**2** and Rd**4** as the temperature-sensitive element for reference are designed to fall within the second resistance range when the thermistors Rd**2** and Rd**3** are heated to about 300° C., so that it is necessary to set the resistance values of the thermistors Rd**1** and Rd**4** lower than the resistance values of the thermistors Rd**2** and Rd**3** under the condition of the same temperature in order to make the first and second resistance ranges overlap or coincide with each other.

[0040] In the example illustrated in FIG. **3**, the thermistor films **31** and **33** are separated from each other, and the thermistor films **32** and **34** are also separated from each other; however, as in the example illustrated in FIG. **5**, it is possible to use a common thermistor film **35** for the counter electrodes **41** and **42** and counter electrodes **45** and **46** and a common thermistor film **36** for the counter electrodes **43** and **44** and counter electrodes **47** and **48**. In this case, a first portion of the thermistor film **35** that is positioned between the pair of counter electrodes **41** and **42** and the counter electrodes **41** and **42** constitute the thermistor Rd**1**, a first portion of the thermistor film **36** that is positioned between the pair of counter electrodes **43** and **44** and the counter electrodes **43** and **44** constitute the thermistor Rd**2**, a second portion of the thermistor film **35** that is positioned between the pair of counter electrodes **45** and **46** and the counter electrodes **45** and **46** constitute the thermistor Rd**3**, and a second portion of the thermistor film **36** that is positioned between the pair of counter electrodes **47** and **48** and the counter electrodes **47** and **48** constitute the thermistor Rd**4**.

[0041] The following describes the operation of the gas sensor **1** according to the first embodiment.

[0042] FIG. **6** is a flowchart for explaining the operation of the gas sensor **1**. FIG. **7** is a timing chart for explaining the operation of the gas sensor **1**.

[0043] The signal processing circuit **10** included in the gas sensor **1** acquires a temperature signal T indicating a temperature in the measuring atmosphere (step **100**) and calculates a correction value based on the temperature signal T (step **101**). The calculated correction value is used for cancelling offsets of the heater voltages Vmh**1** and Vmh**2** and reference voltage Vref due to the temperature in the measuring atmosphere.

[0044] Then, the signal processing circuit **10** performs operation steps in a period T**1**. In the period T**1**, the signal processing circuit **10** outputs the heater voltages that have been corrected based on the Vmh**1** and Vmh**2** correction value (step **102**). In the period T**1**, the heater resistors MH**1** and MH**2** are heated so that the thermistors Rd**1** and Rd**3** become about 150° C. and that the thermistors Rd**2** and Rd**4** become about 300° C. For example, the heater voltages Vmh**1** and Vmh**2** are set so as to heat the thermistors Rd**1** and Rd**3** to 150° C. and heat the thermistors Rd**2** and Rd**4** to 300° C. when the concentration of CO_2 gas in the measuring atmosphere is the same as CO_2 average concentration in the atmosphere. In this state, the signal processing circuit **10** turns on the switches SW**1** and SW**3** and turns off the switches SW**2** and SW**4** (step **103**). As a result, the detection voltage Vgas**1** corresponding to the CO_2 gas concentration in the measuring atmosphere appears at the node N**1**. The detection voltage Vgas**1** is fetched in the signal processing circuit **10** (step **104**), and then the control circuit **14** included in the signal processing circuit **10** calculates a measurement result signal OUT indicating CO_2 gas concentration and externally outputs it (step **105**). The thermistors Rd**3** and Rd**4** are heated in the period T**1**; however, the switches SW**2** and SW**4** are in an off state in the period T**1**, so that the thermistors Rd**3** and Rd**4** have no influence on the detection voltage Vgas**1**.

[0045] Then, the signal processing circuit **10** performs operation steps in a period T**2**. In the period T**2**, the signal processing circuit **10** outputs the heater voltages Vmh**1** and Vmh**2** that have been corrected based on the correction value (step **106**). In the period T**2**, the heater resistors MH**1** and MH**2** are heated so that the thermistors Rd**1** and Rd**3** become about 300° C. and that the thermistors Rd**2** and Rd**4** become about 150° C. For example, the heater voltages Vmh**1** and Vmh**2** are set so as to heat the thermistors Rd**1** and Rd**3** to 300° C. and heat the thermistors Rd**2** and Rd**4** to 150° C. when the concentration of CO_2 gas in the measuring atmosphere is the same as CO_2 average concentration in the atmosphere. In this state, the signal processing circuit **10** turns off the switches SW**1** and SW**3** and turns on the switches SW**2** and SW**4** (step **107**). As a result, the detection voltage Vgas**1** corresponding to the CO_2 gas concentration in the measuring atmosphere appears at the node N**2**. The detection voltage Vgas**1** is fetched in the signal processing circuit **10** (step **108**), and then the control circuit **14** included in the signal processing circuit **10** calculates the measurement result signal OUT indicating CO_2 gas concentration and externally outputs it (step **109**). The thermistors Rd**1** and Rd**2** are heated in the period T**2**; however, the switches SW**1** and SW**3** are in an off state in the period T**2**, so that the thermistors Rd**1** and Rd**2** have no influence on the detection voltage Vgas**1**.

[0046] By repeating the above-described steps **102** to **109**, it is possible to periodically acquire the measurement result signal OUT (step **110**).

[0047] As described above, in the operation of the gas sensor **1** according to the present embodiment, the period T**1** during which the thermistors Rd**1** and Rd**3** are heated to about 150° C. and the thermistors Rd**2** and Rd**4** are heated to about 300° C. and the period T**2** during which the thermistors Rd**1** and Rd**3** are heated to about 300° C. and the thermistors Rd**2** and Rd**4** are heated to about 150° C. are alternately repeated. This makes it possible to acquire the measurement result signal OUT in both the periods T**1** and T**2** while making the thermal histories of the thermistors Rd**1** and Rd**2** coincide with each other and thermal histories of the thermistors Rd**3** and Rd**4** coincide with each other. The periods T**1** and T**2** need not necessarily be alternately repeated; alternatively, a set of operation steps in the period T**1** is performed plural times, and successively a set of operations in the period T**2** is performed plural times.

[0048] FIG. **8** is a flowchart for explaining the operation of the gas sensor **1** according to a modification. The same steps as those in the flowchart of FIG. **6** are denoted by the same step numbers.

[0049] After acquiring the temperature signal T (step **100**) and calculating the correction value (step **101**), the signal processing circuit **10** performs a first round of the period T**1**. The operation steps (steps **202** to **205**) in the first round of the period T**1** are basically the same as steps **102** to **105** described above; however, in step **205**, the measurement result signal OUT is only calculated but is not externally output.

[0050] Then, the signal processing circuit **10** performs operation steps in the period T**2**. The operation steps (steps **106** to **109**) in the period T**2** according to the modification are basically the same as above-described steps **106** to **109**; however, in step S**109** according to the modification, the average value of the measurement result signal OUT calculated in step **205** and measurement result signal OUT calculated in step **109** is externally output.

[0051] Then, the signal processing circuit **10** performs operation steps in the period T**1**. The operation steps in the period T**1** are basically the same as above-described steps **102** to **105**; however, in step **105** according to the modification, the average value of the measurement result signal OUT calculated in step **109** and the measurement result signal OUT calculated in step **105** is externally output.

[0052] As described above, in the example of FIG. **8**, the average value of the measurement result signal OUT acquired in the measurement performed at a certain point of time and the measurement result signal acquired in the immediately preceding measurement is externally output, so that, as illustrated in FIG. **9**A for example, even when there exists a certain offset between the detection voltage Vgas**1** appearing at the node N**1** and the detection voltage Vgas**1** appearing at the node N**2**, the offset does not appear in the measurement result signal OUT to be actually output, as illustrated in FIG. **9**B. Although the moving average of two measurement result signals OUT is output in the above example, it is possible to calculate and output the moving average of three or more measurement result signals OUT (e.g., measurement result signal OUT acquired in the current measurement and measurement result signals OUT acquired in a plurality of immediately preceding measurements).

Second Embodiment

[0053] FIG. **10** is a circuit diagram illustrating the configuration of a gas sensor **2** according to a second embodiment of the technology according to the present disclosure.

[0054] As illustrated in FIG. **10**, the gas sensor **2** according to the second embodiment differs from the gas sensor **1** according to the first embodiment in that the switches SW**3** and SW**4** are omitted with the result that the other ends of the thermistors Rd**2** and Rd**3** are directly connected to the ground lines. Other basic configurations are the same as those of the gas sensor **1** according to the first embodiment, so the same reference numerals are given to the same elements, and overlapping description will be omitted.

[0055] The gas sensor **2** according to the second embodiment performs the same operation content as that of the gas sensor **1** according to the first embodiment except that it does not control the switches SW**3** and SW**4**. That is, the switches SW**3** and SW**4** are absent in the gas sensor **2** according to the second embodiment, so that the node N**2** is connected to the ground line through the thermistor Rd**3** for reference in the period T**1**, and the node N**1** is connected to the ground line through the thermistor Rd**2** for reference in the period T**2**. However, the thermistor Rd**3** is heated to about 150° C. in the period T**1**, and the thermistor Rd**2** is heated to about 150° C. in the period T**2**, while the resistance values of the thermistors Rd**2** and Rd**3** for reference are designed so as to fall within a predetermined resistance range when the thermistors Rd**2** and Rd**3** are heated to about 300° C. Therefore, the resistance values of the thermistors Rd**2** and Rd**3** heated to about 150° C. have a negative temperature coefficient of resistance and thus are sufficiently high, so that the influence of the thermistor Rd**3** in the period T**1** and the influence of the thermistor Rd**2** in the period T**2** become negligeable.

[0056] As described above, owing to the omission of the switches SW**3** and SW**4**, circuit scale can be further simplified in the gas sensor **2** according to the second embodiment.

Third Embodiment

[0057] FIG. **11** is a circuit diagram illustrating the configuration of a gas sensor **3** according to a third embodiment of the technology according to the present disclosure.

[0058] As illustrated in FIG. **11**, in the gas sensor according to the third embodiment, the switches SW**1** to SW**4** are omitted. Accordingly, the other end of the thermistor Rd**1** is directly connected to the line to which the power supply voltage Vcc**1** is supplied, the other ends of the thermistors Rd**2** and Rd**3** are directly connected to their corresponding ground lines, and the other end of the thermistor Rd**4** is directly connected to the line to which the power supply voltage Vcc**2** is supplied. Further, in the gas sensor **3** according to the third embodiment, a switch SW**5** connecting one of the nodes N**1** and N**2** to the amplifier **11** is additionally provided. The switch SW**5** is controlled by the signal processing circuit **10**. When the node N**1** is selected, a detection voltage Vgas**1***a* appearing at the node N**1** is supplied to the amplifier **11** as the detection voltage Vgas**1**, while when the node N**2** is selected, a detection voltage Vgas**1***b* appearing at the node N**2** is supplied to the amplifier **11** as the detection voltage Vgas**1**. The signal processing circuit **10** controls the switch SW**5** to select the node N**1** in the period T**1** and controls the switch SW**5** to select the node N**2** in the period T**2**. Other basic configurations are the same as those of the gas sensor **1** according to the first embodiment, so the same reference numerals are given to the same elements, and overlapping description will be omitted.

[0059] As described above, in the gas sensor **3** according to the third embodiment, the nodes N**1** and N**2** are exclusively connected, through the switch SW**5**, to the amplifier **11** without being short-circuited, thus preventing the detection voltage Vgas**1***a* appearing at the node N**1** and the detection voltage Vgas**1***b* appearing at the node N**2** from influencing each other.

Fourth Embodiment

[0060] FIG. **12** is a circuit diagram illustrating the configuration of a gas sensor **4** according to a fourth embodiment of the technology according to the present disclosure.

[0061] As illustrated in FIG. **12**, in the gas sensor **4** according to the fourth embodiment, the detection voltage Vgas**1***a* appearing at the node N**1** is supplied to an amplifier **11***a*, and the detection voltage Vgas**1***b* appearing at the node N**2** is supplied to an amplifier **11***b*. The amplifier **11***a* is a differential amplifier, for example, and compares the detection voltage Vgas**1***a* and the reference voltage Vref, for example, to generate an amplified detection voltage Vgas**2***a*. The amplifier **11***b* is a differential amplifier, for example, and compares the detection voltage Vgas**1***b* and the reference voltage Vref, for example, to generate an amplified detection voltage Vgas**2***b*. The detection voltages Vgas**2***a* and Vgas**2***b* are input to the AD converter **12**. The AD converter **12** A-D converts the input detection voltages Vgas**2***a* and Vgas**2***b* into digital detection voltages Vgas**2***a* and Vgas**2***b* and supplies the digital detection voltages Vgas**2***a* and Vgas**2***b* to the control circuit **14**. Other basic configurations are the same as those of the gas sensor **3** according to the third embodiment, so the same reference numerals are given to the same elements, and overlapping description will be omitted.

[0062] As described above, in the gas sensor **4** according to the fourth embodiment, the nodes N**1** and N**2** are connected to the different amplifiers **11***a* and **11***b*, respectively, without being short-circuited, thus preventing the detection voltage Vgas**1***a* appearing at the node N**1** and the detection voltage Vgas**1***b* appearing at the node N**2** from influencing each other.

Fifth Embodiment

[0063] FIG. **13** is a circuit diagram illustrating the configuration of a gas sensor **5** according to a fifth embodiment of the technology according to the present disclosure.

[0064] As illustrated in FIG. **13**, the gas sensor **5** according to the fifth embodiment differs from the gas sensor **1** according to the first embodiment in that the switches SW**1** and SW**2** are omitted with the result that the other ends of the thermistors Rd**1** and Rd**4** are directly connected to the lines to which the power supply voltages Vcc**1** and Vcc**2** are supplied, respectively, and that the thermistor films **31** to **34** are each made of a material having a positive temperature coefficient of resistance. Further, as illustrated in FIG. **14**, in the gas sensor **5** according to the fifth embodiment, the counter electrodes **43** and **44** (also counter electrodes **45** and **46**) are so shaped as to be engaged with each other in a comb-like shape, while the counter electrodes **41** and **42** (also counter electrodes **47** and **48**) are so shaped as to linearly face each other. As a result, the opposing length between the counter electrodes **43** and **44** (also counter electrodes **45** and **46**) is longer than the opposing length between the counter electrodes **41** and **42** (also counter electrodes and **47** and **48**). Further, the inter-electrode distance (opposing width) between the counter electrodes **43** and **44** (also counter electrodes **45** and **46**) is smaller than the inter-electrode distance (opposing width) between the counter electrodes **41** and **42** (also counter electrodes **47** and **48**). Thus, when the thermistor films **31** to **34** having substantially the same resistivity are heated to substantially the same temperature, the resistance value of the thermistor film **31** positioned between the counter electrodes **41** and **42** and that of the thermistor film **34** positioned between the counter electrodes **47** and **48** become higher than the resistance value of the thermistor film **32** positioned between the counter electrodes **43** and **44** and that of the thermistor film **33** positioned between the counter electrodes **45** and **46**. Other basic configurations are the same as those of the gas sensor **1** according to the first embodiment, so the same reference numerals are given to the same elements, and overlapping description will be omitted.

[0065] The gas sensor **5** according to the fifth embodiment performs the same operation content as that of the gas sensor **1** according to the first embodiment except that it does not control the switches SW**1** and SW**2**. That is, the switches SW**1** and SW**2** are absent in the gas sensor **5** according to the fifth embodiment, so that the node N**2** is connected, through the thermistor Rd**4** for detection, to the line to which the power voltage Vcc**2** is supplied in the period T**1**, and the node N**1** is connected, through the thermistor Rd**1** for detection, to the line to which the power voltage Vcc**1** is supplied in the period T**2**. However, the thermistor Rd**4** is heated to about 300° C. in the period T**1**, and the thermistor Rd**1** is heated to about 300° C. in the period T**2**, while the resistance values of the thermistors Rd**1** and Rd**4** for detection are designed so as to fall within a predetermined resistance range when the thermistors Rd**1** and Rd**4** are heated to about 150° C. Therefore, the resistance values of the thermistors Rd**1** and Rd**4** heated to about 300° C. have a positive temperature coefficient of resistance and thus are sufficiently high, so that the influence of the thermistor Rd**4** in the period T**1** and the influence of the thermistor Rd**1** in the period T**2** become negligeable.

[0066] As exemplified in the gas sensor **5** according to the fifth embodiment, the thermistor films **31** to **34** may each be made of a material having a positive temperature coefficient of resistance.

[0067] While some embodiments of the technology according to the present disclosure have been described, the technology according to the present disclosure is not limited to the above embodiments, and various modifications may be made within the scope of the present disclosure, and all such modifications are included in the technology according to the present disclosure.

[0068] For example, although a thermistor is used as the temperature-sensitive element, the present invention is not limited to this.

[0069] The technology according to the present disclosure includes the following configuration examples, but not limited thereto.

[0070] A gas sensor according to an aspect of the present disclosure includes: a first series circuit including a first temperature-sensitive element and a second temperature-sensitive element connected in series; a second series circuit including a third temperature-sensitive element and a fourth temperature-sensitive element connected in series; a first power supply circuit configured to apply voltage to the first series circuit; a second power supply circuit configured to apply voltage to the second series circuit; and a signal processing circuit. The signal processing circuit is configured to: detect a first detection voltage appearing at a first node at which the first temperature-sensitive element and the second temperature-sensitive element are connected in a first period during which the first temperature-sensitive element and a third temperature-sensitive element are heated to a first temperature range and the second temperature-sensitive element and the fourth temperature-sensitive element are heated to a second temperature range; detect a second detection voltage appearing at a second node at which the third temperature-sensitive element and the fourth temperature-sensitive element are connected in a second period during which the first temperature-sensitive element and the third temperature-sensitive element are heated to the second temperature range and the second temperature-sensitive e element and the fourth temperature-sensitive element are heated to the first temperature range; and calculate a concentration of a gas to be detected based on the first detection voltage and the second detection voltage. This can make thermal histories of the first and second temperature-sensitive elements coincide with each other, make thermal histories of the third and fourth temperature-sensitive elements coincide with each other, and can achieve measurement of the gas to be detected in both the first and second periods.

[0071] In the above gas sensor, the resistance values of each of the first temperature-sensitive element and the fourth temperature-sensitive element falls within a first resistance range when the first temperature-sensitive element and the fourth temperature-sensitive element are heated to the first temperature range, and the resistance value of each of the second temperature-sensitive element and the third temperature-sensitive element falls within a second resistance range when the second temperature-sensitive element and the third temperature-sensitive element are heated to the second temperature range. This makes it possible to detect the concentration of a non-flammable gas (e.g., CO_2 gas) contained in the atmosphere.

[0072] In this case, the first resistance range and the second resistance range may overlap each other. This can achieve a wide dynamic range.

[0073] The above gas sensor may further include a first heater configured to heat the first temperature-sensitive element and the third temperature-sensitive element in common, and a second heater configured to heat the second temperature-sensitive element and the fourth temperature-sensitive element in common. This makes it possible to heat the first and third temperature-sensitive elements to the same temperature and to heat the second and fourth temperature-sensitive elements to the same temperature.

[0074] In the above gas sensor, the first temperature-sensitive element may include a first portion of a first thermistor film heated by the first heater and a pair of first counter electrodes facing each other through the first portion of the first thermistor film, the second temperature-sensitive element may include a first portion of a second thermistor film heated by the second heater and a pair of second counter electrodes facing each other through the first portion of the second thermistor film, the third temperature-sensitive element may include a first portion of a third thermistor film heated by the first heater and a pair of third counter electrodes facing each other through the first portion of the third thermistor film, and the fourth temperature-sensitive element may include a first portion of a fourth thermistor film heated by the second heater and a pair of fourth counter electrodes facing each other through the first portion of the fourth thermistor film. This can enhance insulation between the first counter electrodes and the third counter electrodes and between the second counter electrodes and the fourth counter electrodes.

[0075] In the above gas sensor, the first temperature-sensitive element may include a first portion of a first thermistor film heated by the first heater and a pair of first counter electrodes facing each other through the first portion of the first thermistor film, the second temperature-sensitive element may include a first portion of a second thermistor film heated by the second heater and a pair of second counter electrodes facing each other through the first portion of the second thermistor film, the third temperature-sensitive element may include a second portion of the first thermistor film and a pair of third counter electrodes facing each other through the second portion of the first thermistor film, and the fourth temperature-sensitive element may include a second portion of the second thermistor film and a pair of fourth counter electrodes facing each other through the second portion of the second thermistor film. This can miniaturize the first to fourth temperature-sensitive elements.

[0076] In the above gas sensor, each of the first to fourth temperature-sensitive elements may have a negative temperature coefficient of resistance, the second temperature range may be higher than the first temperature range, the opposing length between the first counter electrodes may be larger than the opposing length between the second counter electrodes, and the opposing length between the fourth counter electrodes may be larger than the opposing length between the third counter electrodes. This can make the resistance value of the first temperature-sensitive element lower than the resistance value of the second temperature-sensitive element and make the resistance value of the fourth temperature-sensitive element lower than the resistance value of the third temperature-sensitive element.

[0077] In the above gas sensor, each of the first to fourth temperature-sensitive elements may have a negative temperature coefficient of resistance, the second temperature range may be higher than the first temperature range, the inter-electrode distance between the first counter electrodes may be smaller than the inter-electrode distance between the second counter electrodes, and the inter-electrode distance between the fourth counter electrodes may be smaller than the inter-electrode distance between the third counter electrodes. This can make the resistance value of the first temperature-sensitive element lower than the resistance value of the second temperature-sensitive element and make the resistance value of the fourth temperature-sensitive element lower than the resistance value of the third temperature-sensitive element.

[0078] In the above gas sensor, each of the first to fourth temperature-sensitive elements may have a positive temperature coefficient of resistance, the second temperature range may be higher than the first temperature range, the opposing length between the second counter electrodes may be larger than the opposing length between the first counter electrodes, and the opposing length between the third counter electrodes may be larger than the opposing length between the fourth counter electrodes. This can make the resistance value of the second temperature-sensitive element lower than the resistance value of the first temperature-sensitive element and make the resistance value of the third temperature-sensitive element lower than the resistance value of the fourth temperature-sensitive element.

[0079] In the above gas sensor, each of the first to fourth temperature-sensitive elements may have a positive temperature coefficient of resistance, the second temperature range may be higher than the first temperature range, the inter-electrode distance between the second counter electrodes may be smaller than the inter-electrode distance between the first counter electrodes, and the inter-electrode distance between the third counter electrodes may be smaller than the inter-electrode distance between the fourth counter electrodes. This can make the resistance value of the second temperature-sensitive element lower than the resistance value of the first temperature-sensitive element and make the resistance value of the third temperature-sensitive element lower than the resistance value of the fourth temperature-sensitive element.

[0080] In the above gas sensor, each of the first to fourth temperature-sensitive elements may have a negative temperature coefficient of resistance, the second temperature range may be higher than the first temperature range, the first power supply circuit may include a first switch connected between a first power supply line to which a first power supply voltage is supplied or a ground line and the first temperature-sensitive element, and the second power supply circuit may include a second switch connected between a second power supply line to which a second power supply voltage is supplied or a ground line and the fourth temperature-sensitive element. This allows the first temperature-sensitive element to be separated from the first power supply line or ground line and allows the fourth temperature-sensitive element to be separated from the second power supply line or ground line. In this case, the first node and the second node may be short-circuited, and the signal processing circuit may turn on the first switch and turn off the second switch in the first period and may turn off the first switch and turn on the second switch in the second period. This allows the fourth temperature-sensitive element to be separated from the second power supply line or ground line in the first period and allows the first temperature-sensitive element to be separated from the first power supply line or ground line in the second period.

[0081] In the above gas sensor, each of the first to fourth temperature-sensitive elements may have a positive temperature coefficient of resistance, the second temperature range may be higher than the first temperature range, the first power supply circuit may include a first switch connected between a first power supply line to which a first power supply voltage is supplied or a ground line and the second temperature-sensitive element, and the second power supply circuit may include a second switch connected between a second power supply line to which a second power supply voltage is supplied or a ground line and the third temperature-sensitive element. This allows the second temperature-sensitive element to be separated from the first power supply line or ground line and allows the third temperature-sensitive element to be separated from the second power supply line or ground line. In this case, the first node and the second node may be short-circuited, and the signal processing circuit may turn on the first switch and turn off the second switch in the first period and may turn off the first switch and turn on the second switch in the second period. This allows the third temperature-sensitive element to be separated from the second power supply line or ground line in the first period and allows the second temperature-sensitive element to be separated from the first power supply line or ground line in the second period.

[0082] In the above gas sensor, the first power supply circuit may include a first switch connected between one of a first power supply line to which a first power supply voltage is supplied and a ground line and the first temperature-sensitive element and a third switch connected between the other one of the first power supply line and the ground line and the second temperature-sensitive element, and the second power supply circuit may include a second switch connected between one of a second power supply line to which a second power supply voltage is supplied and the ground line and the fourth temperature-sensitive element and a fourth switch connected between the other one of the second power supply line and ground line and the third temperature-sensitive element. This allows the first temperature-sensitive element to be separated from one of the first power supply line and ground line, allows the second temperature-sensitive element to be separated from the other one of the first power supply line and ground line, allows the third temperature-sensitive element to be separated from one of the second power supply line and ground line, and allows the fourth temperature-sensitive element to be separated from the other one of the second power supply line and ground line. In this case, the first node and the second node may be short-circuited and the signal processing circuit may be configured to turn on the first switch and the third switch and turn off the second switch and the fourth switch in the first period and turn off the first switch and the third switch and turn on the second switch and the fourth switch in the second period. Thus, the second node is opened in the first period, and the first node is opened in the second period.

[0083] In the above gas sensor, the signal processing circuit may be configured to calculate the moving average of the concentration of the gas to be detected acquired based on the first detection voltage and the concentration of the gas to be detected acquired based on the second detection voltage. Thus, even when there occurs a certain offset in the first and second detection voltages, the offset can be cancelled.

What is claimed is:

1. A gas sensor comprising:

a first series circuit including a first temperature-sensitive element and a second temperature-sensitive element connected in series;

a second series circuit including a third temperature-sensitive element and a fourth temperature-sensitive element connected in series;

a first power supply circuit configured to apply voltage to the first series circuit;

a second power supply circuit configured to apply voltage to the second series circuit; and

a signal processing circuit configured to:

detect a first detection voltage appearing at a first node at which the first temperature-sensitive element and the second temperature-sensitive element are connected in a first period during which the first temperature-sensitive element and a third temperature-sensitive element are heated to a first temperature range and the second temperature-sensitive element and the fourth temperature-sensitive element are heated to a second temperature range;

detect a second detection voltage appearing at a second node at which the third temperature-sensitive element and the fourth temperature-sensitive element are connected in a second period during which the first temperature-sensitive element and the third temperature-sensitive element are heated to the second temperature range and the second temperature-sensitive element and the fourth temperature-sensitive element are heated to the first temperature range; and

calculate a concentration of a gas to be detected based on the first detection voltage and the second detection voltage.

2. The gas sensor as claimed in claim **1**,

wherein a resistance value of each of the first temperature-sensitive element and the fourth temperature-sensitive element falls within a first resistance range when the first temperature-sensitive element and the fourth temperature-sensitive element are heated to the first temperature range, and

wherein a resistance value of each of the second temperature-sensitive element and the third temperature-sensitive element falls within a second resistance range when the second temperature-sensitive element and the third temperature-sensitive element are heated to the second temperature range.

3. The gas sensor as claimed in claim **2**, wherein the first resistance range and the second resistance range overlap each other.

4. The gas sensor as claimed in claim **1**, further comprising:

a first heater configured to heat the first temperature-sensitive element and the third temperature-sensitive element in common; and

a second heater configured to heat the second temperature-sensitive element and the fourth temperature-sensitive element in common.

5. The gas sensor as claimed in claim **4**,

wherein the first temperature-sensitive element includes a first portion of a first thermistor film heated by the first heater and a pair of first counter electrodes facing each other through the first portion of the first thermistor film,

wherein the second temperature-sensitive element includes a first portion of a second thermistor film heated by the second heater and a pair of second counter electrodes facing each other through the first portion of the second thermistor film,

wherein the third temperature-sensitive element includes a first portion of a third thermistor film heated by the first heater and a pair of third counter electrodes facing each other through the first portion of the third thermistor film, and

wherein the fourth temperature-sensitive element includes a first portion of a fourth thermistor film heated by the second heater and a pair of fourth counter electrodes facing each other through the first portion of the fourth thermistor film.

6. The gas sensor as claimed in claim **4**,

wherein the first temperature-sensitive element includes a first portion of a first thermistor film heated by the first heater and a pair of first counter electrodes facing each other through the first portion of the first thermistor film,

wherein the second temperature-sensitive element includes a first portion of a second thermistor film heated by the second heater and a pair of second counter electrodes facing each other through the first portion of the second thermistor film,

wherein the third temperature-sensitive element includes a second portion of the first thermistor film and a pair of third counter electrodes facing each other through the second portion of the first thermistor film, and

wherein the fourth temperature-sensitive element includes a second portion of the second thermistor film and a pair of fourth counter electrodes facing each other through the second portion of the second thermistor film.

7. The gas sensor as claimed in claim **5**,

wherein each of the first to fourth temperature-sensitive elements has a negative temperature coefficient of resistance,

wherein the second temperature range is higher than the first temperature range,

wherein an opposing length between the first counter electrodes is larger than an opposing length between the second counter electrodes, and

wherein an opposing length between the fourth counter electrodes is larger than an opposing length between the third counter electrodes.

8. The gas sensor as claimed in claim **6**,

wherein each of the first to fourth temperature-sensitive elements has a negative temperature coefficient of resistance,

wherein the second temperature range is higher than the first temperature range,

wherein an opposing length between the first counter electrodes is larger than an opposing length between the second counter electrodes, and

wherein an opposing length between the fourth counter electrodes is larger than an opposing length between the third counter electrodes.

9. The gas sensor as claimed in claim **5**,

wherein each of the first to fourth temperature-sensitive elements has a negative temperature coefficient of resistance,

wherein the second temperature range is higher than the first temperature range,

wherein an inter-electrode distance between the first counter electrodes is smaller inter-electrode distance between the second counter electrodes, and

wherein an inter-electrode distance between the fourth counter electrodes is smaller than an inter-electrode distance between the third counter electrodes.

10. The gas sensor as claimed in claim **6**,

wherein each of the first to fourth temperature-sensitive elements has a negative temperature coefficient of resistance,

wherein the second temperature range is higher than the first temperature range,

wherein an inter-electrode distance between the first counter electrodes is smaller than an inter-electrode distance between the second counter electrodes, and

wherein an inter-electrode distance between the fourth counter electrodes is smaller than an inter-electrode distance between the third counter electrodes.

11. The gas sensor as claimed in claim **5**,

wherein each of the first to fourth temperature-sensitive elements has a positive temperature coefficient of resistance,

wherein the second temperature range is higher than the first temperature range,

wherein an opposing length between the second counter electrodes is larger than an opposing length between the first counter electrodes, and

wherein an opposing length between the third counter electrodes is larger than an opposing length between the fourth counter electrodes.

12. The gas sensor as claimed in claim **6**,

wherein each of the first to fourth temperature-sensitive elements has a positive temperature coefficient of resistance,

wherein the second temperature range is higher than the first temperature range,

wherein an opposing length between the second counter electrodes is larger than an opposing length between the first counter electrodes, and

wherein an opposing length between the third counter electrodes is larger than an opposing length between the fourth counter electrodes.

13. The gas sensor as claimed in claim **5**,

wherein each of the first to fourth temperature-sensitive elements has a positive temperature coefficient of resistance,

wherein the second temperature range is higher than the first temperature range,

wherein an inter-electrode distance between the second counter electrodes is smaller than an inter-electrode distance between the first counter electrodes, and

wherein an inter-electrode distance between the third counter electrodes is smaller than an inter-electrode distance between the fourth counter electrodes.

14. The gas sensor as claimed in claim **6**,

wherein each of the first to fourth temperature-sensitive elements has a positive temperature coefficient of resistance,

wherein the second temperature range is higher than the first temperature range,

wherein an inter-electrode distance between the second counter electrodes is smaller than an inter-electrode distance between the first counter electrodes, and

wherein an inter-electrode distance between the third counter electrodes is smaller than an inter-electrode distance between the fourth counter electrodes.

15. The gas sensor as claimed in claim **1**,

wherein each of the first to fourth temperature-sensitive elements has a negative temperature coefficient of resistance,

wherein the second temperature range is higher than the first temperature range,

wherein the first power supply circuit includes a first switch connected between a first power supply line to which a first power supply voltage is supplied or a ground line and the first temperature-sensitive element, and

wherein the second power supply circuit includes a second switch connected between a second power supply line to which a second power supply voltage is supplied or the ground line and the fourth temperature-sensitive element.

16. The gas sensor as claimed in claim **1**,

wherein each of the first to fourth temperature-sensitive elements has a positive temperature coefficient of resistance,

wherein the second temperature range is higher than the first temperature range,

wherein the first power supply circuit includes a first switch connected between a first power supply line to which a first power supply voltage is supplied or a ground line and the second temperature-sensitive element, and

wherein the second power supply circuit includes a second switch connected between a second power supply line to which a second power supply voltage is supplied or the ground line and the third temperature-sensitive element.

17. The gas sensor as claimed in claim **15**,

wherein the first node and the second node are short-circuited, and

wherein the signal processing circuit is configured to turn on the first switch and turn off the second switch in the first period and turn off the first switch and turn on the second switch in the second period.

18. The gas sensor as claimed in claim **1**,

wherein the first power supply circuit includes:

- a first switch connected between one of a first power supply line to which a first power supply voltage is supplied and a ground line and the first temperature-sensitive element; and
- a third switch connected between other one of the first power supply line and the ground line and the second temperature-sensitive element, and

wherein the second power supply circuit includes:

- a second switch connected between one of a second power supply line to which a second power supply voltage is supplied and the ground line and the fourth temperature-sensitive element; and
- a fourth switch connected between other one of the second power supply line and the ground line and the third temperature-sensitive element.

19. The gas sensor as claimed in claim **18**,

wherein the first node and the second node are short-circuited, and

wherein the signal processing circuit is configured to turn on the first switch and the third switch and turn off the second switch and the fourth switch in the first period and turn off the first switch and the third switch and turn on the second switch and the fourth switch in the second period.

20. The gas sensor as claimed in claim **1**, wherein the signal processing circuit is configured to calculate a moving average of the concentration of the gas to be detected acquired based on the first detection voltage and the concentration of the gas to be detected acquired based on the second detection voltage.

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