# United States Patent [19]

**Scheidweiler**

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[54] **IONIZATION FIRE ALARM**


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[58] **Field of Search** ..........340/237 S; 250/43.5 D, 44, 250/83.6 FT; 207/251, 279, 304



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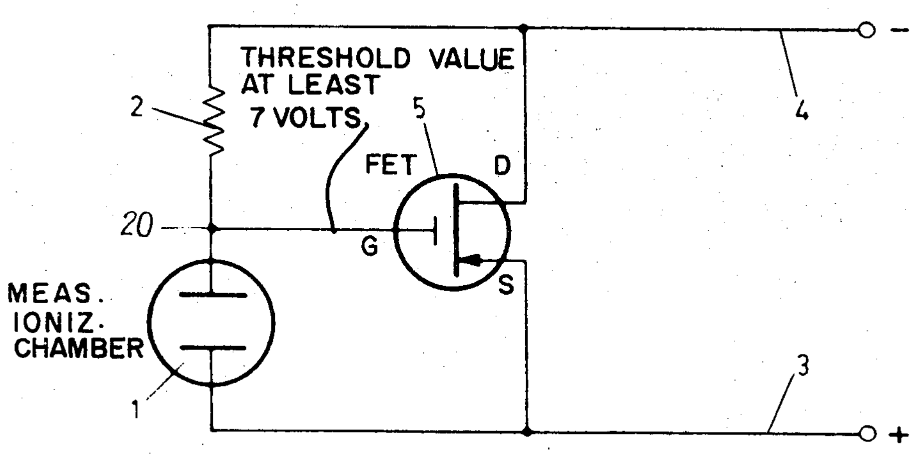
[57] **ABSTRACT**

An ionization fire alarm utilizing at least one transistor with high input resistance, such transistor being a field-effect transistor of the enhancement type having a threshold voltage above 7 volts. Further, the voltage value of the voltage source and the resistance value of a resistor element are selected such that the voltage drop at the ionization chamber without the influence of combustion aerosols is smaller than the threshold voltage of the field-effect transistor so that the field-effect transistor is therefore non-conductive or blocked, and additionally these values are simultaneously chosen such that the field strength, in the chamber regions of the ionization chamber in which at least 85 percent of the ionization current flows, is smaller than 5 V/cm.


**13 Claims, 3 Drawing Figures**



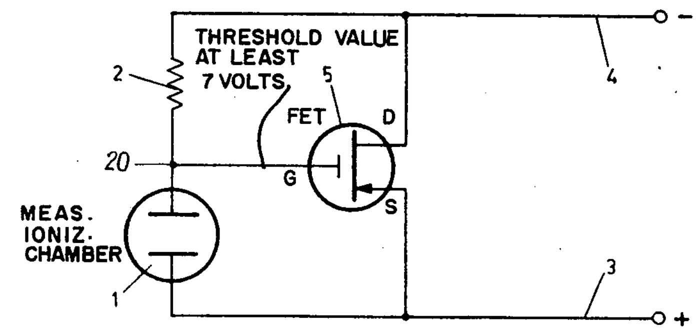



Fig. 1

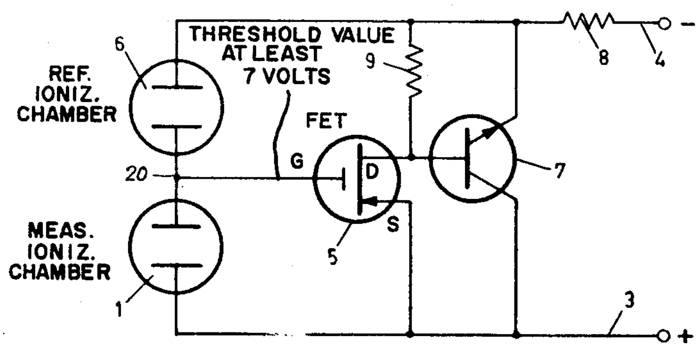



Fig. 2

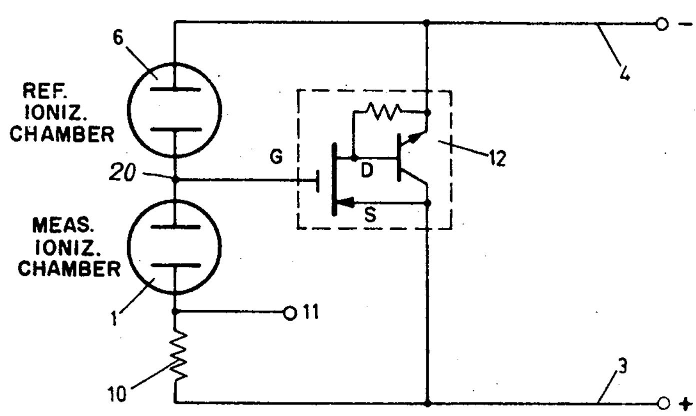



Fig. 3

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## IONIZATION FIRE ALARM

### BACKGROUND OF THE INVENTION

The present invention relates to an improved ionization fire alarm comprising at least one ionization chamber connected by a resistance element in series with a direct-current voltage source, and further includes an electric circuit equipped with at least one transistor possessing high input resistance, the control electrode of which is coupled with the junction point of the ionization chamber and the resistance element.

The mode of operation of an ionization fire alarm is predicated upon the face that the electric current flowing in an ionization chamber will be reduced in the presence of smoke aerosols. Thus, fire alarms of this type contain an ionization chamber accessible to the surrounding air. This ionization chamber possesses a radioactive radiation source for producing the required ionization. In most of the known ionization fire alarms this ionization chamber, also commonly known as a measuring chamber, is connected in series with a resistance element and electrically coupled to a voltage supply delivered from a central signal station. Oftentimes there is selected as the resistance element a second ionization chamber which is hermetically sealed or at least sealed to such an extent that combustion aerosols can only enter with great difficulty. In other words, the second ionization chamber is designed such that it only weakly responds to combustion aerosols. Upon entry of smoke particles into the measuring chamber, a voltage change takes place at the junction point of the ionization chamber with the resistance element due to a change in current in the ionization chamber. This voltage change id delivered to an electric circuit which produces an appropriate signal, for instance a current change at the central signal station, when the smoke density in the measuring chamber exceeds a predetermined threshold.

In a fire alarm of the mentioned type it would be desirable to have high sensitivity as well as operational reliability over a long span of time. Yet, the known fire alarms only fulfill these prerequisites in part.

The operational reliability of an electronic device depends to a large extent upon the type and number of the employed components. With ionization fire alarms one is particularly concerned with the amplification of an electrical signal which originates from an extremely high ohm source with an internal resistance of $10^{10}$ to $10^{11}$ ohms. This means that the electric circuit must possess a correspondingly high input resistance. Furthermore, the circuit must be able to differentiate between the presence and non-presence of an electrical magnitude, this is to say, it must contain a threshold-forming element. These requirements already demand for most of the known ionization fire alarms the use of a number of sensitive components which impair operational reliability. Furthermore, the additional use of components is required when further demands are placed upon the fire alarm, for instance, if there is desired self-holding of the fire alarm, an individual indicating device, or monitoring of the central signal station.

There is apparently only one ionization fire alarm known which operates with a very small expenditure of components. It contains essentially a cold cathode tube which has been specially developed for this purpose, and which possesses not only the required high input resistance but also the desired switching properties upon exceeding a threshold value. The measuring chamber is located directly parallel to the control electrode-cathode path and as the threshold valve there is used the ignition voltage of this tube path, which in the conventional ignition voltage range for gas discharge tubes is about 100 volts. Although this circuit works very reliably, it requires the use of a special tube with very narrow tolerances, and additionally, because of the required high ignition voltages, is limited to the operation of ionization chambers with relatively high chamber voltages.

A different problem is the smoke sensitivity of the ionization fire alarm. It has been found that for this purpose the electric field strength in that portion of the measuring chamber in which the major portion of the ionization current flows, approximately 85 percent, is decisive. A further known ionization fire alarm attains optimum smoke sensitivity in that, the field strength in the major portion of the measuring chamber is below 5 V/cm. However, it is necessary to work in the region of relatively low measuring chamber voltages, and specifically below about 20 volts. Yet, from the foregoing it has become apparent that an optimum sensitive ionization fire alarm cannot be realized when using gas discharge tubes as the amplifier element since the reduction of the ignition voltage of a gas discharge below 20 volts is not possible for physical reasons.

Therefore, attempts have been made to find other components operated with low voltage and having a sufficiently high input resistance.

A known circuit incorporates, for instance, at the input a capacitance diode which is located in an oscillator circuit. However, this required a large number of components and renders the circuitry subject to breakdown.

Other circuits use at the input field-effect transistors which as the sole transistor type possesses a sufficiently high input resistance.

Field-effect transistors are differentiated by two types, the enhancement type and the depletion type. Whereas the first type does not conduct current with zero control gate voltage, that is to say, provides a very high electrical resistance and only upon application of a voltage of the same polarity as the operating voltage of the transistor begins to conduct, in the second type a maximum current already flows with zero control gate voltage. In order to cut off the current there is required, just as in the case of an electron tube, an auxiliary voltage of opposite polarity in the operating voltage.

A known ionization fire alarm uses a field-effect transistor of the depletion type which without the presence of smoke particles in the measuring chamber conducts considerable current. This current, upon entry of combustion aerosols into the measuring chamber, only changes so slightly that additional components, for instance controlled rectifiers, are required as the threshold detector. This increases the susceptibility to breakdown.

Another known ionization fire alarm indeed utilizes a field-effect transistor of the enhancement type which in its rest state or condition does not conduct current, and only upon exceeding a certain smoke density concentration in the measuring chamber switches into its conductive state. However, known field-effect transistors possess a threshold voltage between 2 and 5 volts. In the event that the transistor should be non-conductive or blocked in its rest condition, then either the chamber voltage must be smaller than 5 volts or by using additional components there must be applied a pre-biasing to the transistor. The first proposal cannot be carried out since it has been found that the ionization current of ionization chambers with currents in the order of magnitude of $10^{-9} - 10^{-11}$ amperes is no longer stable with chamber voltages below 5 volts. The reason for this primarily resides in the influencing of the electric field through electrostatic charging. With such low field strength even the slightest influencing electrostatic charge is already sufficient to affect the current. The second possibility mentioned above can be realized with the aid of a voltage divider, a battery, a Zener diode or an auxiliary voltage delivered via an additional conductor. In any event, this requires additional expenditure of components, that is to say, more expensive manufacturing costs and, once again, susceptibility to breakdown.

Furthermore, oftentimes a greater relationship is desired of the alarm current to the rest current of a fire alarm, especially if a great number of fire alarms are connected in parallel to a central signal station, in order to be able to positively distinguish an alarm from the total-rest current of the installation. Previously this could be attained in that further components were controlled by the field-effect transistor, which, however, once again increases the susceptibility to breakdown. A direct use of the large resistance change of a field-effect transistor would only be possible if a transistor having zero rest current, in other words of the enhancement type, could be directly switched without further current limiting components in the alarm path through which the major portion of the alarm current flows.

## SUMMARY OF THE INVENTION

Accordingly, a primary objective of the present invention is the provision of a new and improved ionization fire alarm possessing optimum smoke sensitivity, an exceptionally small number of components and, therefore, increased functional reliability.

A further object of this invention is the provision of an ionization fire alarm having a larger ratio or relationship of alarm current to rest current.

Now, in order to implement these and still further objects of the invention, which will become more readily apparent as the description proceeds, the inventive ionization fire alarm is generally manifested by the features that there is employed a transistor with high input resistance, such transistor being a field-effect transistor of the enhancement type having a threshold voltage above 7 volts. Further, the voltage of the voltage source and the resistance of the resistor element are selected such that the voltage drop at the ionization chamber, without the influence of combustion aerosols, is smaller than the threshold voltage of the field-effect transistor so that the field-effect transistor is therefore non-conductive or blocked, and additionally are simultaneously so chosen that the field strength, in the chamber regions of the ionization chamber in which at least 85 percent of the ionization current flows, is smaller than 5 V/cm.

Field-effect transistors of the enhancement type with threshold voltages above 7 volts were not previously used, since any advantage for their prior utilization was not recognized; in fact, in complete contrast thereto, low threshold voltages were intentionally preferred. It is, however, possible to manufacture transistors with higher threshold voltages in that the thickness or the material of the dielectric between the semiconductor body and the control electrode are appropriately changed. For instance, it is possible to produce a sufficiently thick silicon oxide layer for a silicon semiconductor and, thereafter to apply a control electrode in such a manner that the threshold voltage of the thus produced transistor amounts to 9 volts.

The control path of such a transistor can be connected directly parallel to the measuring ionization chamber without necessitating a further auxiliary voltage. Consequently, all of the mentioned advantages can thus be obtained, namely, increased smoke sensitivity, increased operational reliability, less susceptibility to breakdown, simpler manufacturing operations and larger relationship of alarm current to rest current.

## BRIEF DESCRIPTION OF THE DRAWING

The invention will be better understood and objects other than those set forth above, will become apparent when consideration is given to the following detailed description thereof. Such description makes reference to the annexed drawings wherein:

FIG. 1 is a circuit diagram of an ionization fire alarm using one transistor;

FIG. 2 is a circuit diagram of an ionization fire alarm using two transistors; and

FIG. 3 is an ionization fire alarm with an integrated switching circuit.

## DESCRIPTION OF THE PREFERRED EMBODIMENTS

Describing now the drawing, in FIG. 1 the ionization chamber 1 which is open to the surrounding air is connected in series with a resistor or resistance 2. Ionization chamber 1 and resistor 2 are supplied via conductors 3 and 4 from a non-illustrated central signal station with a direct-current voltage of 12 to 24 volts. The spacing and the configuration of the electrodes in the ionization chamber 1 are chosen such that, there where the major portion of the ionization current flows the electric field strength is smaller than 5 V/cm. The junction point 20 of the ionization chamber 1 and the resistor 2 is coupled with the control electrode or gate of a field-effect transistor 5 of the enhancement type, the source electrode and drain electrode of which are coupled with the supply conductors 3 and 4 respectively. The threshold voltage of transistor 5, that is, the control voltage above which the field-effect transistor 5 becomes conductive, is about 9 volts.

The resistance 2 is dimensioned such that the voltage drop across the electrodes of the ionization chamber 1 under normal conditions, that is, when the surrounding atmosphere does not contain combustion aerosols, is about 6 volts to 8 volts, in other words below the threshold voltage of the field-effect transistor 5 so that such therefore is non-conductive or blocks and only delivers a very small rest current. If combustion aerosols enter the ionization chamber 1, then its resistance increases and therefore also the voltage drop across the ionization chamber and the control path of the field-effect transistor **5** arranged parallel to the ionization chamber, so that the field-effect transistor begins to conduct and an increased alarm current appears at the supply conductors **3** and **4** which is recorded or detected at the central signal station. Since this circuit only contains a single semi-conductor element it is extremely operationally reliable. Since the field-effect transistor **5** itself forms the alarm path of the fire alarm through which the main current flows between the supply conductors in the case of an alarm, the resistance change of the field-effect transistor group response is directly employed for forming the alarm current. As a result, the relationship of the alarm current to the rest current can become especially large without further components being required for this purpose.

In FIG. **2** instead of a resistor a second ionization chamber **6** is connected in series with the ionization chamber **1**. Although the ionization chamber **1** is accessible to the surrounding atmosphere, the other ionization chamber **6** is either completely or almost completely closed, so that changes in the surrounding atmosphere only affect the ionization chamber **6** with a time delay. Further, ionization chamber **6** can also be constructed such that it responds considerably weaker to changes in the surroundings than the ionization chamber **1**. It is advantageous if the ionization chamber **6** is saturated. Once again both ionization chambers **1** and **6** are connected via supply conductors **3** and **4** respectively, with a central signal station. The junction point **20** of both ionization chambers **1** and **6** is again coupled with the gate or control electrode of field-effect transistor **5**. Here also there is used a field-effect transistor **5** of the enhancement type with a threshold voltage of about **9** volts, and the voltage at the ionization chamber under normal circumstances is again less than 9 volts. The source electrode of the field-effect transistor **5** is coupled with the base of a further transistor **7**. A resistor **9** is connected between the base and supply conductor **4**. Through use of the second transistor **7** the current increases more rapidly with increasing voltage above the threshold voltage of the field-effect transistor, than if only a single transistor were used, that is to say, the steepness of the circuit is further improved. As a result, there is achieved the effect that already upon slightly exceeding the alarm threshold a higher alarm current flows. If necessary, to limit the alarm current there can be used a resistor **8** in the supply conductor in the event that limiting of the alarm current is not undertaken at the central signal station.

In the arrangement shown in FIG. **3** the ionization chamber **1** and the ionization chamber **6** are again connected in series and the junction point **20** of both chambers **1**, **6** is coupled with the gate or control electrode of a field-effect transistor. Between the ionization chamber **1** and the supply conductor **3** there is additionally connected a resistor **10** which, however, is smaller by at least one order of magnitude, i.e., by a factor of **10**, than the resistance of ionization chamber **1**, so that the ionization current is not appreciably influenced by this resistor **10**. With the aid of this resistor **10** the ionization current can be further checked at the connection terminal **11**. The electronic circuit, indicated generally by reference numeral **12**, once again will be seen to contain a field-effect transistor, a second transistor and a base resistor, but in this case these components are combined into an integrated circuit **12**.

Additionally, it is of course also possible to provide for these circuits known expedients for improving the utility of fire alarms, for instance time-delayed response means, self-holding means which, after a fire alarm has responded and upon termination of the alarm conditions, does not allow such fire alarm to return to its normal state unless it is reset manually, and the different known types of monitoring devices for a fire alarm installation with respect to functional readiness of the individual fire alarms or for indicating malfunctioning of non-functioning fire alarms, as well as individual indication of fire alarms of an installation which have responded.

The different exemplary embodiments of inventive fire alarms clearly indicate that through the use of a field-effect transistor of the enhancement type with a threshold voltage above 7 volts, it is possible to build an ionization fire alarm which possesses both optimum sensitivity due to low field strength in the measuring chamber as well as also increased functional reliability and less susceptibility to breakdown because of the reduced number of components, and thus can be manufactured cheaper. Additionally, it is possible in this manner, and without having to use additional components, to build a fire alarm with increased ratio or relationship of alarm current to rest current.

It is here still further mentioned that an optional resistance element can be connected in series with the ionization chamber **1**. In FIG. **1** this resistance element was designed in the form of the ohmic resistor **2**, in FIG. **2** as the reference ionization chamber **6** which, as is known, exhibits a non-linear current-voltage characteristic, and in FIG. **3** as a combination of reference ionization chamber **6** and ohmic resistor **10**. As far as the function of the ionization fire alarm is concerned, the characteristic of the resistance element is without importance. Under the term "resistance element" there can be thus understood a resistor with optional dependency upon voltage drop and current.

It should now be apparent that the objects set forth at the outset of this specification have been successfully achieved. Accordingly,

What is claimed is:

1. An ionization fire alarm comprising an ionization chamber accessible to the surrounding air, said ionization chamber being provided with two electrodes, a source of direct-current voltage, a resistance element with two terminals, one electrode of said ionization chamber being connected to one terminal of said resistance element and the other electrode of said ionization chamber and the other terminal of said resistance element being connected to said direct-current voltage source, an electric circuit incorporating at least one field-effect transistor having gate, source, and drain electrodes, the gate electrode of said field-effect transistor being connected to the connection point of said one electrode of said ionization chamber and said one terminal of said resistance element, the source and drain electrodes being electrically connected to said

voltage source, said field-effect transistor being of the enhancement type and having a threshold voltage above 7 volts, the control path of said transistor connected directly parallel to the measuring ionization chamber without the need for further auxiliary elements, said direct-current voltage source having a voltage value and said resistance element having a resistance value such that the voltage drop across said two electrodes of said ionization chamber without the influence of combustion aerosols is smaller than said threshold voltage of said field-effect transistor, whereby said field-effect transistor is nonconductive, and said voltage source having a voltage value and said two electrodes of said ionization chamber being spaced from one another by an amount such that the field strength in the chamber regions of the ionization chamber in which at least 85 percent of the ionization current flows, is smaller than 5 V/cm.

**2.** An ionization fire alarm as defined in claim **1**, wherein said resistance element is a second ionization chamber.

**3.** An ionization fire alarm as defined in claim **2**, wherein said second ionization chamber has a saturated ion current.

**4.** An ionization fire alarm as defined in claim **1**, wherein said at least one ionization chamber is connected in parallel between the gate electrode and one of said source or drain electrodes of the field-effect transistor.

**5.** An ionization fire alarm as defined in claim **1**, wherein the source electrode of the field effect transistor is electrically connected with the control electrode of a further transistor.

**6.** An ionization fire alarm as defined in claim **5**, wherein said field-effect transistor and at least said further transistor are connected in an integrated circuit.

**7.** An ionization fire alarm as defined in claim **6**, further including a load resistor constituting part of said integrated circuit.

**8.** An ionization fire alarm as defined in claim **1**, wherein the drain electrode of the field effect transistor is electrically connected with the control electrode of a further transistor.

**9.** An ionization fire alarm as defined in claim **8**, wherein said field-effect transistor and at least said further transistor are connected in an integrated circuit.

**10.** An ionization fire alarm as defined in claim **9**, further including a load resistor constituting part of said integrated circuit.

**11.** An ionization fire alarm as defined in claim **1**, wherein said electric circuit includes a current-limiting resistance.

**12.** An ionization fire alarm as defined in claim **1**, wherein said electric circuit is provided with a current flow path composed exclusively of controlled semiconductors through which current flow path the main current flows in the event of an alarm.

**13.** An ionization fire alarm as defined in claim **1**, wherein said ionization chamber is connected in series with said resistance element, a further resistance connected with said direct-current voltage source, said ionization chamber having a resistance value between its two electrodes which is greater by at least a factor of 10 than the resistance value of said further resistance, said ionization chamber and said further resistance being connected between the gate electrode and one of the other electrodes of said field-effect transistor.

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