United States Patent

Sasaki

[15] **3,702,468**

[45] **Nov. 7, 1972**

[54] **FIRE ALARMING SYSTEM**

[72] Inventor: **Koji Sasaki,** Tokyo, Japan

[73] Assignee: **Nittan Company Limited,** Tokyo, Japan

[22] Filed: **July 28, 1971**

[21] Appl. No.: **166,756**

[30] **Foreign Application Priority Data**

Aug. 10, 1970	Japan	45/69275
Aug. 10, 1970	Japan	45/69278
Aug. 20, 1970	Japan	45/72365
Aug. 31, 1970	Japan	45/75628

[52] **U.S. Cl.** ....**340/237 S,** 340/409

[51] **Int. Cl.** **G08b 17/10,** G08b 29/00

[58] **Field of Search**...340/237 S, 409, 276, 331, 256; 250/83.6 FT, 43.5 D, 44

[56] **References Cited**

UNITED STATES PATENTS

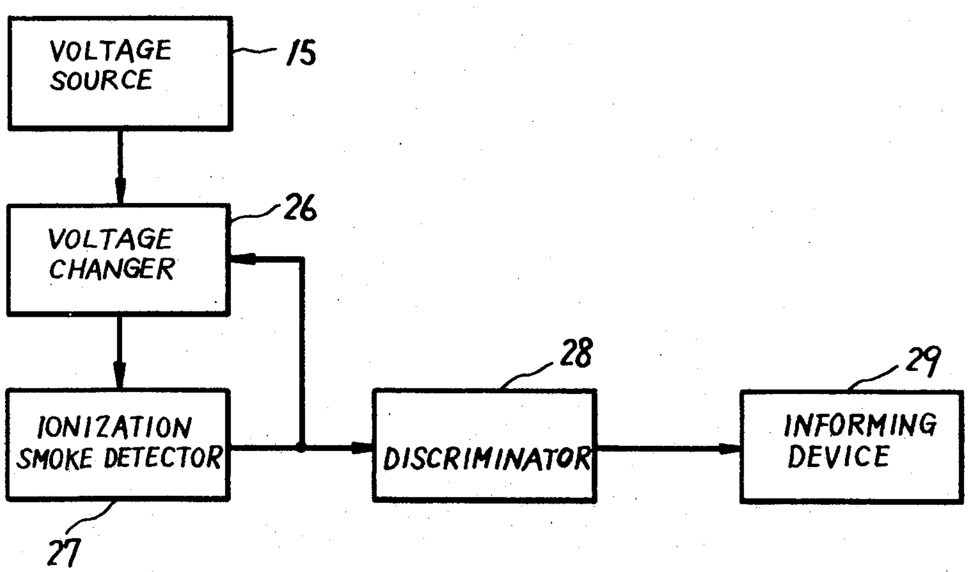
2,646,556	7/1953	Allen	340/409 UX
2,782,404	2/1957	Bergman	340/409 X
3,160,866	12/1964	Meili	340/237 S UX
3,530,450	9/1970	Walthard et al.	340/237 S UX
3,564,524	2/1971	Walthard et al.	340/237 S UX
3,588,842	6/1971	Scheidweiler	340/237 S UX
3,603,949	9/1971	Walthard	340/237 S UX
3,657,713	4/1972	Kojusasaki et al.	340/237 S X
3,665,461	5/1972	Gnägi et al	340/256 X

Primary Examiner—John W. Caldwell
Assistant Examiner—Daniel Myer
Attorney—Eugene E. Geoffrey

[57] **ABSTRACT**

An ionization smoke detector having means for briefly reducing the voltage across the series connected ionization chambers when the detector is actuated by either smoke or the failure of a component part. The detector therefor, when actuated by smoke will produce a periodic signal as the voltage is reduced and returns again to the normal voltage. However, if the detector is defective a continuous signal is produced. Through the use of a discriminator connected to the detector the periodic signal will produce an alarm while the continuous signal will provide an indication of a faulty detector.

9 Claims, 10 Drawing Figures



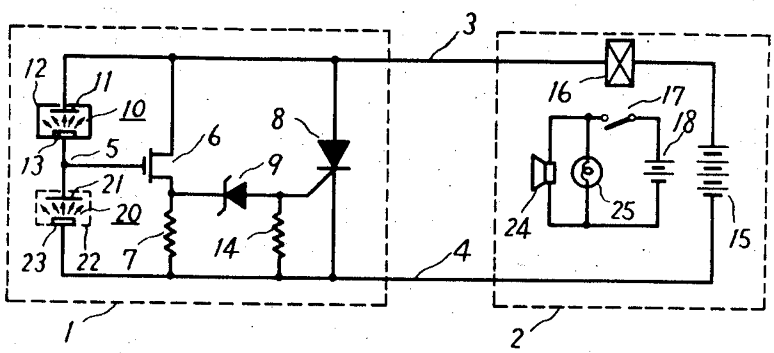


Fig. 1 PRIOR ART

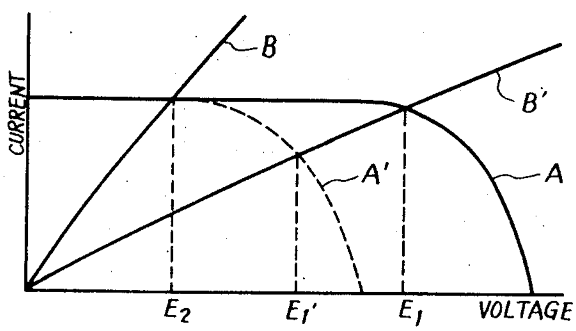


Fig. 2

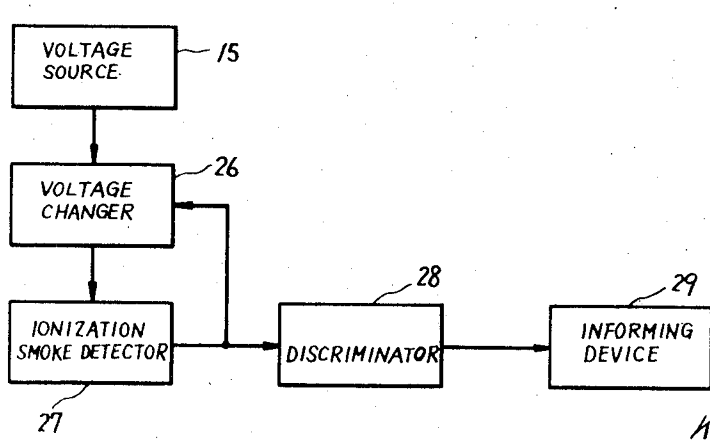


Fig. 3

INVENTOR.
KOJU SASAKI

BY

ATTORNEY

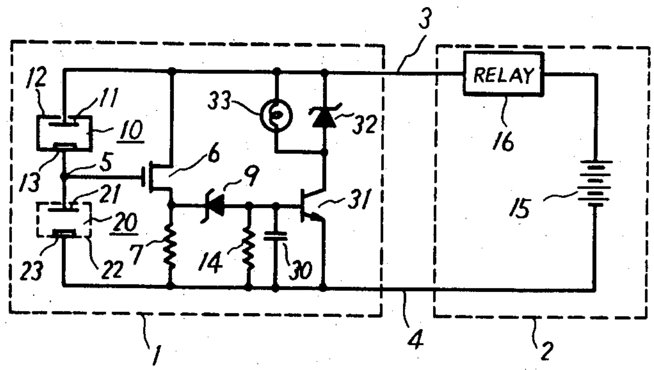


Fig. 4

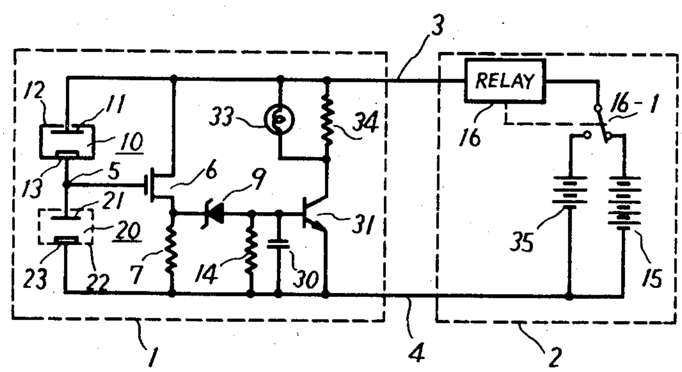


Fig. 5

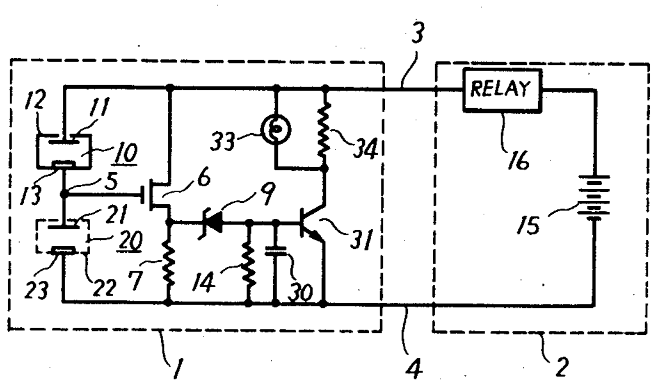


Fig. 6

INVENTOR.
KOJU SASAKI
BY
ATTORNEY

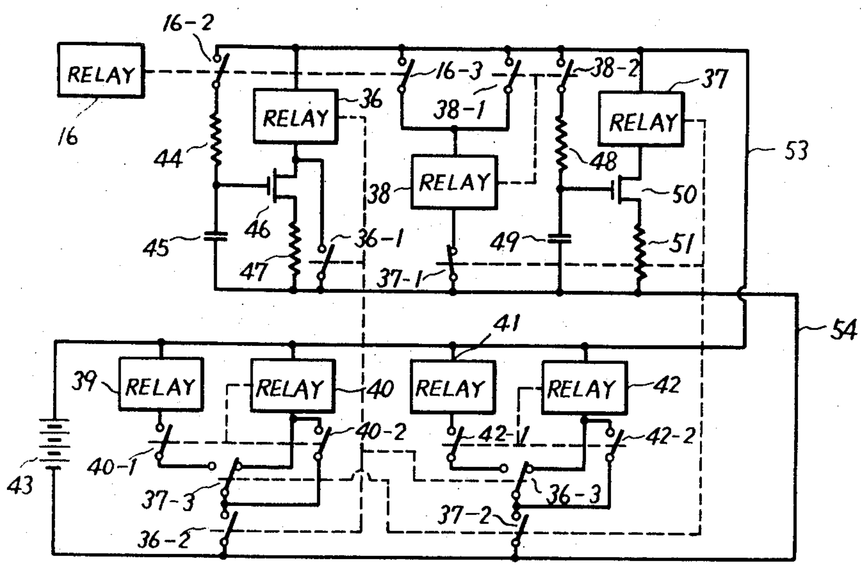


Fig. 7

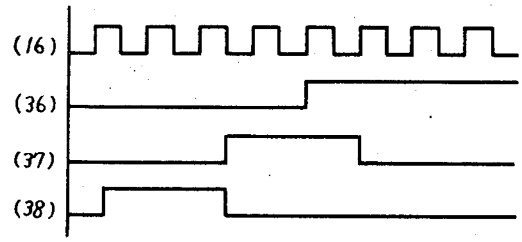


Fig. 8-1

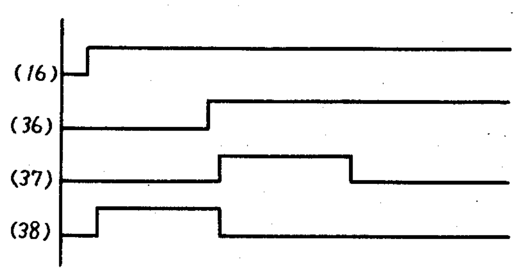


Fig. 8-2

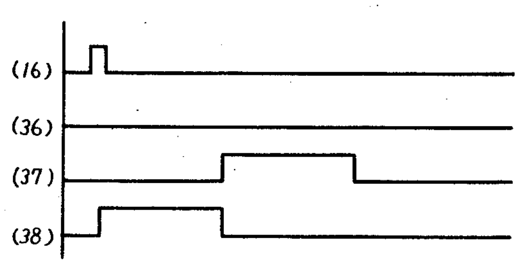


Fig. 8-3

INVENTOR.
KOJU SASAKI
BY
ATTORNEY

FIRE ALARMING SYSTEM

This invention relates to a fire alarm system, especially a fire alarm system of a type utilizing ionization smoke detectors and more particularly an alarm system capable of distinguishing the erroneous actuation of the detector from its true actuation and indicating the erroneous actuation separately from the true actuation.

Prior ionization type fire alarm systems include a plurality of local units consisting of ionization smoke detectors connected in parallel between a pair of conductors extending from a central unit including a power supply and a relay connected in series between the pair of conductors and an alarm device responding to the relay. The ionization smoke detector constituting each local unit includes a pair of ionization chambers each having a pair of electrodes and a radioactive source for ionizing the atmosphere in the chamber, one chamber being closed to the external air and referred as "closed ionization chamber" while the other being open to the external air and referred as "open ionization chamber," the both chambers being connected in series between the pair of conductors. A field effect transistor (hereinafter referred to as "FET") having a gate electrode is connected to the connection point of both ionization chambers and a drain-to-source conduction path is connected in series with a load resistor between the pair of conductors. A silicon controlled rectifier (hereinafter referred to as "SCR") having a control electrode is connected through a Zener diode to the source electrode of the FET and the conductor path is connected between the pair of conductors.

When smoke enters the open ionization chamber, the ionization current in the open ionization chamber is reduced to raise the potential at the connection point of both ionization chambers and accordingly at the gate electrode of the FET. This results in a rise of the source potential of the FET and when it exceeds the zener voltage of the Zener diode it is applied to the control electrode of the SCR to drive it into conduction to short-circuit the pair of conductors. Thus, the relay is energized to actuate the alarm device.

In the such prior fire alarm systems an alarm is also sounded when the ionization smoke detector operates erroneously due to breakdown of the FET, insufficient insulation and the like, even if smoke does not enter the open ionization chamber. This is a very troublesome phenomenon.

Accordingly, the principal object of this invention resides in the provision of a fire alarm system which can distinguish erroneous actuation of the ionization smoke detector from its true actuation and indicate it separately from the true actuation.

This object is attained in accordance with this invention by providing means for reducing the applied voltage below the enabling voltage of the ionization smoke detector in response to the actuation of the detector and means for detesting the mode of current change in the conductors.

The above and other features of this invention will be more clearly understood from the following description with reference to the accompanying drawings.

In the drawings

FIG. 1 is a schematic circuit diagram representing a typical example of the ionization type fire alarm system according to the prior art;

FIG. 2 is a current-to-voltage characteristic diagram of the ionization chambers to aid in the explanation of the invention;

FIG. 3 is a block diagram representing a fire alarm system according to this invention;

FIG. 4 is a schematic circuit diagram of one embodiment of the system according to this invention;

FIg. 5 is a schematic circuit diagram of another embodiment of the system according to this invention;

FIG. 6 is a schematic circuit diagram of a further embodiment of the system of this invention;

FIG. 7 is a schematic circuit diagram of an embodiment of the means for discriminating the current changing mode according to this invention; and

FIGS. 8–1 through 8–3 are charts illustrating the modes of actuation of the various relays in the circuit of FIG. 7.

Throughout the drawings, like reference numerals are used to corresponding components.

Referring first to FIG. 1 illustrating a typical example of the prior ionization type fire alarm system, a local unit 1 and a central unit 2 are connected by a pair of conductors 3 and 4. Although a plurality of local units are connected in parallel between the conductors 3 and 4 in the practical system, only one unit is shown for the purposes of simplicity. The local unit 1 consists of a conventional ionization smoke detector including a closed ionization chamber 10 and an open ionization chamber 20 connected in series between the conductors 3 and 4, an FET 6 having a gate electrode connected to the connection point 5 of both ionization chambers and a drain-source conduction path connected through a load resistor 7 between the conductors 3 and 4 and an SCR 8 having a control electrode connected through a Zener diode 9 to the source electrode of the FET 6 and a conduction path connected also between the conductors 3 and 4. The control electrode of the SCR 8 is also connected through a leakage resistor 14 to the conductor 4. The closed ionization chamber 10 includes a pair of electrodes 11 and 12 and a radioactive source 13 and the open ionization chamber 20 similarly includes a pair of electrodes 21 and 22 and a radioactive source 23. The closed ionization chamber 10 itself may be replaced by a fixed resistor having a comparable impedance. The central unit 2 includes a power supply 15 and an electromagnetic relay 16 connected in series between both conductors 3 and 4 and an alarm device comprising a relay contact 17, a power supply 18, a speaker 24 and an indicating lamp 25.

The operation of the circuit of FIG. 1 will now be described with reference to FIG. 2. In FIG. 2 the potential at the connection point 5 of both ionization chambers 10 and 20 in FIG. 1 is shown on the abscissa and the ionization current flowing through each chamber is shown on the ordinate. Curve A shows the load curve of the closed ionization chamber 10 representing the ionization current in the closed ionization chamber 10 with respect to the voltage at the connection point 5 with a normal applied voltage, and Curve B shows the characteristic of the open ionization chamber 20 representing the ionization current in the open ionization chamber with respect to the voltage at the same point 5 under a normal operating condition and in the absence of smoke in the open ionization chamber. As the ionization currents in both of the ionization chambers are equal in the circuit of FIG. 1, it is clear that the voltage at the point 5 is stabilized at voltage E2 which corresponds to the intersection of both curves A and B when smoke does not exist in the open ionization chamber 20. When smoke enters the open ionization chamber 20, however, the characteristic of the open ionization chamber is changed to Curve B', as an example. Therefore, the voltage at point 5, that is, the gate voltage of the FET 6, is raised to E1 from E2 as shown in FIG. 2. This results in a corresponding rise in the source voltage of the FET 6 and, when it exceeds the Zener voltage of the Zener diode 9, it is applied to the control electrode of the SCR 8 to drive it into conduction. Thus, the conductors 3 and 4 are short-circuited through the SCR 8 and the relay 16 in the central unit 2 is energized to close the contact 17, thereby producing an alarm indicating the presence of fire.

Once the SCR 8 conducts it is never restored to its cut-off condition unless the power supply 15 is disconnected therefrom. This is also true in the case of an erroneous actuation of the detector due to a damaged FET 6, broken insulation or the like and in the case of momentary actuation due to electrical noise, a rapid flow of air or the like, and such erroneous actuation cannot be distinguished from a normal and true actuation.

The block diagram of FIG. 3 represents a basic scheme of the fire alarm system of this invention. As shown, a voltage changer 26 is inserted between a voltage source 15 and the ionization smoke detector 27. The voltage changer 26 has the function of reducing the applied voltage to a specific low value in response to actuation of the ionization smoke detector 27 and restoring the reduced voltage to the original value in response to actuation of the ionization smoke detector 27 and restoring the reduced voltage to the original value in response to deactuation of the detector. The ionization smoke detector 27 according to this invention is constructed so that it cannot be actuated at the above mentioned reduced applied voltage even when smoke enters the open ionization chamber. In the normal operation of the detector when smoke enters the open ionization chamber, the detector is actuated by incoming smoke and is soon deactuated by the reduced applied voltage produced by the voltage changer 26 in response to the actuation of the detector. The applied voltage is then restored to the original high value by the voltage changer 26 in response to the deactuation of the detector. Thus, the ionization smoke detector 27 of this invention repeats actuation and deactuation alternately at a specific frequency and energizes the relay 16 periodically.

The value of the reduced applied voltage is also selected to maintain the relay 16 in energized condition when the ionization smoke detector 27 is erroneously actuated. Therefore, in such abnormal actuation of the detector due to damage thereof, the detector 27 is not deactuated at the reduced applied voltage and the relay 16 is not restored to its original open condition. When the ionization smoke detector is momentarily actuated by an electrical noise or rapid flow of air, the detector is actuated momentarily but is soon restored, and only energizes the relay 16 momentarily but does not energize the relay repeatedly or continuously.

A discriminator 28 in FIG. 3 discriminates or detects the difference between the mode of actuation of the ionization smoke detector 27 in normal and abnormal operations and produces output signals corresponding to the respective modes of actuation. An informing or indicating device 29 in FIG. 3 receives the output signals from the discriminator 28 and informs or indicates a condition such as presence of fire or damage to the detector.

FIGS. 4, 5 and 6 represent three embodiments of a fire alarm system according to this invention, which show practical arrangements of the voltage changer 26 and the ionization smoke detector 27 of FIG. 3. The systems of FIGS. 1, 2 and 3 include, respectively, a local unit 1 and a central unit 2 connected by a pair of conductors 3 and 4 as shown in FIG. 1. In practice, a plurality of local units are connected in parallel between the conductors 3 and 4, but only one unit is shown in each drawing for purposes of simplification.

In FIG. 4 the local unit 1 consists of an ionization smoke detector which is almost similar to that of FIG. 1, but the SCR 8 in FIG. 1 is substituted by a bipolar transistor 31. The transistor 31 has a base electrode connected to the Zener diode 9 and an emitter-to-collector path connected through another Zener diode 32 between the both conductors 3 and 4. The transistor 31 and the Zener diode 32 cooperate as described hereinunder to serve the function of the voltage changer 26 of FIG. 3. The Zener diode 32 has an indicating lamp 33 connected in parallel therewith for indicating conduction of the Zener diode 32.

When smoke enters the open ionization chamber 20 of the ionization smoke detector of FIG. 4, the operation as described in conjunction with the prior detector of FIG. 1 is produced and a control voltage is produced at the base electrode of the transistor 31 to drive it into conduction. Due to the Zener diode 32, however, the conductors 3 and 4 are not short-circuited directly and a voltage corresponding to the Zener voltage of the Zener diode 32 remains as the reduced applied voltage as described hereinbefore. If a reduced voltage is applied to the series connection of both ionization chambers 10 and 20, the load curve A of the closed ionization chamber 10 is changed as shown by a dashed curve A' in FIG. 2 and the gate voltage of the FET 6 is correspondingly reduced to E1' from E1 even when smoke exists in the open ionization chamber 20. Therefore, if the Zener voltage of the Zener diode 32 is selected so that the gate voltage E1' produces the source voltage of the FET 6 which does not exceed the Zener voltage of the Zener diode 9, the transistor 31 is cut off and the original applied voltage is restored between both conductors 3 and 4. Thus, the transistor 31 is alternately switched between conductive and non-conductive conditions and the relay 16 included in the central unit 2 periodically energized as schematically represented by a waveform (16) of FIG. 8–1.

The local unit 1 of FIG. 5 is the same as that of FIG. 4 except that a fixed resistor 34 is substituted for the Zener diode 32. The central unit 2 however includes another power supply 35 which can be substituted for the power supply 15 by a change-over switch 16–1 actuated by the relay 16. The voltage of the power supply 35 is lower than that of the power supply 15 and the value is selected to provide the above mentioned reduced voltage condition.

When smoke enters the open ionization chamber 20 and the transistor 31 is similarly driven into conduction, the relay 16 is energized to actuate the switch 16–1 to transfer the system from power supply 15 to power supply 35 so that the applied voltage between the conductors 3 and 4 is reduced and the transistor 31 is restored to its cut-off condition in the same manner as in the case of FIG. 4. This results in a similar periodic energization of the relay 16.

The system of FIG. 6 is the same as that of FIG. 5 except that the auxiliary power supply 35 and the changeover switch 16–1 are removed. In this system the impedance of the relay 16 is previously selected so that the reduced voltage meeting the above mentioned condition is produced between both conductors 3 and 4 when it is energized. This serves the same function of changing applied voltage as the circuit 4 in FIGS. 4 and 5 and the relay 16 is similarly energized periodically when smoke enters the open ionization chamber 20.

In the case of erroneous actuation of the detector due to a damaged FET 6 or broken insulation, the detector is not restored to its original condition even if the applied voltage is reduced as discussed above, since the reduced voltage is previously selected so that it will maintain the detector in the actuated condition. Thus, the relay 16 is energized continuously as schematically shown by a waveform (16) in FIG. 8–2. In the case of an erroneous actuation due to the electrical noise or momentary flow of air, the detector is momentarily actuated and is soon restored and the relay 16 is energized as shown by the waveform (16) in FIG. 8–3.

FIG. 7 illustrates an embodiment of the discriminator 28 of FIG. 3. It includes a series connection of a normally opened switch 16–2. A resistor 44 and a capactior 45 which form a time constant circuit. This circuit is connected between a pair of conductors 53 and 54 extending from the power supply 43. The connection point of the resistor 44 and the capacitor 45 is connected to the gate electrode of an FET 46 having a source-to-drain path connected in series with a relay 36 and a load resistor 47 between the conductors 53 and 54. A normally open switch 36–1 which is actuated by the relay 36 is connected in parallel with the series connection of the FET 46 and the load resistor 47 to form a self-holding contact of the relay 36. A normally open switch 16–3, a relay 38 and a normally closed switch 37–1 are connected in series between the conductors 53 and 54, and a normally open switch 38–1 which is actuated by the relay 38 is connected in parallel with the switch 16–3 to form a self-holding contact of the relay 38. The switches 16–2 and 16–3 are actuated by the relay 16 which also appears in FIGS. 4, 5 and 6. The switch 37–1 is actuated by a relay 37 which will be described. A normally open switch 38–2 which is actuated by the relay 38, a resistor 48, and a capacitor 49 which also form a time constant circuit are connected in series between the conductors 53 and 54. The time constants relating the relays 36 and 37 must be selected in order to meet the operational requirements of the device as described below. Both time constants may be made equal by using time constant circuit elements having the same values.

The above described portion of the circuit of FIG. 7 will now be explained with reference to the waveform diagrams of FIGS. 8–1, 8–2 and 8–3 and wherein the same time constant is used for both relays 36 and 37. When smoke comes in the open ionization chamber 20 of an ionization smoke detector of the fire alarm system of this invention, the relay 16 in the central unit 2 is periodically actuated and the mode of actuation is schematically represented by the waveform (16) of FIG. 8–1, as described above. Such periodic actuation of the relay 16 and the similar operation of switch 16–2 results in gradual charging-up of the capacitor 45 and consequent rise of the gate voltage and increase of the drain current of the FET 46. When the drain current reaches a specific value, the relay 36 is energized and actuates its self-holding contact 36–1. The mode of actuation of relay 16 is represented schematically by the waveform (36) of FIG. 8–1. The relay 16 also actuates the switch 16–3 which energizes the relay 38. The relay 38 actuates its self-holding contact 38–1 and, at the same time, actuates the switch 38–2 to form a charging path for capacitor 49. When the drain current of the FET 50 reaches a specific value by reason of the change in capacitor 49, the relay 37 is energized and actuates the normally closed switch 37–1 to deenergize the relay 38 and open the switches 38–1 and 38–2. Then, the capacitor 49 is gradually discharged and, when the drain current of the FET 50 falls below a specific value, the relay 37 is deenergized. Since the switch 38–2 is continuously actuated by the self-holding relay 38 and the charging time constants of both capacitors 45 and 49 are the same, the capacitor 49 is charged more quickly than the capacitor 45 and the relay 37 is therefore energized earlier than the relay 36. Thus, the modes of actuation of the relay 37 and 38 are represented schematically by the waveforms (37) and (38) of FIG. 8–1, respectively. The time difference appearing between the leading edges of the waveforms (16) and (38) corresponds to the time lag of actuation of the relay 38 after actuation of the relay 16.

However, when the ionization smoke detector is actuated erroneously due to a damaged FET or broken insulation, the relay 16 is energized continuously as shown by the waveform (16) of FIG. 8–2 and the charging conditions of the capacitors 45 and 49 are the same except for the time lag in the charging of the capacitor 49. Therefore, the actuation of the relay 36 is earlier than the relay 37 by a time corresponding to that time lag. Accordingly, the modes of actuation of the various relays are represented by FIG. 8–2, since the actuation of both relays 37 and 38 are identical to those in the case of FIG. 8–1.

When the ionization smoke detector is erroneously actuated momentarily by an electrical noise or flow of air, the relay 16 is also energized momentarily but does not energize the relay 36. The modes of actuation of these relays are shown by FIG. 8–3.

With reference to the timing relation of the actuation of the relays 36 and 37, it is found that the true and erroneous actuations of the ionization smoke detector can be distinguished by order in which each relay is actuated. An example of such a discriminating circuit is shown in the lower portion of FIG. 7.

Referring again to FIG. 7, four relays 39, 40, 41 and 42 are disposed between the conductors 53 and 54. The relay 39 is actuated in response to an erroneous operation informing device (not shown) and the relay 41 is actuated by a fire alarm device (not shown). The relay 39 is connected between conductors 53 and 54 through a normally open switch **40–1** which is actuated by the relay **40**, the normally open contacts of a single-pole double!-throw switch **37-3** which is actuated by the relay **37** and a normally open switch **36–2** which is actuated by the relay **36**. The relay **40** is connected between conductors **53** and **54** through a normally closed contact of the switch **37–3** and the switch **36–2**. A normally open switch **40–2** which is actuated by the relay **40** is connected across the normally closed contact of the switch **37–3** to form a self-holding contact of the relay **40**. The relay **41** is connected between conductors **53** and **54** through a normally open switch **42–1** which is actuated by the relay element **42**, the normally open contact of the single-pole double-throw switch **36–3** which is actuated by the relay **36** and a normally open contact **37–2** which is actuated by the relay **37**. The relay **42** is also connected between conductors **53** and **54** through the normally closed contacts of the switch **36–3** and the switch **37–2**. A normally open switch **42–2** which is actuated by the relay **42** is connected across the normally closed contacts of the switch **36–3** to form a self-holding contact of the relay **42**.

When the relay **37** is first energized and the relay **36** is then energized as shown in FIG. **8–1**, the switch **37–2** is closed to energize the relay **42** and the relay **42** closes the switches **42**–and **42–2** and is self-held by the switch **42–2**, and then the movable arm of the switch **36–3** is moved to the fixed contact connected to the relay **41** to energize the relay **41** and thereby gives a fire alarm from the fire alarm device (not shown). As the relay **40**, however, since the movable arm of the switch **37–3** is moved to the fixed contact connected to the relay **39** before the switch **36–2** is closed by the relay **36**, the relay **40** cannot be energized at all and the switch **40–1** is therefore not closed. Therefore, the relay **39** is not energized.

Furthermore, when the relay **36** is energized and thereafter the relay **37** is energized as shown in FIG. **8–2**, completely opposite operation results with the relays **39** and **40** and the relay **39** is energized to give an erroneous operation alarm from the erroneous operation informing device (not shown) but the relay **41** is not energized. In the case of erroneous operation as shown in FIG. **8–3**, neither relay **39** nor relay **41** is energized and no alarm is given in accordance with this circuit.

As described in the above, according to the system of this invention, true and erroneous actuations of the ionization smoke detector can be readily distinguished from each other and a false alarm cannot be produced by erroneous actuations of the smoke detector.

It should be noted that the circuit configurations described above are presented to aid in the explanation of this invention and various modifications and changes are possible for practicing the principle of this invention without departing from the scope of the invention. For example, the discriminator may include a conventional pulse counter for counting the number of pulses produced by the ionization smoke detector according to this invention.

What is claimed is:

1. A fire alarm system comprising an ionization smoke detector having a specific minimum enabling voltage and detecting smoke to produce a detection output under the condition that the applied voltage is higher than said minimum enabling voltage, a voltage source for supplying a voltage at least higher than said minimum enabling voltage to said ionization smoke detector, an alarm device for producing an alarm in response to said detection output, voltage changing means for reducing said higher applied voltage below said minimum enabling voltage to disable said detector in response to said detection output and restoring said higher applied voltage in response to said disabling of said detector, and discriminating means producing a periodic output produced by cooperation of said detector and said voltage changing means and a continuous output produced by erroneous operation, said outputs selectively operating said alarm device.

2. A fire alarm system according to claim **1** wherein said alarm device includes a fire alarm unit and an erroneous operation indicating unit, and said both units are driven selectively by said discriminating means.

3. A fire alarm system according to claim **1** wherein said voltage changing means includes a bipolar transistor controlled by said detection output and a Zener diode having a Zener voltage lower than said minimum enabling voltage, and said transistor and said Zener diode are connected in series between the supply terminals of said applied voltage.

4. A fire alarm system according to claim **1** wherein said applied voltage changing means includes a bipolar transistor connected between the supply terminals of said applied voltage and controlled by said detection output, a second voltage source having a voltage lower than said minimum enabling voltage, and means for interchanging said applied voltage source and said second voltage source in response to the conduction current of said transistor.

5. A fire alarm system according to claim **4** wherein said interchanging means includes a relay and said relay produces an output for driving said discriminating means.

6. A fire alarm system according to claim **1** wherein said applied voltage changing means includes a bipolar transistor connected between the supply terminals of said applied voltage and controlled by said detection output, and a resistance element connected in series to said supplied voltage source, the value of said resistance element being selected to make the applied voltage of said detector during production of the detection output lower than said minimum enabling voltage.

7. A fire alarm system according to claim **6** wherein said resistance element consists of the electromagnetic winding of a relay for producing an output for driving said discriminating means.

8. A fire alarm system according to claim **1** wherein said discriminating means includes a first capacitor which starts charging concurrently with initiation of said periodic output and continuous output and continues charging during the duration of said outputs, a first relay energized in response to a specific charge in said first capacitor, a second capacitor which starts charging with a specific delay from the initiation of said outputs and continues charging constantly, a second relay energized in response to a specific charge in said second capacitor, and means for discriminating the order of said energization of said first and second relays and driving said alarm device selectively, the time constants of charging said first and second capacitors being selected so that said second relay is energized earlier in the case of charging according to said periodic output and said first relay is energized earlier in the case of charging according to said continuous output.

9. An ionization smoke detector used in the system according to claim 1, including a pair of terminals, a closed ionization chamber and an open ionization chamber connected in series between said terminals, a field effect transistor having a gate electrode connected

to the connection point of said both ionization chambers and a source-to-drain path connected between said terminals and having a specific minimum enabling voltage, and a bipolar transistor and a Zener diode connected in series between said terminals, said bipolar transistor being controlled by said field effect transistor and said Zener diode having a Zener voltage lower than said minimum enabling voltage.

* * * * *