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(54) **COMBUSTION CONTROLLING DEVICE AND COMBUSTION SYSTEM**

(57) A determination precision of an abnormality detection element such as an interlock is improved using a combustion controlling device that includes an output circuit that supplies a binary output signal to one contact of an abnormality detection element, an input circuit that generates a binary input signal corresponding to a signal output from another contact of the abnormality detection element, a sampling portion that samples the input signal within a first period and a second period in which the output signal is respectively a first logic level and a second logic level, an abnormality detection element state determining portion that determines the state of the object to be monitored on the basis of a sampling result in the first period, and a circuit failure determining portion that determines whether a failure occurs in the output circuit and the input circuit on the basis of a sampling result in the second period.

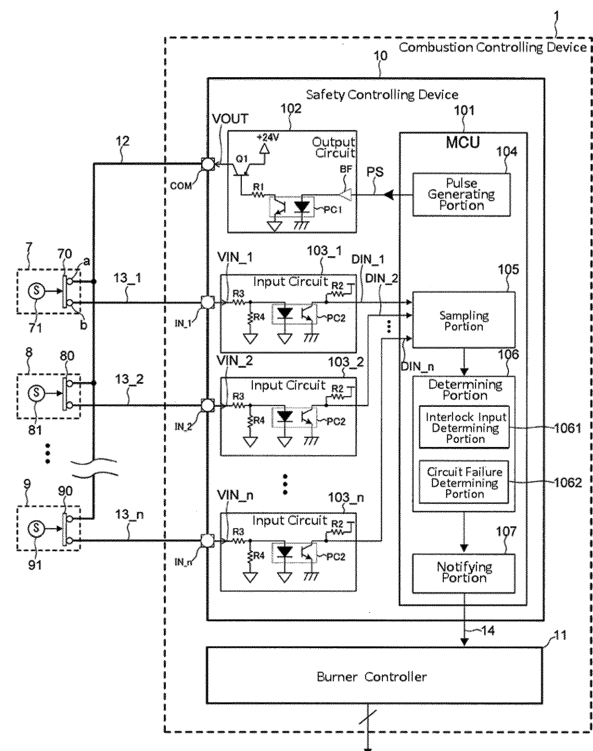


Fig. 2

Description

[Technical Field]

[0001] The present invention relates to a combustion controlling device and a combustion system, and more particularly relates to a combustion controlling device that can perform a safety control of combustion with a high precision.

[Background Art]

[0002] In general, in an operation control system of a combustion furnace, a combustion controlling device performs a combustion control while monitoring a flame of a burner disposed in a combustion furnace, a furnace temperature, a pressure of a combustion air, or a pressure of a fuel to be supplied to the burner, to thereby ensure the safety of combustion. More specifically, the combustion controlling device reflects a state of a gas pressure or an air pressure involved in the safety operation of the combustion furnace on a state of an abnormality detection element, and controls the combustion so as to permit the operation of the combustion furnace only when the state of the abnormality detection element is indicated to be normal (for example, refer to JP 2010-286128 A).

[0003] In this example, the abnormality detection element is structured to put into any one of a short-circuit state and an open state between two contacts according to a state to be monitored, and is generally called, for example, "interlock" or "limit". As the interlock, for example, an air pressure lower limit interlock for monitoring whether a combustion air is supplied, or not, and a gas pressure upper limit interlock and a gas pressure lower limit interlock for monitoring a supply state of the fuel have been known.

[0004] The general interlock includes a switch disposed between the two contacts, and has a structure of switching between on/off states of the switch according to an output of a sensor. The interlock of this type is controlled to turn on the switch to turn to short-circuit the two contacts when an object to be monitored is normal, and to turn off the switch to open the two contacts when the object to be controlled is abnormal.

[0005] In a conventional combustion controlling device, for example, as disclosed in Non-Patent Document 1, a pulse signal is input to one contact of the interlock having the above structure, and the open or the short-circuiting of the interlock is determined according to whether the pulse signal is output from the other contact of the interlock, or not.

[Prior Art Documents]

[Patent Documents]

[0006] [PTL 1] JP-A-2010-286128

[Non-Patent Documents]

[0007] [Non-Patent Document 1] "Development of Controller using Combustion Safety Control Technique", Yuichi KUMAZAWA, Azbil Technical Review, issued in January of 2011, Azbil Corporation

[Summary of the Invention]

10 [Problems to be Solved by the Invention]

[0008] Meanwhile, in the combustion system, there is a need to rapidly stop combustion operation to ensure the safety when abnormality occurs in an operation control system of the combustion furnace. On the other hand, there is a need to realize stable combustion operation when the operation control system of the combustion furnace is normal. For that reason, rapidity and high precision are required for abnormality detection involved in the interlock for safety control. For example, the rapidity of the detection is required for abnormality that leads directly to a serious accident such as explosion of the combustion furnace, as with the abnormality of the object to be monitored (gas pressure or air pressure) caused by the interlock. On the other hand, a high detection precision is required for a failure of a peripheral circuit of the interlock for the purpose of preventing the stop of the combustion operation by erroneous detection.

[0009] However, the conventional technique for determining the interlock described above is to determine the input of the interlock according to whether there is the pulse signal to be input to the combustion controlling device through the interlock, or not. Because the presence or absence of the abnormality in the interlock and the presence or absence of a circuit failure cannot be determined, distinctively, the rapidity of the determination of the object to be determined may be sufficient. However, it is hard to say that a precision of the determination is sufficient.

[0010] For example, in the combustion system having a large combustion furnace such as a steel furnace in a plant or the like, there is a case in which wires for connecting the respective interlocks and the combustion controlling device have hundreds meters, and the combustion system is liable to be affected by strong noise from a power source or an inverter in close proximity to the wire due to an increase in a parasitic impedance component of the wire. In addition, because there are many cases in which multiple wires are bundled and laid, when a pulse signal is propagated to one wire, the pulse signal is induced to another wire, and the induced pulse signal may become a noise component. When such noise is propagated to the wire, it is hardly say to obtain a sufficient determination precision in the conventional technique for determining the interlock.

[0011] An object of the present invention is to improve a determination precision of an abnormality detection element such as an interlock in a combustion control.

[Means for Solving the Problems]

[0012] A combustion controlling device (1, 10) according to the present invention includes: an output circuit (102) that supplies a binary output signal (VOUT) to one of two contacts of an abnormality detection element (6 to 9) that puts into any one of a short-circuit state and an open state between the two contacts according to a state of an object to be monitored; an input circuit (103_1 to 103_n) that receives a signal output from the other contact of the abnormality detection element to which the output signal is supplied, and generates a binary input signal (DIN_1 to DIN_n) corresponding to a logic level of the input signal; a sampling portion (105) that samples the input signal within a first period (T1) in which the output signal is a first logic level (H), and samples the input signal within a second period (T2) in which the output signal is a second logic level (L); an abnormality detection element state determining portion (1061) that determines the state of the object to be monitored by the abnormality detection element on the basis of a sampling result in the first period by the sampling portion; and a circuit failure determining portion (1062) that determines whether a failure occurs in the output circuit and the input circuit, or not, on the basis of a sampling result in the second period by the sampling portion.

[0013] In the above combustion controlling device, the abnormality detection element state determining portion may determine that the object to be monitored by the abnormality detection element is normal when it is detected that the logic level of the signal (VIN_1 to VIN_n) input to the input circuit in the first period is the first logic level N times in a row with reference to sampling values in the first period for successive N (N is an integer of two or more) times, and determine that the object to be monitored by the abnormality detection element is abnormal when it is detected that the logic level of the signal input to the input circuit in the first period is the second logic level N times in a row.

[0014] In the above combustion controlling device, the circuit failure determining portion may determine that at least one of the output circuit and the input circuit fails when it is detected that the logic level of the signal input to the input circuit in the second period is the second logic level M times in a row with reference to sampling values in the second period for successive M (M is an integer of two or more) times.

[0015] In the above combustion controlling device, $M \geq N$ may be satisfied. M and N are arbitrary.

[0016] In the above combustion controlling device, the sampling portion may perform sampling in the first period after a first time period (Td1) elapses since the output signal switches from the second logic level to the first logic level.

[0017] In the above combustion controlling device, the sampling portion may perform sampling in the second period after a second time period (Td2) elapses since the output signal switches from the first logic level to the

second logic level.

[0018] In the above combustion controlling device, the first time period may be set to be less than the second time period. The first time period and the second time period are arbitrary.

[0019] In the above combustion controlling device, multiple sets of function blocks (110) including the sampling portion, the abnormality detection element state determining portion, and the circuit failure determining portion are provided, and the respective function blocks are configured by multiple different program processing devices (101 a, 101b), individually.

[0020] In the above combustion controlling device, a controlling portion (11) that controls the operation of a burner (43) on the basis of determination results of the abnormality detection element state determining portion and the circuit failure determining portion may be further provided.

[0021] A combustion system (500) according to the present invention includes the combustion controlling device (1); and the burner that is disposed in a combustion chamber (40) and controlled by the combustion controlling device.

[0022] In the above description, as an example, components on the drawings corresponding to components of the present invention are represented by reference numerals in parentheses.

[Advantage of the Invention]

[0023] As described above, according to the present invention, a determination precision of the abnormality detection element such as an interlock can be improved in a combustion control.

[Brief Description of the Drawings]

[0024]

[FIG. 1] FIG. 1 is a diagram illustrating a configuration of a combustion system having a combustion controlling device according to an embodiment.

[FIG. 2] FIG. 2 is a diagram illustrating a configuration of a safety controlling device in the combustion controlling device according to the embodiment.

[FIG. 3] FIG. 3 is a timing chart for illustrating a determination process involved in an interlock by the combustion controlling device according to the embodiment.

[FIG. 4] FIG. 4 is a flowchart illustrating a flow of the determination process involved in the interlock by the combustion controlling device according to the embodiment.

[FIG. 5] FIG. 5 is a flowchart illustrating a flow of an interlock input determination process by the combustion controlling device according to the embodiment.

[FIG. 6] FIG. 6 is a flowchart illustrating a flow of a

circuit failure determination process by the combustion controlling device according to the embodiment. [FIG. 7] FIG. 7 is a diagram illustrating a configuration example when the safety controlling device is realized by multiple microcontrollers in the combustion controlling device according to the embodiment.

[Mode for Carrying Out the Invention]

[0025] Embodiments of the invention will be described below with reference to the drawings.

(Configuration of Combustion System)

[0026] FIG. 1 is a diagram illustrating a configuration of a combustion system having a combustion controlling device according to the present embodiment.

[0027] A combustion system 500 illustrated in the figure is a system that allows a combustion in a combustion chamber by a burner. The combustion system 500 can be exemplified by small industrial combustion furnaces such as a deodorizing furnace or a heating furnace, or large industrial combustion furnaces such as a steel furnace in a plant.

[0028] Specifically, the combustion system 500 includes a combustion device 4, a fuel flow channel 2, an air flow channel 3, a controller 5, an excessive temperature rise limit 6 as an abnormality detection element, interlocks 7 to 9, and a combustion controlling device 1.

[0029] The combustion device 4 includes temperature sensors 41 and 42, a main burner 43, a pilot burner 44, a flame detector 45, and an ignition device (igniter) 46. The main burner 43 is disposed in a combustion chamber 40 to heat the combustion chamber 40. The pilot burner 44 is a burner for igniting the main burner 43. The ignition device (IG) 46 is a device for igniting the burner, includes, for example, an ignition transformer and an electrode rod, and generates a spark of high voltage by the ignition transformer to ignite the pilot burner 44 through the electrode rod. The flame detector 45 is a device for detecting whether a flame from the main burner 43 is present, or not. The temperature sensor 41 is a sensor for detecting a temperature in the combustion chamber 40, and a temperature measured value from the sensor is used for a control of the temperature in the combustion chamber 40. The temperature sensor 42 is a sensor for detecting a temperature in the combustion chamber 40, and a temperature measured value from the sensor is used for detection of an abnormally high temperature state in the combustion chamber 40.

[0030] The fuel flow channel 2 is a flow channel for supplying a fuel to the combustion device 4. The fuel flow channel 2 includes a main flow channel 2a to which the fuel is supplied from an external, and a first flow channel 2b and a second flow channel 2c branched from the main flow channel 2a. The first flow channel 2b is connected to the main burner 43, and the second flow channel 2c is connected to the pilot burner 44. Accordingly, the fuel

supplied to the main flow channel 2a is delivered to the main burner 43 and the pilot burner 44. Safety shutoff valves 21 and 22 are disposed in the first flow channel 2b, and safety shutoff valves 23 and 24 are disposed in the second flow channel 2c. The opening and closing of the safety shutoff valves 21 to 24 are controlled by, for example, a burner controller 11.

[0031] The air flow channel 3 has one end connected to a blower 31 and the other end connected to the first flow channel 2b, and supplies an air discharged from the blower 31 to the main burner 43 through the first flow channel 2b together with the fuel (gas).

[0032] The controller 5 is a temperature indicating controller (TIC), and generates a control signal to the combustion controlling device 1 on the basis of the temperature measured value of the temperature sensor 41 so that the temperature in the combustion chamber 40 reaches a target temperature.

[0033] The excessive temperature rise limit 6 is an overheat protector for detecting an abnormally high temperature of the combustion chamber 40. The excessive temperature rise limit 6 includes two contacts, a switch 60 disposed between those contacts, a switch driving portion 61 that determines whether the temperature measured value from the temperature sensor 42 exceeds a predetermined setting temperature, or not, and controls the on and off operation of the switch 60 according to a determination result. For example, the switch driving portion 61 turns on the switch 60 if the temperature measured value from the temperature sensor 42 exceeds the set temperature, and turns off the switch 60 if the temperature measured value from the temperature sensor 42 does not exceed the setting temperature.

[0034] The interlock (air pressure switch) 7 is an air pressure lower limit interlock that is disposed in the air flow channel 3, and detects whether a pressure of the air to be supplied to the air flow channel 3 exceeds a predetermined set pressure value, or not. Specifically, the interlock 7 includes the two contacts, a switch 70 that is disposed between those contacts, and a switch driving portion 71 that determines whether the air pressure in the air flow channel 3 which is detected by the sensor exceeds a predetermined set pressure value, or not, and controls the on and off operation of the switch 70 according to the determination result. For example, the switch driving portion 71 turns on the switch 70 if the air pressure in the air flow channel 3 exceeds the set pressure value, and turns off the switch 70 if the air pressure in the air flow channel 3 does not exceed the set pressure value.

[0035] The interlock (gas pressure switch) 8 is a gas pressure lower limit interlock that is disposed in the main flow channel 2a, and detects whether a pressure of a fuel (gas) to be supplied to the main flow channel 2a exceeds a predetermined lower limit pressure value, or not. Specifically, the interlock 8 includes the two contacts, a switch 80 that is disposed between those contacts, and a switch driving portion 81 that determines whether the gas pressure in the main flow channel 2a which is detected by

the sensor exceeds a lower limit pressure value, or not, and controls the on and off operation of the switch 80 according to the determination result. For example, the switch driving portion 81 turns on the switch 80 if the gas pressure in the main flow channel 2a exceeds the lower limit pressure value, and turns off the switch 80 if the gas pressure in the main flow channel 2a does not exceed the lower limit pressure value.

[0036] The interlock (gas pressure switch) 9 is a gas pressure upper limit interlock that is disposed in the first flow channel 2b, and detects whether a pressure of a fuel (gas) to be supplied to the main burner 43 exceeds a predetermined upper limit pressure value, or not. Specifically, the interlock 9 includes the two contacts, a switch 90 that is disposed between those contacts, and a switch driving portion 91 that determines whether the gas pressure in the first flow channel 2b which is detected by the sensor exceeds an upper limit pressure value, or not, and controls the on and off operation of the switch 90 according to the determination result. For example, the switch driving portion 91 turns on the switch 90 if the gas pressure in the first flow channel 2b does not exceed the upper limit pressure value, and turns off the switch 90 if the gas pressure in the first flow channel 2b exceeds the upper limit pressure value.

[0037] In the following description, the interlocks 7 to 9 and the excessive temperature rise limit 6 as the abnormality detection element having a structure in which the short-circuit and the open between the two contacts are controlled according to a state of an object to be monitored may be collectively referred to as "limit interlock".

(Configuration of Combustion Controlling Device)

[0038] The combustion controlling device 1 is a device for safely controlling combustion in the combustion chamber 40 by the burner. As illustrated in FIG. 1, the combustion controlling device 1 includes a burner controller 11 and a safety controlling device 10.

[0039] The burner controller 11 controls the operation of the burners (the main burner 43 and the pilot burner 44) to control the combustion in the combustion chamber 40. Specifically, the burner controller 11 controls the opening and closing of the safety shutoff valves 21 to 24 and a start of the ignition device 46 on the basis of a command (notification signal 14) from the safety controlling device 10 to be described later, a control signal from the controller 5, and a flame detection signal from the flame detector 45, to thereby ignite the main burner 43 according to a set ignition sequence.

[0040] FIG. 1 illustrates a case in which the combustion system 500 is provided with one main burner 43. Alternatively, when the combustion system is provided with multiple main burners, the multiple burner controllers for controlling the corresponding main burners are provided for the respective main burners, and those burner controllers are controlled by the single safety controlling device 10.

[0041] The safety controlling device 10 is a device for monitoring states of the respective limit interlocks, and determining the permission or non-permission of the operation of the burners for the purpose of performing the safe operation of the combustion system 500, in other words, preventing the explosion of the combustion system 500. Specifically, the safety controlling device 10 generates the notification signal 14 indicative of the permission or non-permission of the operation of the burners according to a state (open or short-circuit) of the contacts in the interlocks 7 to 9 and the excessive temperature rise limit 6, and supplies the notification signal 14 to the burner controller 11, thereby giving an instruction on the permission or non-permission of the operation of the burners (supply and stop of the fuel to the respective burners).

[0042] The safety controlling device 10 can be exemplified by a limit interlock module for monitoring a limit interlock manufactured on the basis of safety general rules (for example, JIS B 8415, etc.) of industrial combustion furnaces, or a programmable logic controller (so-called safety PLC) that configures a dedicated software complying with the safety general rules.

[0043] The safety controlling device 10 supplies a pulse signal to one contact of each limit interlock, and determines a logic level of a signal output from the other contact of each limit interlock, to thereby determine a state of each limit interlock.

[0044] Specifically, the safety controlling device 10 performs an interlock input determination process for determining the state of each limit interlock on the basis of the logic level of the input signal from each limit interlock in a period where the pulse signal is a first logic level. In addition, the safety controlling device 10 performs a circuit failure determination process for determining a failure in an output circuit 102 and an input circuit 103 which will be described later on the basis of the logic level of the input signal from each limit interlock in a period where the pulse signal is a second logic level.

[0045] Hereinafter, a configuration and operation of the safety controlling device 10 will be described in detail.

[0046] In the present specification, as an example, a description will be made assuming that the first logic level is "high (H) level", and the second logic level is "low (L) level".

(Configuration of Safety Controlling Device)

[0047] FIG. 2 is a diagram illustrating a configuration of the safety controlling device 10 in the combustion controlling device 1 according to the embodiment.

[0048] As illustrated in FIG. 2, the safety controlling device 10 includes multiple external terminals, a microcontroller (MCU) 101, an output circuit 102, and n-number (n is an integer of 1 or more) of input circuits 103_1 to 103_n. Meanwhile, in FIG. 2, only terminals COM and IN_1 to IN_n involved in a state monitoring of the limit interlocks are illustrated as the multiple external

terminals.

[0049] The terminal COM is an external terminal for outputting an output signal VOUT to be described later, and is connected commonly to one ends (one contacts) of the switches configuring the respective limit interlocks. For example, as illustrated in FIG. 2, the terminal COM is connected through a wire 12 to one contact "a" of the switch 70 in the interlock 7, one contact "a" of the switch 80 in the interlock 8, ..., and one contact "a" of the switch 90 in the interlock 9. Although not shown, one contact of the switch 60 in the excessive temperature rise limit 6 is connected with the terminal COM.

[0050] The terminals IN₁ to IN_n are external terminals that are disposed in correspondence with the respective limit interlocks, for receiving signals from the respective limit interlocks. For example, as illustrated in FIG. 2, the terminal IN₁ is connected to the other contact "b" of the switch 70 in the interlock 7 by a wire 13₁, the terminal IN₂ is connected to the other contact "b" of the switch 80 in the interlock 8 by a wire 13₂, ..., and the terminal IN_n is connected to the other contact "b" of the switch 90 in the interlock 9 by a wire 13_n. Although not shown, the other contact of the switch 60 in the excessive temperature rise limit 6 is connected to a corresponding input terminal.

[0051] The output circuit 102 is a circuit for generating a binary output signal VOUT to be supplied to the respective limit interlocks. Specifically, the output circuit 102 generates the binary output signal VOUT synchronous with a reference pulse signal PS generated by a pulse generating portion 104 which will be described later, and outputs the output signal VOUT to the terminal COM.

[0052] Specifically, for example, as illustrated in FIG. 2, the output circuit 102 includes a buffer circuit BF, a photocoupler PC1, a resistor R1, and a PNP transistor Q1. The output circuit 102 electrically insulates the external terminal COM and the MCU 101 from each other, and converts the pulse signal of, for example, 0 - 3.3 V (or 5.0 V) output from the MCU 101 into the binary output signal VOUT of, for example, 0 V - 24 V to output the output signal to the terminal COM. For example, when the reference pulse signal PS output from the MCU 101 is H (for example, 3.3V), the transistor Q1 is turned on to output the output signal VOUT of +24V. When the reference pulse signal PS output from the MCU 101 is L (for example, 0 V), the transistor Q1 is turned off. In that case, if the contacts of a destination limit interlock are short-circuited, the output signal VOUT becomes 0 V by pull-down resistors R3 and R4 of each input circuit 103 which will be described later. On the other hand, if the contacts of the destination limit interlock are opened, the terminal COM becomes high impedance.

[0053] The input circuits 103₁ to 103_n are disposed in correspondence with the respective limit interlocks. The input circuits 103₁ to 103_n (collectively referred to as "input circuits 103") receive signals VIN₁ to VIN_n (collectively referred to as "signals VIN") output to the respective terminals IN₁ to IN_n (collectively referred

to as "terminals IN") from the respective limit interlocks, and generate binary input signals DIN₁ to DIN_n (collectively referred to as "input signals DIN") corresponding to the logic levels of the input signals VIN. For example, FIG. 2 illustrates the input circuit 103₁ to which the signal VIN₁ output from the other contact "b" of the switch 70 in the interlock 7 is input through the terminal IN₁, the input circuit 103₂ to which the signal VIN₂ output from the other contact "b" of the switch 80 in the interlock 8 is input through the terminal IN₂, and the input circuit 103_n to which the signal VIN_n output from the other contact "b" of the switch 90 in the interlock 9 is input through the terminal IN_n. Meanwhile, although not shown, a signal output from the other contact of the switch 60 in the excessive temperature rise limit 6 is input to the corresponding input circuit.

[0054] Specifically, for example, as illustrated in FIG. 2, each of the input circuits 103 includes resistors R2 to R4 and a photocoupler PC2. Each of the input circuits 103 electrically insulates the corresponding terminal IN and the MCU 101 from each other, and converts a binary signal of, for example, 0 - 24V input to the corresponding terminal IN into the input signals DIN of, for example, 0 V - 3.3 V (or 5.0 V) to output the input signal IN to the MCU 101. In this example, resistance values of the resistors R3 and R4 are adjusted to turn on a photodiode on a primary side of the photocoupler PC2 when the output signal VOUT of H level (for example, 24V) is output in a state where the contacts of each limit interlock are short-circuited.

[0055] The MCU 101 includes, for example, a processor such as a CPU, various memories, and the other peripheral circuits. The MCU 101 allows the above processor to execute data processing according to programs stored in the above memories, to thereby function as the pulse generating portion 104, a sampling portion 105, a determining portion 106, and a notifying portion 107.

[0056] The pulse generating portion 104 is a function portion for generating the reference pulse signal PS used for monitoring the states of the interlocks 7 to 9 and the excessive temperature rise limit 6. Specifically, the pulse generating portion 104 is a function portion that, for example, divides a reference clock signal generated by a clock generator such as a crystal oscillator to generate the reference pulse signal PS having a predetermined period and a predetermined duty ratio. The reference pulse signal PS is, for example, a binary signal of 0 V - 3.3V (5.0 V) generated on the basis of a power supply voltage (for example, 3.3V or 5.0 V) of the MCU 101.

[0057] The sampling portion 105 is a function portion for sampling the respective input signals DIN₁ to DIN_n generated by the input circuits 103₁ to 103_n. The sampling portion 105 performs a sampling process in synchronization with the reference clock signal generated by the pulse generating portion 104. Specifically, the sampling portion 105 samples the input signals DIN in a period T1 where the output signal VOUT (the above reference pulse signal PS) is the first logic level (H level),

and samples the input signals DIN in a period T2 where the output signal VOUT (the above reference pulse signal PS) is the second logic level (L level). The sampling of the respective input signals DIN_1 to DIN_n may be performed by the sampling portion 105 in time division, or the plural input signals may be sampled at the same time.

[0058] The determining portion 106 includes an interlock input determining portion 1061 as an abnormality detection element state determining portion for determining whether there is an abnormality in the respective limit interlocks, or not, on the basis of a sampling result by the sampling portion 105 in the period T1. In addition, the determining portion 106 includes a circuit failure determining portion 1062 for determining whether there is a failure in the output circuit 102 and the input circuits 103, or not, on the basis of a sampling result by the sampling portion 105 in the period T2.

[0059] The notifying portion 107 generates the above-mentioned notification signal 14 indicative of the permission and the non-permission of the operation of the burners on the basis of the determination result from the determining portion 106.

[0060] For example, if it is determined by the interlock input determining portion 1061 that the limit interlock is "normal", the notifying portion 107 generates the notification signal 14 indicative of the "permission" of the operation of the burners. If it is determined by the circuit failure determining portion 1062 that "there is no failure in the circuit", the notifying portion 107 generates the notification signal 14 indicative of the "permission" of the operation of the burners. On the other hand, if it is determined by the interlock input determining portion 1061 that the limit interlock is "abnormal", the notifying portion 107 generates the notification signal 14 indicative of the "non-permission" of the operation of the burners. If it is determined by the circuit failure determining portion 1062 that "there is a failure in the circuit", the notifying portion 107 generates the notification signal 14 indicative of the "non-permission" of the operation of the burners.

(Operation of Safety Controlling Device)

[0061] Subsequently, a description will be given of a determination process (interlock input determination process and circuit failure determination process) involved in the interlock by the combustion controlling device 1 in detail.

[0062] Meanwhile, in the combustion controlling device 1 according to the present embodiment, because the same determination process is performed on the respective limit interlocks, the determination process involved in the interlock 7 will be typically described below, and a description of the determination processes involved in the other limit interlocks will be omitted.

[0063] FIG. 3 is a timing chart for illustrating the determination process involved in the interlock by the combustion controlling device according to the embodiment. A top of FIG. 3 indicates the voltage (output signal VOUT)

of the terminal COM, a second stage from the top in the figure indicates a state (short-circuit or open) of the contacts in the interlock 7, a third stage from the top of the figure indicates a voltage (signal VIN_1 input to the input circuit 103_1) of the terminal IN_1, and a bottom of the figure indicates the input signal DIN_1 generated by the input circuit 103_1.

[0064] If a waveform on the second stage from the top of the figure is high level, the waveform represents that the switch 70 turns on, and the contacts "a" and "b" of the interlock 7 are short-circuited, and if the waveform illustrated in the figure is low level, the waveform represents that the switch 70 turns off, and the contacts "a" and "b" of the interlock 7 are opened.

[0065] As illustrated in FIG. 3, when the pulse generating portion 104 generates the reference pulse signal PS of a given cycle TC, the output signal VOUT synchronous with the reference pulse signal PS is output from the terminal COM. In this example, it is assumed that the logic level of the above reference pulse signal PS matches the logic level of the output signal VOUT.

[0066] When the output signal VOUT is output from the terminal COM, if the switch 70 of the interlock 7 is on (contacts are short-circuited), the output signal VOUT is input to the input circuit 103_1 through the switch 70. In this case, for example, as indicated in a period from a time t0 to a time t1 in FIG. 3, the signal VIN_1 synchronous with the output signal VOUT is input to the terminal IN_1, and the input signal DIN_1 of the logic opposite to that of the output signal VOUT is generated by the input circuit 103_1.

[0067] On the other hand, when the output signal VOUT is output from the terminal COM, if the contacts of the interlock 7 are opened (switch 70 is off), the output signal VOUT is not input to the input circuit 103_1. In this situation, since the terminal IN_1 is pulled down to the ground voltage (0 V) by the resistors R3 and R4, the voltage (signal VIN_1) of the terminal IN_1 becomes "0 V", and the input signal DIN_1 becomes "H level". For example, as indicated in a period from the time t1 to a time t2 in FIG. 3, if the contacts of the interlock 7 are opened, the input signal DIN_1 becomes "H level" regardless of the logic level of the output signal VOUT.

[0068] In addition, in the state where the contacts of the interlock 7 are short-circuited, for example, if the transistor Q1 of the output circuit 102 is subjected to a short circuit fault, or if a secondary side phototransistor of the photocoupler PC2 in the input circuit 103_1 is subjected to a ground fault, the input signal DIN_1 is fixed to "L level". For example, FIG. 3 illustrates a case in which the secondary side phototransistor of the photocoupler PC2 in the input circuit 103_1 is subjected to the ground fault at a time t3, and the input signal DIN_n after the time t3 is fixed to L level.

[0069] Subsequently, the sampling process by the sampling portion 105 will be described.

[0070] The sampling portion 105 samples the input signal DIN_1 in the period T1 where the output voltage

VOUT (reference clock signal) is "H level". For example, as illustrated in FIG. 3, the input signal DIN_1 is sampled in the respective periods T1 in such a manner that the input signal DIN_1 is sampled (sampling value: L) in a sampling timing SI1 in a first period T1, and the input signal DIN_1 is sampled (sampling value: L) in a sampling timing SI2 in a second period T1, and so on.

[0071] The sampling portion 105 samples the input signal DIN_1 in the period T2 where the output voltage VOUT (reference clock signal) is "L level". For example, as illustrated in FIG. 3, the input signal DIN_1 in the respective periods T2 is sampled in such a manner that the input signal DIN_1 is sampled (sampling value: H) in a sampling timing SC1 in a first period T2, and the input signal DIN_1 is sampled (sampling value: H) in a sampling timing SC2 in a second period T2, and so on.

[0072] It is desirable that the above-mentioned sampling by the sampling portion 105 is performed after a predetermined time elapses since the logic level of the output voltage VOUT (reference clock signal) has switched to another. For example, as illustrated in FIG. 3, it is desirable that the sampling in the period T1 is performed in a period Ts1 after a predetermined time td1 has elapsed since the output voltage VOUT (reference clock signal) switches from "L level" to "H level". Also, it is desirable that the sampling in the period T2 is performed in a period Ts2 after a predetermined time td2 has elapsed since the output voltage VOUT (reference clock signal) switches from "H level" to "L level". For example, a delay circuit (a CR circuit, a multistage logic circuit, etc.) for delaying and outputting the output voltage VOUT or the reference clock signal may be provided, and the sampling portion 105 may start the sampling process with the signal output from the delay circuit as a start signal. Alternatively, a timer that counts a time with a changeover of the logic of the output voltage VOUT or the reference clock signal as a trigger, and outputs a signal upon counting a predetermined time may be provided in advance, and the sampling portion 105 may start the sampling process with the signal output from the timer as the start signal.

[0073] According to the above configuration, as described above, even if the wires 12 and 13 that connect the safety controlling device 10 and the respective limit interlocks are longer, and the parasitic impedance component is larger, since the sampling can be performed after the voltage of the input signals DIN has been stabilized, a reduction in the precision of the determination involved in the interlock is suppressed.

[0074] Waiting times Td1 and Td2 since the logic level of the output signal VOUT switches to another until the sampling starts may be appropriately set taking a transition time until a signal caused by the parasitic impedance component of the wires 12 and 13 is stabilized into account. For example, with the condition of $Td1 < Td2$, the presence or absence of the abnormality of an object to be monitored by the interlock is rapidly detected while a circuit failure that is a permanent failure can be deter-

mined with a higher precision by performing sampling after the signal propagating through the wire is more stabilized.

[0075] The sampling of one input signal DIN in the period T1 and the period T2 may be performed only once in the periods T1 and T2, or may be performed plural times in the periods T1 and T2.

[0076] Subsequently, the interlock input determination process by the interlock input determining portion 1061 will be described.

[0077] If the sampling values of the input signal DIN in the period T1 by the sampling portion 105 match each other N times (N is an integer of 2 or more) in a row, the interlock input determining portion 1061 determines whether the object to be monitored by the limit interlock is "normal" or "abnormal" according to the matched logic level.

[0078] More specifically, the interlock input determining portion 1061 counts the number of times that the sampling values of the input signal DIN in the period T1 match each other in a row, and when the counted number of matches becomes N times, the interlock input determining portion 1061 determines the sampling value matched at that time as a determined value of the logic level of the input signals DIN. For example, referring to FIG. 3, when the sampling values of the input signal DIN_1 at N number of successive sampling timings SI1 to SIN match each other at the "L level", the interlock input determining portion 1061 determines the logic level of the input signal DIN_1 as "L". When the sampling values of the input signal DIN_1 at N number of successive sampling timings SI1 to SIN match each other at the "H level", the interlock input determining portion 1061 determines the logic level of the input signal DIN_1 as "H". The interlock input determining portion 1061 determines that both contacts of the limit interlock corresponding to the input signal DIN are "opened", that is, the object to be monitored by the limit interlock corresponding to the input signal DIN is "abnormal" if the determined value is "H level". On the other hand, if the determined value is "L level", the interlock input determining portion 1061 determines that both contacts of the limit interlock corresponding to the input signal DIN are "short-circuited", that is, the object to be monitored by the limit interlock corresponding to the input signal DIN is "normal".

[0079] Subsequently, the circuit failure determination process by the circuit failure determining portion 1062 will be described.

[0080] If the sampling values of the input signal DIN in the period T2 become "L level" M (M is an integer of 2 or more) times in a row, the circuit failure determining portion 1062 determines that at least one of the input circuits 103 and the output circuit 102 "fails". More specifically, the circuit failure determining portion 1062 counts the number of times that the sampling values of the input signal DIN in the period T2 become "L level" in a row, and if the number of times becomes "M", the circuit failure determining portion 1062 determines that at least one of

the input circuits 103 and the output circuit 102 "fails".

[0081] For example, as illustrated in FIG. 3, if the ground fault occurs on the secondary side of the photo-coupler PC2 in the input circuit 103_1 at the time t3, the input signal DIN_1 after the ground fault occurs is fixed to "L level" regardless of the signal VIN_1. In that case, the circuit failure determining portion 1062 determines that at least one of the input circuits 103 and the output circuit 102 "fails" if the number of times that the sampling values of the input signal DIN in the period T2 after the time t3 become "L level" in a row becomes "M".

[0082] The number of matches N of the sampling values used for the interlock input determination process and the number of matches M of the sampling values used for the circuit failure determination process can be adjusted according to the type of the combustion system to which the combustion controlling device 1 is applied or a required safety level. For example, with the condition of $N < M$, the presence or absence of the abnormality of the object to be monitored by the interlock is rapidly detected while the combustion operation can be prevented from frequently stopping due to an erroneous detection caused by noise in the circuit failure that is a permanent failure.

[0083] Subsequently, a flow of the determination process involved in the interlock by the combustion controlling device will be described.

FIG. 4 is a flowchart illustrating a flow of the determination process involved in the interlock by the combustion controlling device according to the embodiment.

[0084] As described above, the determination process involved in the interlock by the combustion controlling device 1 includes the determination process (interlock input determination process) based on the sampling value in the period T1 and the determination process (circuit failure determination process) based on the sampling value in the period T2.

[0085] As illustrated in FIG. 4, when the determination process involved in the interlock by the combustion controlling device 1 starts, first, the pulse generating portion 104 generates a reference pulse signal PS, and the output circuit 102 generates the output signal VOUT synchronous with the reference pulse signal PS (S1). In this example, a timing at which the determination process involved in the interlock is executed is set for each of the limit interlocks. For example, the determination process of a part of the limit interlocks is always performed after the combustion system 500 starts, and the determination process of the other limit interlocks is performed at a predetermined timing after the combustion system 500 starts.

[0086] Then, the sampling portion 105 starts the sampling of the input signals DIN_1 to DIN_n (S2). When the sampling is started by the sampling portion 105, the determination process based on the sampling values in the period T1, that is, the interlock input determination process is started by the interlock input determining portion 1061 (S3). Also, the determination process based on the

sampling values in the period T2, that is, the circuit failure determination process is started by the circuit failure determining portion 1062 (S4). When the respective determination processes in Steps S3 and S4 are executed, the notification signal 14 indicative of the permission or the non-permission of the operation of the burners is output to the burner controller 11.

[0087] The determination process based on the sampling values in the period T2 of Step S4 may be executed after the determination process based on the sampling values in the period T1 of Step S3 as illustrated in FIG. 4, or may be executed in parallel to the determination process based on the sampling values in the period T1 of Step S3 after the sampling by the sampling portion 105 starts.

[0088] Hereinafter, a description will be given of the respective flows of the interlock input determination process in Step S3 and the circuit failure determination process in Step S4 in detail.

[0089] First, the flow of the interlock input determination process in Step S3 will be described.

FIG. 5 is a flowchart illustrating the flow of the interlock input determination process by the combustion controlling device according to the embodiment.

[0090] As illustrated in FIG. 5, when the sampling starts in Step S2, the interlock input determining portion 1061 counts the number of times that the sampling values in the period T1 match each other in a row (S31). After the count starts, the interlock input determining portion 1061 determines whether the sampling values in the period T1 by the sampling portion 105 match each other N times in a row, or not (S32). In this case, if the sampling values do not match each other N times in a row, the interlock input determining portion 1061 continues to count the number of matches of the sampling values in the period T1 by the sampling portion 105. If the N number of matches in a row do not occur due to noise or the like, the determined value may be set to "H (open)" under the control after a predetermined time has elapsed.

[0091] On the other hand, if the sampling values in the period T1 by the sampling portion 105 match each other N times in a row in Step S32, the interlock input determining portion 1061 determines whether the sampling values are "L", or not (S33).

[0092] If the sampling values that match each other N times in a row in the period T1 are "H" in Step S33, the interlock input determining portion 1061 determines that the contacts of the limit interlock corresponding to the sampled input signal DIN are "opened", and determines that the object to be monitored by the limit interlock is "abnormal" (S36). As a result, the notifying portion 107 outputs the notification signal 14 indicative of the "non-permission" of the operation of the burners to the burner controller 11 on the basis of the determination result of the interlock input determining portion 1061 (S37).

[0093] On the other hand, if the sampling values that match each other N times in a row in the period T1 are "L" in Step S33, the interlock input determining portion

1061 determines that the contacts of the limit interlock corresponding to the sampled input signal DIN are "short-circuited", and determines that the object to be monitored by the limit interlock is "normal" (S34). As a result, the notifying portion 107 outputs the notification signal 14 indicative of the "permission" of the operation of the burners to the burner controller 11 on the basis of the determination result from the interlock input determining portion 1061 (S35).

[0094] Subsequently, the flow of the circuit failure determination process in Step S4 will be described in detail. FIG. 6 is a flowchart illustrating the flow of the circuit failure determination process by the combustion controlling device according to the embodiment.

[0095] When the sampling by the sampling portion 105 starts in Step S2, the circuit failure determining portion 1062 counts the number of times that the sampling values in the period T2 become "L" in a row (S41). In this situation, the circuit failure determining portion 1062 restarts the count operation after resetting the count value if the sampling values in the period T2 become "H".

[0096] After the count starts, the circuit failure determining portion 1062 determines whether the number of times that the sampling values in the period T2 become "L" in a row exceeds M times, or not (S42).

[0097] If the number of times that the sampling values in the period T2 become "L" in a row exceeds M times in Step S42, the circuit failure determining portion 1062 determines that "there is a failure in the circuit" (S43). As a result, the notifying portion 107 outputs the notification signal 14 indicative of the "non-permission" of the operation of the burners to the burner controller 11 on the basis of the determination result of the circuit failure determining portion 1062 (S44).

[0098] On the other hand, if the number of times that the sampling values in the period T2 become "L" in a row does not exceed M times in Step S42, the circuit failure determining portion 1062 determines that "there is no failure in the circuit" (S45). In this case, the flow again returns to Step S41, and the count operation of the number of times that the sampling values in the sampling period T2 become "L" is continued.

(Advantages of Combustion Controlling Device)

[0099] As described above, according to the combustion controlling device of the present invention, the interlock input determination is performed in a high level period of the output signal VOUT (pulse) to be supplied to each limit interlock, and the circuit failure determination is performed in a low level period of the output signal VOUT. Therefore, the abnormality of the object to be monitored by the interlock and the abnormality of the peripheral circuits of the interlock can be determined, distinctively, and the determination precision involved in the interlock can be enhanced.

[0100] Also, according to the combustion controlling device of the present embodiment, if the sampling values

of the input signal DIN in the high level period or the low level period of the output signal VOUT to be input to each of the limit interlocks match each other multiple times in a row, the sampling values are set as the determined value of the input signal DIN, and the interlock input determination and the circuit failure determination are performed on the basis of the determined value. As a result, for example, even if noise is superimposed on signals propagating through the wires 12 and 13, erroneous determination caused by the noise is unlikely to occur, and a reduction in the determination precision involved in the interlock can be suppressed.

[0101] Also, the sampling by the sampling portion 105 is performed after a predetermined time Td1 (Td2) has elapsed since the logic level of the output voltage VOUT (reference clock signal) switches to another. Therefore, as described above, even if the parasitic impedance components of the wires 12 and 13 that connect the safety controlling device 10 to the respective limit interlocks are large, and it takes time to stabilize the signals propagating the wires 12 and 13, since the sampling can be performed after the voltage of the input signal DIN has been stabilized, a reduction in the determination precision involved in the interlock can be suppressed.

[0102] Also, according to the combustion controlling device of the present embodiment, as described above, the number of matches M of the sampling values as a reference of the circuit failure determination is set to a value larger than the number of matches N of the sampling values as a reference of the interlock input determination, and a detection sensitivity of the circuit failure determination is set to be lower than a detection sensitivity of the interlock input determination. As a result, the control can be conducted so that the abnormality of the object to be monitored by the interlock is rapidly detected to perform rapid explosion prevention while the combustion operation is prevented from frequently stopping due to the erroneous detection caused by an influence of the noise in the permanent circuit failure. In other words, the precision of the circuit failure detection involved in the permanent abnormality can be enhanced while the rapidity of the abnormality detection by the interlock is secured, and an improvement in the safety of the combustion control and an improvement in the stable operation can be expected.

[0103] Further, the waiting times until the sampling starts are set to meet $Td1 < Td2$ with the results that the ensuring of rapidity of the abnormality detection by the interlock, and further higher precision of the circuit failure detection can be expected in the same manner as described above.

[0104] From the above viewpoint, it is particularly effective that the combustion controlling device according to the present embodiment is applied to a large combustion furnace in which the wires 12 and 13 for connecting the safety controlling device 10 and the respective limit interlocks are long, and the parasitic impedance components of the wires are large.

[0105] The invention made by the present inventors has been described above on the basis of the embodiments in detail. However, the present invention is not limited to the embodiments, but can be variously changed without departing from a spirit of the invention.

[0106] For example, the above embodiment exemplifies a case in which the combustion controlling device 1 is achieved by one microcontroller, but can be achieved by multiple microcontrollers.

FIG. 7 is a diagram illustrating a configuration example when the safety controlling device is achieved by multiple microcontrollers in the combustion controlling device according to the embodiment.

[0107] As shown in the figure, a main microcontroller (MCU_M) 101 a and a sub-microcontroller (MCU_S) 101b are provided, and the sampling portion 105, the determining portion 106, and the notifying portion 107 are provided in each of the microcontrollers 101 a and 101b, to thereby provide a redundant configuration of the function blocks for the limit interlocks input determination and the circuit failure determination.

[0108] According to the above configuration, even if a problem occurs in one of the microcontrollers, since the interlocks input determination process and the circuit failure determination process can be executed by the other microcontroller, the safety of the combustion system 500 and the stability of the combustion operation can be further improved.

[0109] In that case, the pulse generating portion 104 may be provided in only any one of the microcontroller 101 a and the microcontroller 101b. For example, FIG. 7 illustrates a case in which the pulse generating portion 104 is disposed in the main microcontroller 101 a. In that case, the reference pulse signal PS is supplied from the main microcontroller 101 a to the sub-microcontroller 101b, and the sub-microcontroller 101b performs the sampling on the basis of the timing of the reference pulse signal PS.

[0110] FIG. 7 illustrates the case in which two microcontrollers are provided. However, the present invention is not limited to this configuration, and three or more microcontrollers may be provided, and the function block for performing the limit interlocks input determination and the circuit failure determination may be provided in each of the microcontrollers.

[0111] In the above embodiment, as an example of the abnormality detection element (limit interlock) connected to the combustion controlling device 1, the air pressure lower limit interlock, the gas pressure upper limit/lower limit interlock, and the excessive temperature rise limit are illustrated. Similarly, it is needless to say that abnormality detection elements other than the above elements can employ the interlocks input determination process by the combustion controlling device 1 according to the present invention.

[0112] Further, FIG. 2 illustrates the case in which the output circuit 102 and the input circuits 103 each have the circuit configuration using the photocoupler. Howev-

er, the circuit configuration of the output circuit 102 and the input circuits 103 is limited to the above configuration. For example, when there is no need to electrically insulate the external terminals COM and IN_1 to IN_n from the MCU 101, the output circuit 102 may be configured to drive the transistor Q1 on the basis of the output signal of the buffer circuit BF not through the photocoupler PC1. The input circuits 103 may be configured to provide a transistor between a ground node and one end of the resistor R2 instead of the photocoupler PC2, and connect a connection node of the resistor R3 and the resistor R4 to a control electrode (base electrode) of the transistor.

[Description of Reference Numerals and Signs]

[0113] 1 ... combustion controlling device; 2 ... fuel flow channel; 3 ... air flow channel; 4 ... combustion device; 5 ... controller; 6 ... excessive temperature rise limit; 7, 8, and 9 ... interlock; 10 ... safety controlling device; 11 ... burner controller; 14 ... notification signal; 40 ... combustion chamber; 41 and 42 ... temperature sensor; 43 ... main burner; 44 ... pilot burner; 45 ... flame detector; 46 ... ignition device (igniter); 60, 70, 80, and 90 ... switch; 61, 71, 81, and 91 ... switch driving portion; 31 ... blower; 2a ... main flow channel; 2b ... first flow channel; 2c ... second flow channel; 21, 22, 23, 24 ... safety shutoff valve; COM, IN_1, NI_n ... terminal; 12, 13, 13_1, and 13_n ... wires; 101, 101a, and 101b ... microcontroller; 102 ... output circuit; 103, 103_1, and 103_n ... input circuit; 104 ... pulse generating portion; 105 ... sampling portion; 106 ... determining portion; 1061 ... interlock input determining portion; 1062 ... circuit failure determining portion; 107 ... notifying portion; 110 ... function block; PS ... reference pulse signal; and 500 ... combustion system.

Claims

1. A combustion controlling device, comprising:

an output circuit configured to supply a binary output signal to one of two contacts of an abnormality detection element that is in a short-circuit state or an open state between the two contacts according to a state of an object to be monitored; an input circuit configured to receive a signal output from the other contact of the abnormality detection element to which the output signal is supplied, the input circuit configured to generate a binary input signal corresponding to a logic level of the input signal; a sampling portion configured to sample the input signal within a first period in which the output signal is a first logic level, and samples the input signal within a second period in which the output signal is a second logic level; an abnormality detection element state deter-

- mining portion configured to determine the state of the object to be monitored by the abnormality detection element on the basis of a sampling result in the first period by the sampling portion; and
a circuit failure determining portion configured to determine whether a failure occurs in the output circuit and the input circuit, or not, on the basis of a sampling result in the second period by the sampling portion.
2. The combustion controlling device according to claim 1, wherein
the abnormality detection element state determining portion is configured to determine that the object to be monitored by the abnormality detection element is normal when it is detected that the logic level of the signal input to the input circuit in the first period is the first logic level N times in a row with reference to sampling values in the first period for successive N (N is an integer of two or more) times, and the abnormality detection element state determining portion is configured to determine that the object to be monitored by the abnormality detection element is abnormal when it is detected that the logic level of the signal input to the input circuit in the first period is the second logic level N times in a row.
 3. The combustion controlling device according to claim 2, wherein
the circuit failure determining portion is configured to determine that at least one of the output circuit and the input circuit fails when it is detected that the logic level of the signal input to the input circuit in the second period is the second logic level M times in a row with reference to sampling values in the second period for successive M (M is an integer of two or more) times.
 4. The combustion controlling device according to claim 3, wherein
 $M \geq N$.
 5. The combustion controlling device according to any one of claims 1 to 4,
wherein
the sampling portion performs sampling in the first period after a first time period elapses since the output signal switches from the second logic level to the first logic level.
 6. The combustion controlling device according to claim 5, wherein
the sampling portion performs sampling in the second period after a second time period elapses since the output signal switches from the first logic level to the second logic level.
 7. The combustion controlling device according to claim 6, wherein
the first time period is less than the second time period.
 8. The combustion controlling device according to any one of claims 1 to 4,
wherein
a plurality of sets of function blocks including the sampling portion, the abnormality detection element state determining portion, and the circuit failure determining portion are provided, and
the respective function blocks are configured by a plurality of different program processing devices, individually.
 9. The combustion controlling device according to any one of claims 1 to 4, further comprising
a controlling portion configured to control the operation of a burner on the basis of determination results of the abnormality detection element state determining portion and the circuit failure determining portion.
 10. A combustion system, comprising:

the combustion controlling device according to claim 9; and
the burner that is disposed in a combustion chamber and controlled by the combustion controlling device.

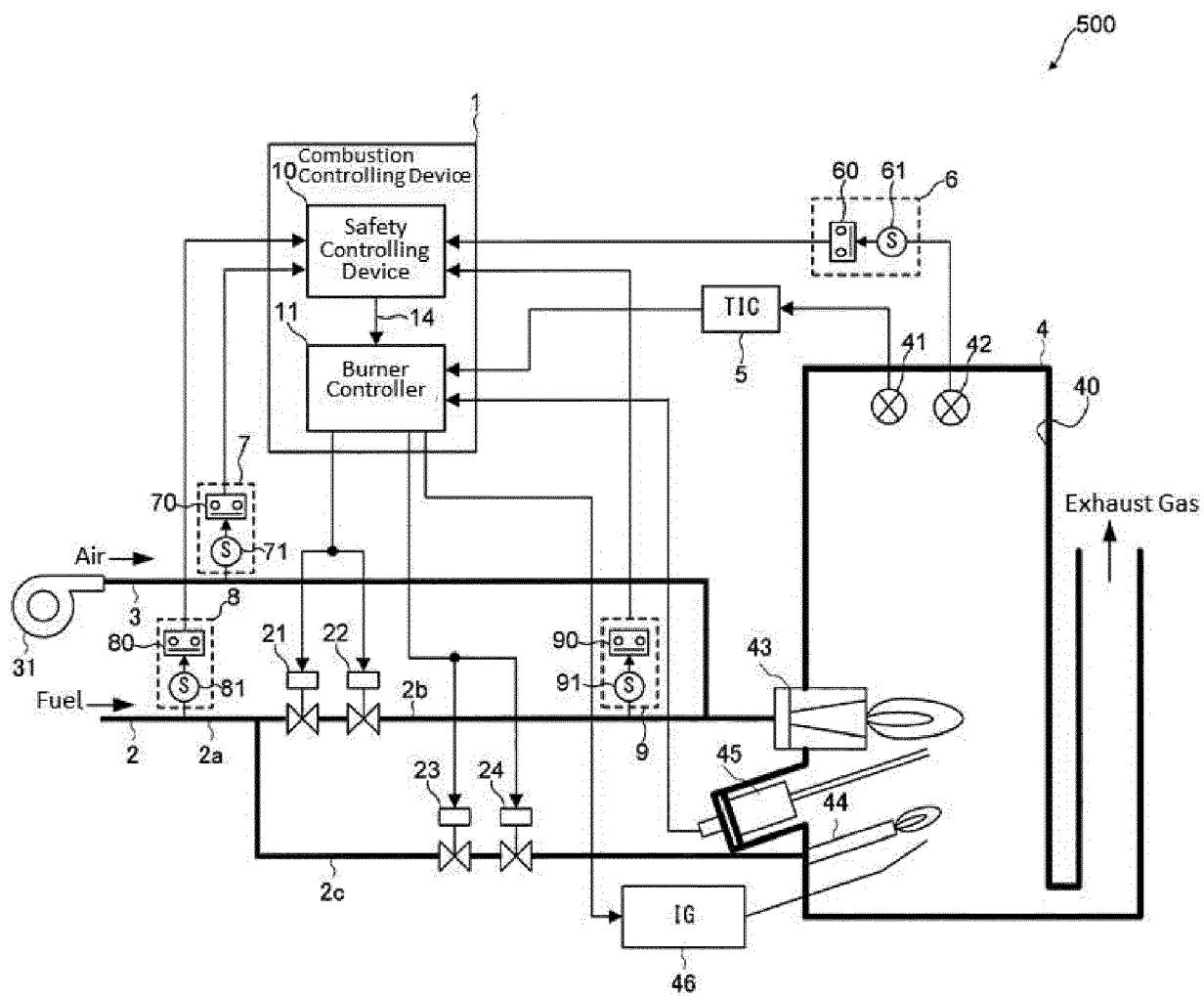


Fig. 1

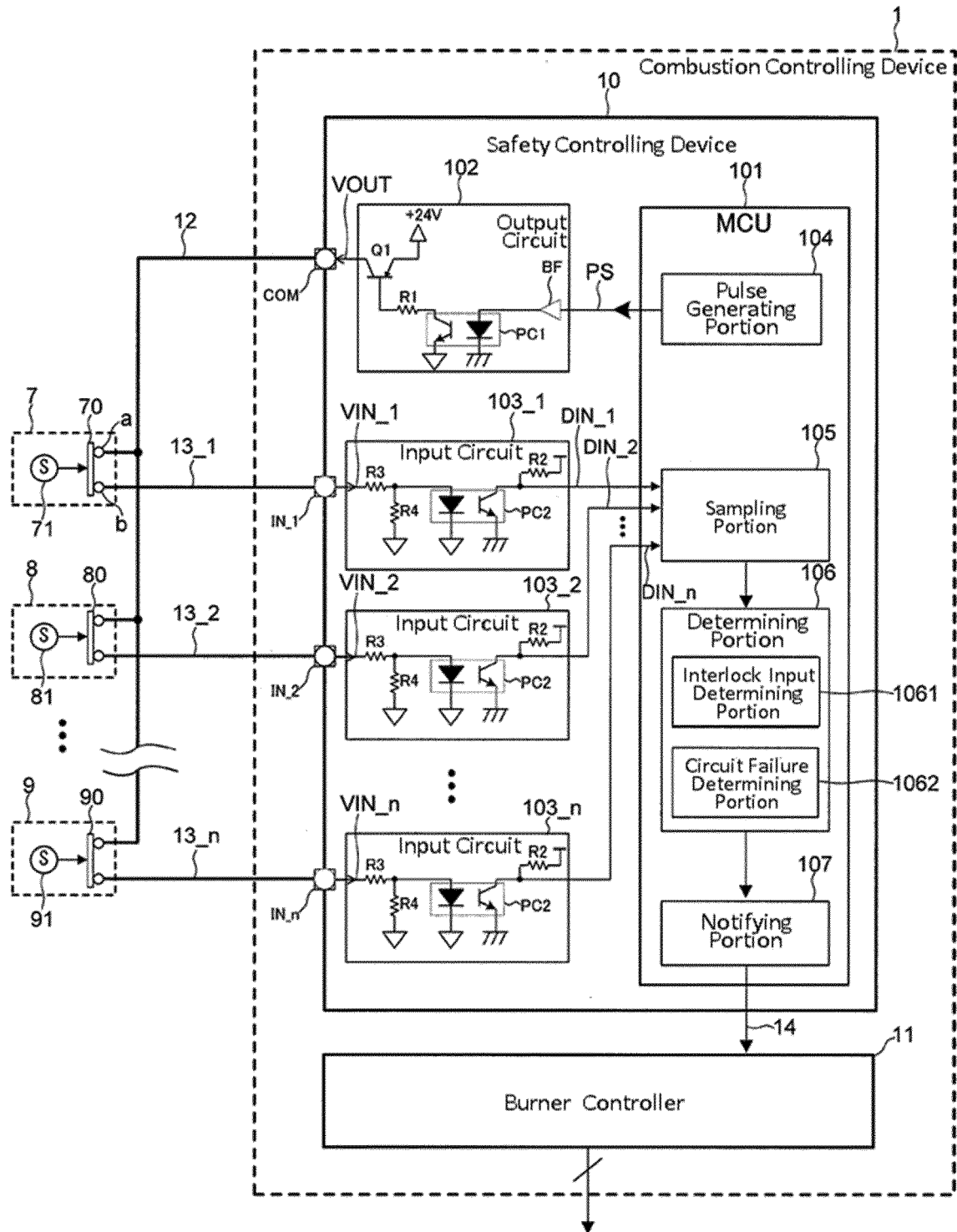


Fig. 2

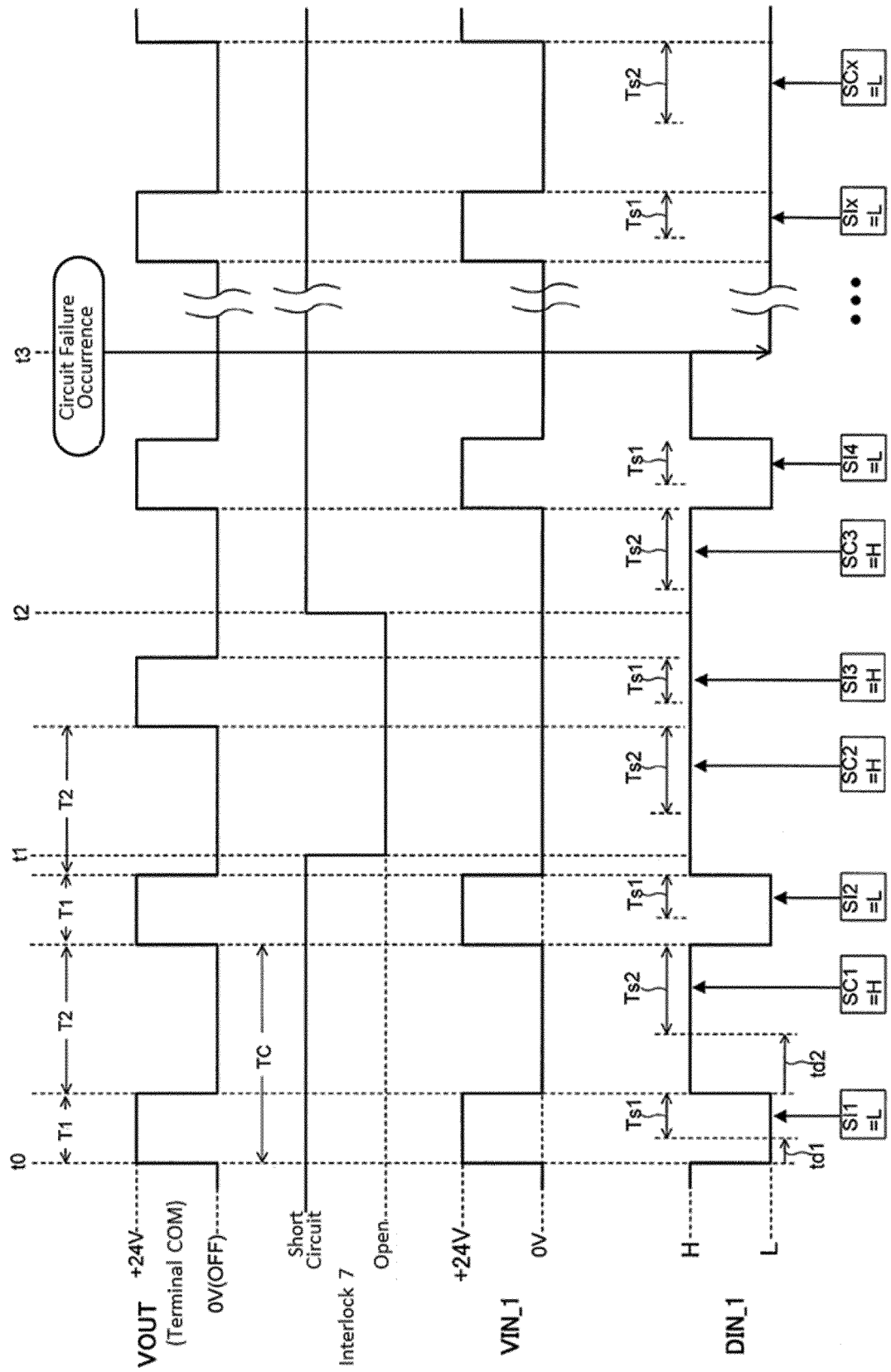


Fig. 3

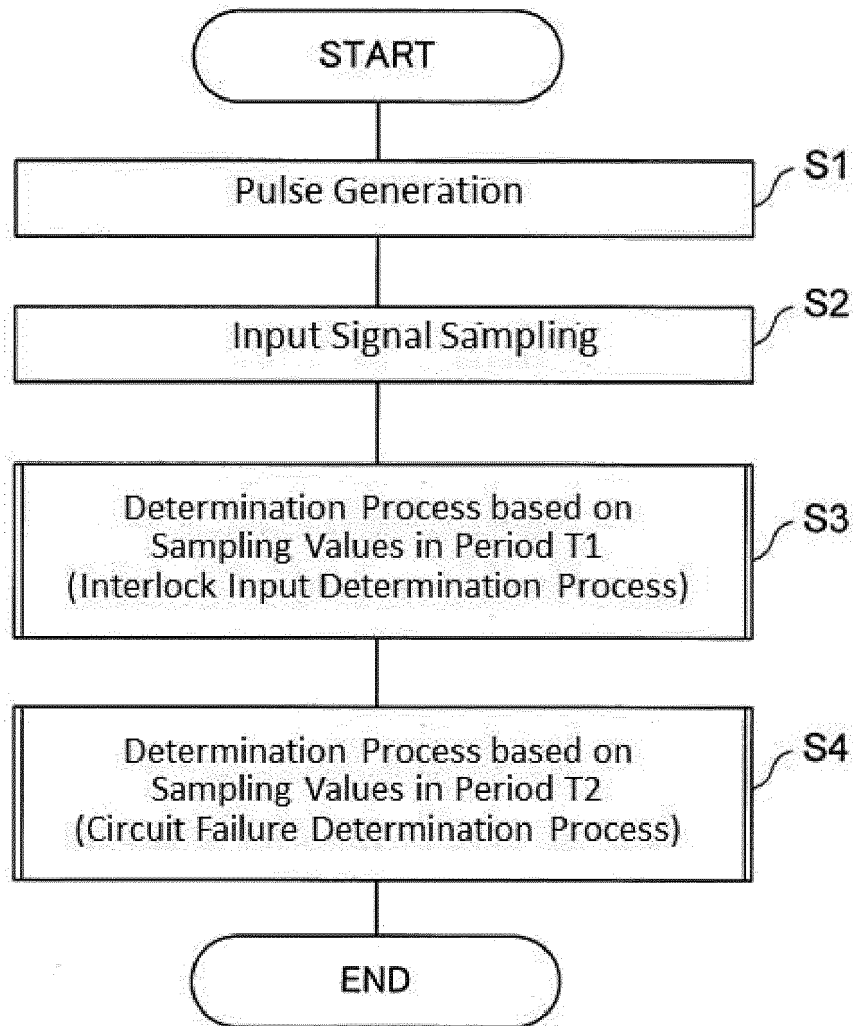


Fig. 4

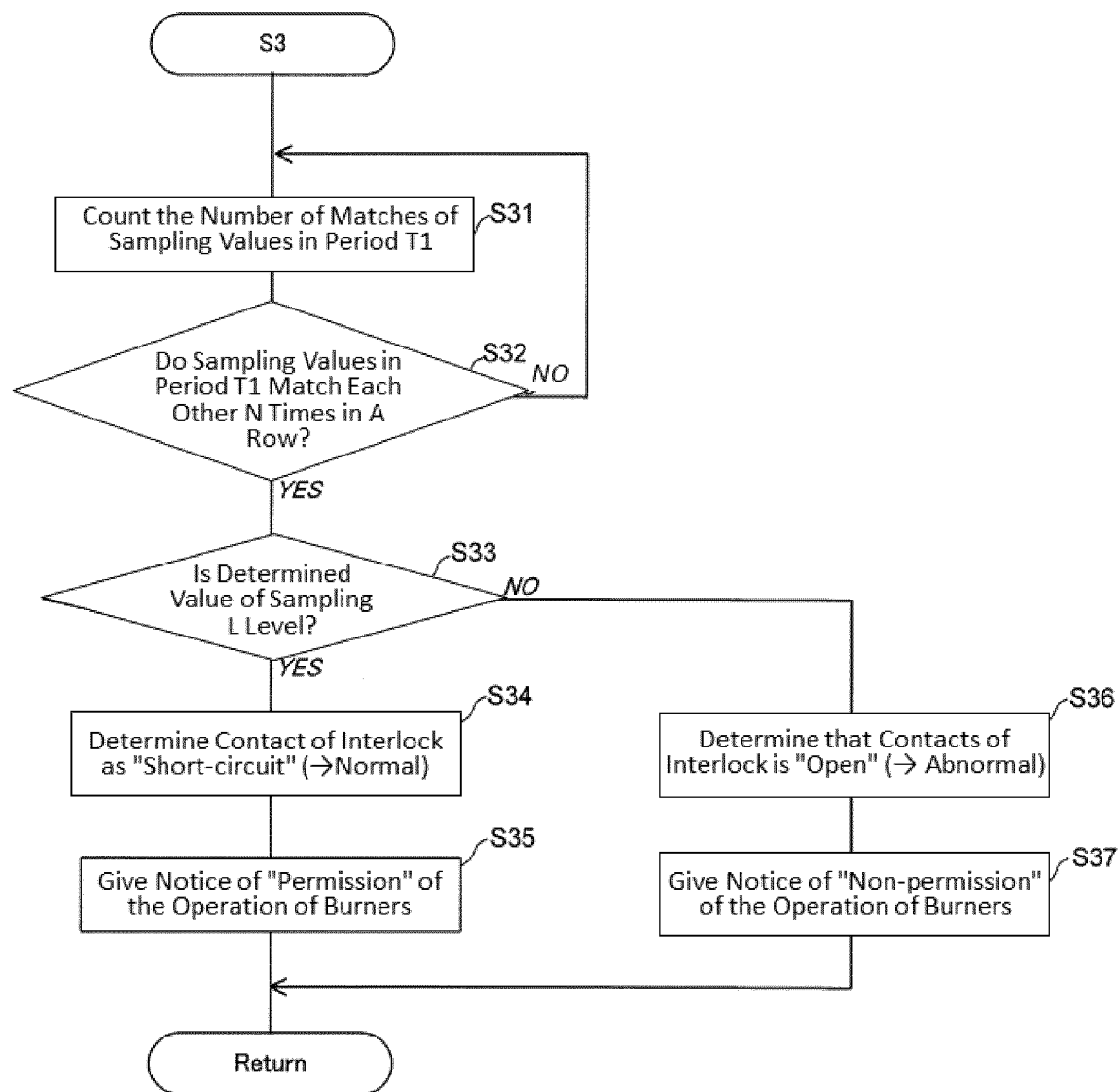


Fig. 5

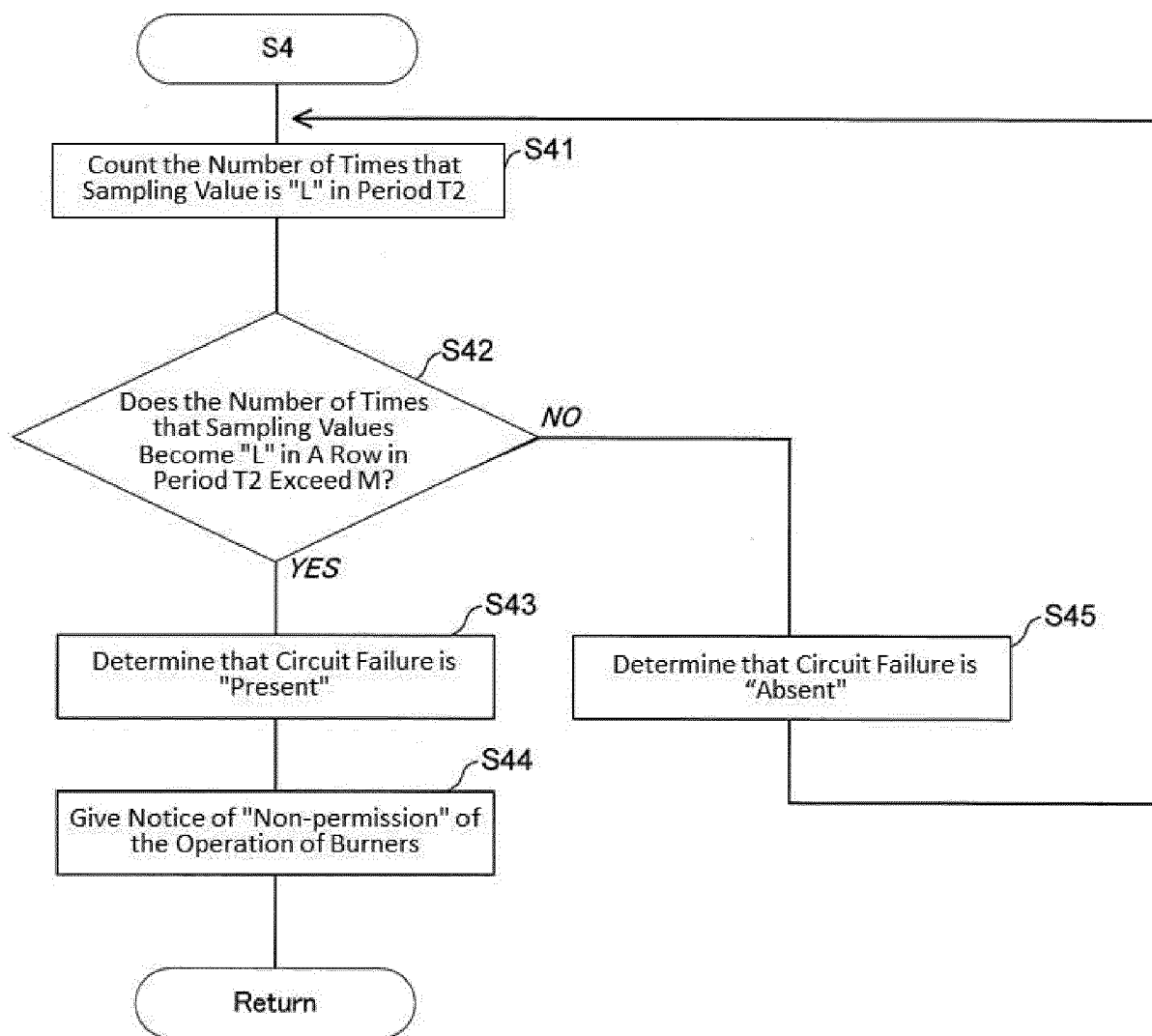


Fig. 6

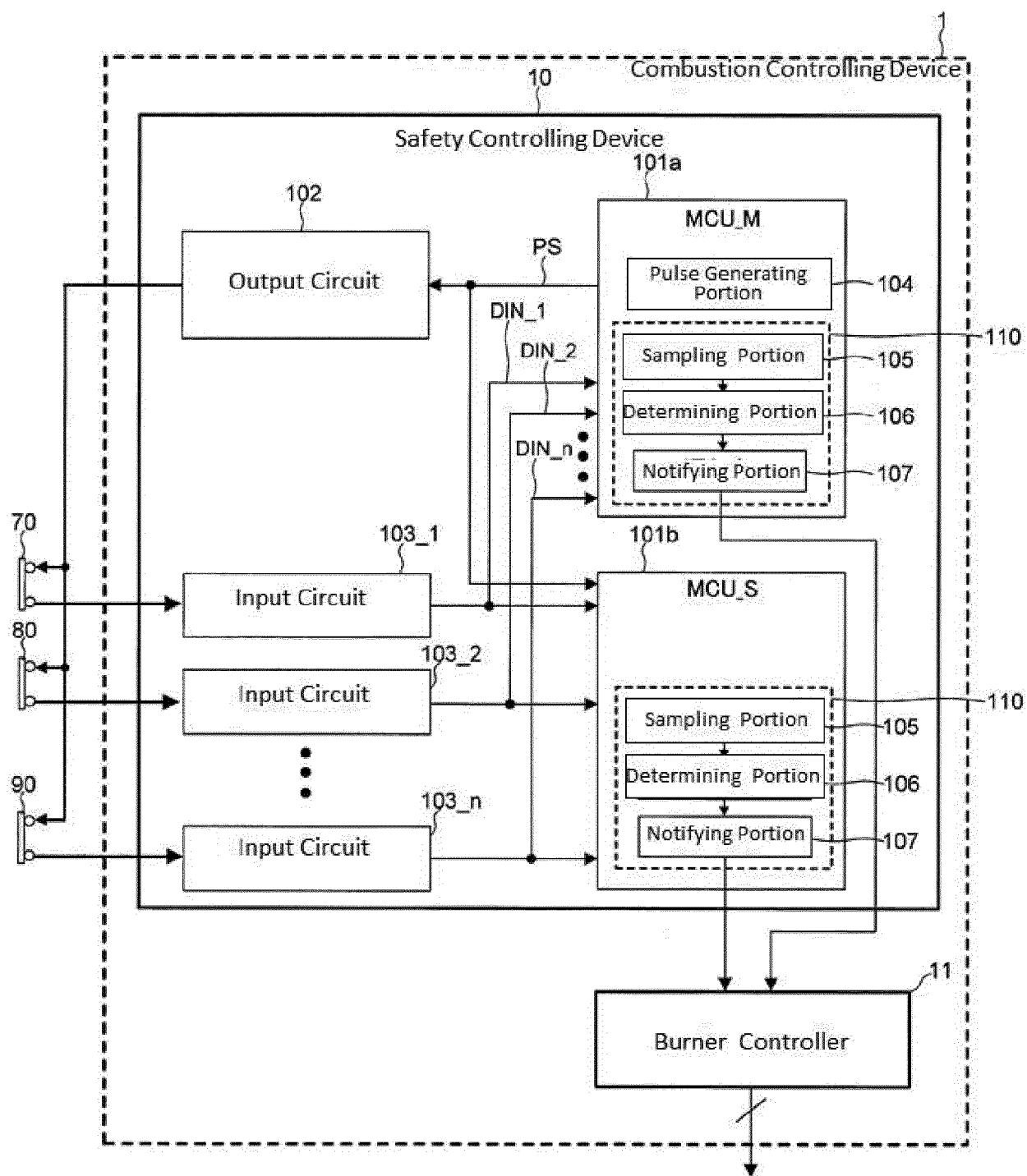


Fig. 7



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Place of search Munich		Date of completion of the search 8 July 2016	Examiner Gavriliu, Costin
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