

United States Patent

Roveti

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[54] CURRENT LIMITER

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323/9

[51] Int. Cl. **H03k 5/08**

[58] Field of Search.....317/16, 20, 33 SC; 307/304,
307/237, 202; 323/9, 16

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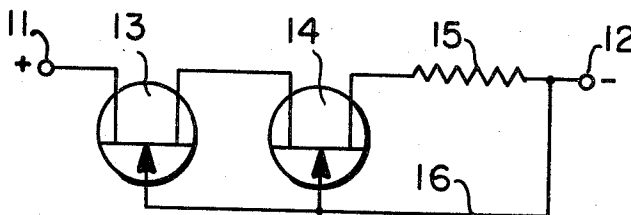
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[57]

ABSTRACT

This invention relates to current limiters particularly for medical equipment. The current limiter of this invention is adapted to be inserted directly into the line which connects a patient to an electronic device. It comprises a pair of field effect transistors connected in series with a biasing resistor. One of the transistors has a lower cut-off potential than the other, and the one with the higher cut-off point also has substantially higher resistance and breakdown strength.

10 Claims, 4 Drawing Figures



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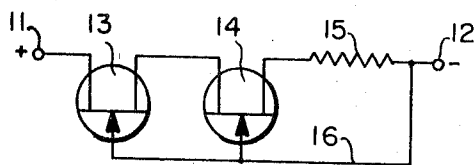


FIG. 1

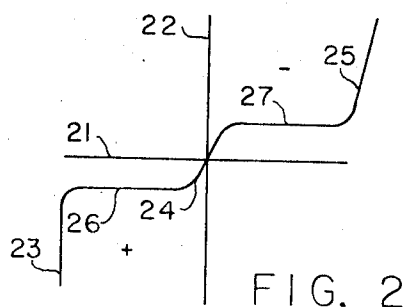


FIG. 2

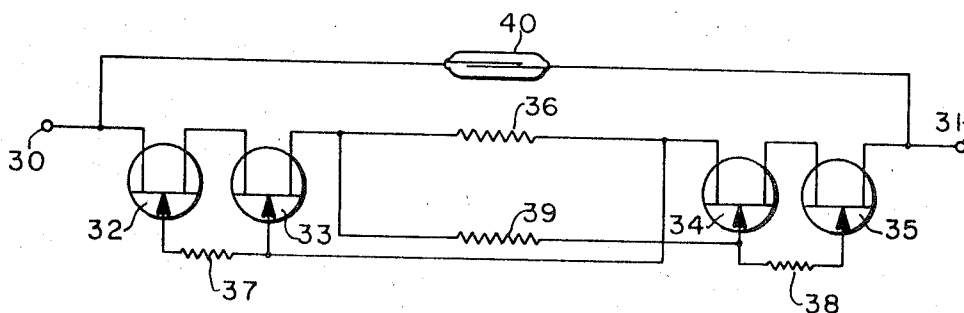


FIG. 3

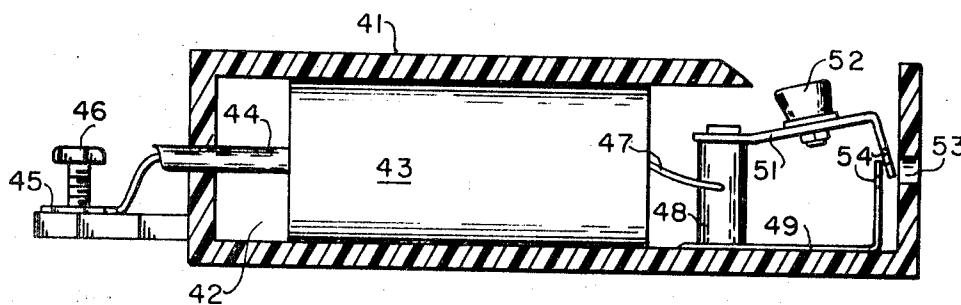


FIG. 4

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CURRENT LIMITER

This invention relates to protective devices, and more particularly to devices which can be incorporated into an electrical circuit with ease to limit the current flowing therethrough.

More electronic equipment than ever before is being used today. And more persons are using that equipment. This is true in every field and every location, but it is particularly true of the medical profession. Medical patients are continually being monitored by electronic equipment during surgery; newer techniques for analyzing heart ailments by computer are being devised; electrocardiograms are common; electroencephalograms are more frequently taken than before; and the list continues to grow. Although these electronic machines are providing the best medical care in the world, they present a constant danger to the patient should they malfunction. This is particularly true of elderly and cardiac patients, and it is more likely to happen with equipment that is directly connected to the patient's body. To illustrate the concern over the possible problems that electricity can cause, the fire insurance underwriters require that operating room floors have an electrical resistance of about 25,000 ohms. This permits accumulating electrical charges to leak off without the danger of a sudden discharge which could ignite the highly flammable anaesthetic. Other dangers are also present with the use of electrical equipment. The most dangerous situation is probably where there is a sudden application to a patient of a large flow of electricity, which could occur should a piece of electronic monitoring gear which is connected to a patient suddenly malfunction.

It is an object of this invention to provide a new and improved protective device.

It is another object of this invention to provide a new and improved device to protect persons from the sudden surge of electricity often produced by a malfunction in electrical equipment.

It is a further object of this invention to provide a new and improved circuit for protecting individuals from excessive electrical currents.

Other objects and advantages of this invention will become more apparent as the following description proceeds, which description should be considered together with the accompanying drawings in which:

FIG. 1 is a schematic circuit diagram of a simple device in accordance with this invention;

FIG. 2 is a curve which reflects the operation of the device of FIG. 1;

FIG. 3 is a circuit diagram of a bipolar system similar to that of FIG. 1; and

FIG. 4 is a sectional view of one physical form the device of this invention can assume.

Referring now to the drawings in detail, the reference characters 11 and 12 designate terminals by which the limiting circuit can be connected in series with a monitor line to be protected. The terminal 11 is connected to the drain electrode of a field effect transistor 13, the source electrode of which is connected to the drain electrode of a second field effect transistor 14. The source electrode of the transistor 14 is connected to one side of a resistor 15, the other side of which is connected to the terminal 12. The gate electrodes of both of the transistors 13 and 14 are connected together and to the terminal 12.

In operation, the application of an electrical voltage across the terminals 11 and 12 cause a current to flow through the resistor 15 and the drain-source conduction path of the two transistors 13 and 14. As current flows through the resistor 15, it generates a voltage drop which is applied to the two gate electrodes of the transistors 13 and 14. As the current flowing in the series circuit increases, the voltage applied to the two gate electrodes also increases until the voltage is reached at which one of the transistors, transistor 14, cuts off (or is pinched off). When the transistor 14 stops conducting, the voltage across the entire circuit rises, and a higher voltage is applied to the gate electrode of the transistor 13 to cut off that transistor. To provide rapid and effective operation of the cir-

cuit, the two transistors 13 and 14 have different operating characteristics. One of the transistors, the transistor 14 in this example, has a fairly low bias voltage at which it pinches off. But those field effect transistors (FET) which have low cut-off biases also usually have low resistance and can withstand only low voltages applied across them. On the other hand, the other transistor 13 has a higher cut-off voltage, a higher cut-off resistance, and can withstand much higher voltages. By using a combination of transistors of the type described, the circuit of FIG. 1 combines rapid response to rises in current flow with high voltage cut-off protection.

The operation of the transistors 13 and 14 can be explained with reference to the curve of FIG. 1. This curve is the conduction curve of a FET in a positive direction. The vertical axis 22 represents current flowing through the FET, and the horizontal axis 21 represents voltage applied across the terminals 11 and 12. Each of the FETs has a normal operation region designated 24 wherein the current flowing through the transistor varies linearly with changes in voltage. However, when the applied voltage rises beyond the knee of the curve, the transistor saturates, and further changes in applied potential have little effect on the current flowing through the transistor. This is shown at 26 and 27. Once the breakdown potential of the transistor is reached, current increases rapidly which increased applied voltage. This is shown at 23 and 25. The curve of FIG. 2 is symmetrical in that it shows both positive and negative portions of the curve. In normal operation of the circuit of FIG. 1, the transistors 13 and 14 operate in the positive region of 24. Should the current flow become excessive, the transistors quickly move into the region represented at 27. Operation in the region 25 is to be avoided.

The current limiter shown in FIG. 1 is unipolar; that is, it responds to current flowing in one direction only. In an alternating current path, such a circuit would act as a half-wave rectifier, and the person being protected would still be able to receive quite a shock. Since most signal paths are alternating, a bipolar circuit is desirable. Such a bipolar circuit is shown in FIG. 3 in which a pair of terminals 30 and 31 are adapted to be connected to the line being protected. The terminal 30 is connected to the drain electrode of a field effect transistor 32 whose source electrode is connected to the drain electrode of a second field effect transistor 33. At the same time, the terminal 31 is connected to the drain electrode of a transistor 34 whose source electrode is connected to the drain electrode of a transistor 35. The source electrodes of the two transistors 33 and 34 are connected to opposite sides of a bias resistor 36. The gate electrode of the transistor 32 is connected through a resistor 37 to the gate electrode of the transistor 33, and these two gate electrodes are connected to the junction of the resistor 36 and the transistor 34. The gate electrodes of the transistors 34 and 35 are connected together through a resistor 38 and the gate electrode of the transistor 34 is connected to the other side of the resistor 36, to the junction of the resistor 36 and the transistor 33. An arc gap 400 is connected across the entire circuit, between the terminals 30 and 31.

The operation of the circuit of FIG. 3 is very similar to the operation of two of the circuit of FIG. 1. The transistors 32 and 33 are connected together to operate as one pair, and the transistors 34 and 35 operate as another pair. The gate electrodes of the transistors 32 and 33 are connected together and to one side of the resistor 36, so that when the current flowing through the circuit from transistor 32 to transistor 35 rises above the safe level, the increased bias pinches off conduction through the transistor 33, and this pinches off conduction through the transistor 32. Similarly, when the current flowing through the circuit from transistor 35 to transistor 32 increases above a safe limit, the transistor 34 is pinched off, and this pinches off the transistor 35. Limiting the conduction through the circuit could raise the voltage across the circuit to an unsafe value causing breakdown of the circuit components and possible open air discharge. Since this condition is to be prevented around anaesthetics, oxygen, or in any similar situa-

tion, the arc gap 40 is provided. This gap can be a simple reed switch which has been found to be inexpensive and quite satisfactory. Since the reeds in the switch are enclosed in an air-tight capsule, the discharge of excess potential across the gap is safe in any atmosphere. In addition, because of the inherent high impedance of the gap 40, little current will flow through it to injure the patient. The resistors 37, 38, and 39 are decoupling resistors which are provided to permit independent operation of the circuit in both directions, without the operation in one direction affecting the other circuit. Since a single resistor 36 is used for biasing both of the circuits, the series resistance of the entire circuit is maintained low. The resistance of the transistors 32-35 are quite low when they are conducting (when they operate in their normal ranges), the resistor 36 acts as virtually the sole resistance in the circuit. This resistance is kept low so that it does not interfere with the operation of the monitoring equipment if the circuit of FIG. 3 is used.

The circuits of FIGS. 1 and 3 are designed to be used in those cases where electrodes or sensing terminals are actually applied to the bodies of individual persons. In such cases, the tests are often conducted by operators having little skill or training. Therefore, it is important to provide a suitable unit which is readily connected into the normal electrode path without requiring special training or skill. In addition, the simpler the device is to use, the less likely it is to be overlooked or ignored. One such unit is shown in FIG. 4. A housing 41, which can be formed of a synthetic resin or other suitable construction material has an interior hollow 42 which contains the circuitry 43 shown in FIG. 3, for example. The individual components such as the transistors 32-35 and the resistors 36-39 are cast in a potting compound such as an epoxy resin to provide additional mechanical support and to provide additional electrical insulation and protection. A wire 44 extends from the potted unit 43 at one end and is connected to a conductive tab 45 which is mounted on an external extension of the housing 41. The tab 45 supports a terminal screw 46 to which one end of the circuit being monitored can be connected. A second wire 47 extends from the other end of the potted unit 43 and is attached to a post 48 which connects two conductive strips 49 and 51. Both of the strips 49 and 51 are generally "L" shaped, with the long leg of the L of the top strip 51 being bent at a slight outward angle. The top strip 51 has a snap terminal 52 attached to its upper surface by any suitable means. The end of the housing 41 has a perforation 53 formed in it, and the lower strip 49 has a perforation in line with the perforation 53. The upper strip 51 also has a perforation in it, but due to the fact that the strip 51 is bent slightly outwardly, its perforation is not in line with the perforation 53.

The housing 41 provides protection from mechanical shocks, from the ravages of the environment, etc., and the potting compound around the electrical components also provides similar protection. In most situations where the apparatus of FIG. 4 would be used, the signal lines being monitored ordinarily terminate in standard electrical terminals such as spade terminals, pins, etc. The housing 41 is designed to provide easy connection to such circuitry. In order to render it more versatile, the terminal screw 46 can be provided with a perforation. If so, then the spade terminal, or the pin terminal, or even the bare wire can be wrapped around the screw 46 or inserted into the perforation in the screw 46. The screw is tightened, and the connection has been made. At the other end of the housing 41, the snap 52 is depressed, bending the strip 51 down until the perforation in that strip is in line with the perforation in housing 41 and the strip 49. One end of the spade terminal, or the pin, or the bare wire, or the like, is then inserted through the aligned perforations, and the snap 52 is released. The natural resilience of the strip 51 causes it to rise against the connector, making a rapid and tight connection to monitoring lines such as those used with electrocardiogram electrodes. The terminal structure including snap 52, perforations 53 and 54, and spring strip 51 is unique since it will accept 95 percent of all bedside monitoring equipment

terminals used in critical patients areas. This provides immediate improvement in electrical safety in the care of patients without complicating and delaying installation procedures.

This specification has described a new and improved protective device particularly suited for use with medical electronic equipment. It is realized that the above description may suggest to others skilled in the art additional ways in which the principles of this invention may be used without departing from its spirit. It is, therefore, intended that this invention be limited only by the scope of the appended claims.

What is claimed is:

1. A current limiter protective device for use with monitoring equipment, said device comprising a first electronic switch comprising a first main conduction path and a first control element, a second electronic switch having a second main conduction path and a second control element, said first control element responding to a relatively low switching potential to drive said first main conduction path into a saturation condition, said second control element responding to a relatively high switching potential to drive said second conduction path into saturation, a biasing impedance means for connecting said first and second main conduction paths and said impedance in series, means for connecting said first and second control elements to said impedance, and means for connecting said series arrangement into a circuit to be protected.

2. The device defined in claim 1 wherein said first and second electronic switches comprise components which have low impedances in their normal operating ranges and higher impedances in their saturation ranges.

3. A current limiter protective device for use with monitoring equipment, said device comprising a first pair of electronic switches connected together in series, a second pair of electronic switches connected together in series, each of said switches of said first and second pairs including a control element, a switching impedance, means for connecting said switching impedance in series with said first and second pairs, means for connecting the control elements of said first pair to said impedance to respond to excessive current flowing in a first direction through said impedance to drive the switches of said first pair into saturation, means for connecting the control elements of said second pair to said impedance to respond to excessive current flowing in a second direction through said impedance to drive the switches of said second pair into saturation, and means for connecting said series arrangement into a circuit to be monitored.

4. The device defined in claim 3 wherein the switches of said first and second pair comprise components which have low impedances in their normal operating ranges and higher impedances in their saturation ranges.

5. The device defined in claim 4 further including a high voltage protective device connected across said series arrangement of said first and second pairs of switches and said impedance.

6. The device defined in claim 5 wherein said high voltage protective device is a hermetically sealed arc gap.

7. The device defined in claim 3 further including a high voltage protective device connected across said series arrangement of said first and second pairs of switches and said impedance.

8. The device defined in claim 7 wherein said high voltage protective device is a hermetically sealed arc gap.

9. The device defined in claim 3 wherein said means for connection into a circuit to be monitored includes a first terminal connector generally comprising a post connector and a second terminal connector generally comprising a spring connector.

10. The device defined in claim 9 wherein said spring connector comprises a first conductive element and a second conductive element, each of said conductive elements having a perforation, the perforations in said first and second elements not being aligned, and means for deflecting said second conductive element to align the perforations in said first and

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second conductive elements to accept a monitoring terminal therein.

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