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J. J. KLEIMACK ET AL

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RESISTOR DEVICE

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FIG. 1

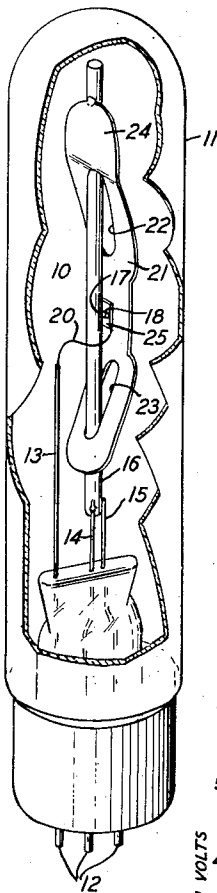


FIG. 2

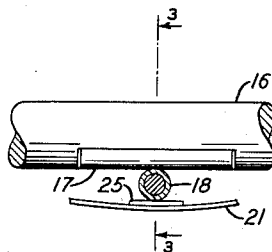


FIG. 3

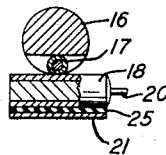
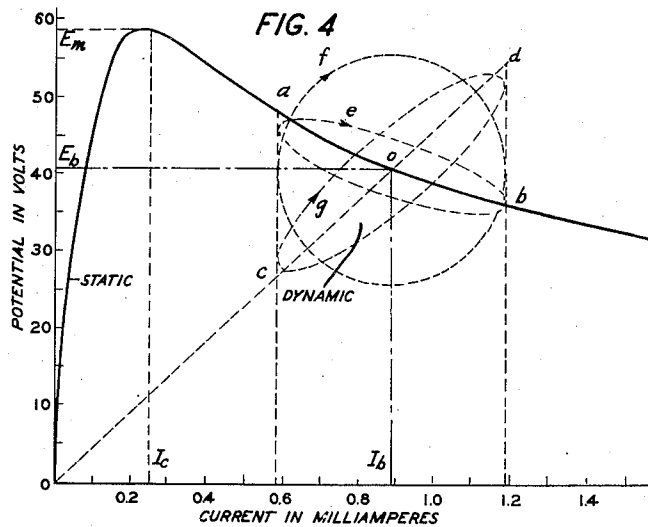


FIG. 4



INVENTORS J. J. KLEIMACK
G. L. PEARSON

BY

Walter C. Kiesel

ATTORNEY

UNITED STATES PATENT OFFICE

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RESISTOR DEVICE

Joseph J. Kleimack, Bayonne, and Gerald L. Pearson, Millington, N. J., assignors to Bell Telephone Laboratories, Incorporated, New York, N. Y., a corporation of New York

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7 Claims. (Cl. 201—63)

This invention relates to resistors and more particularly to resistors having a relatively high temperature coefficient of resistance and low thermal inertia.

Resistors, the resistance of which varies greatly with changes in temperature, have for convenience been called "thermistors," the term being derived from the words "thermal" and "resistor." Wherever the word thermistor appears in this specification or the appended claims, it is intended to designate a resistor having the foregoing characteristic. Since most of the known materials exhibiting thermistor characteristics and at the same time having sufficient conductivity to render them useful as circuit elements, comprise the semiconductors having high negative resistance-temperature coefficients, exemplary descriptions and explanations in this specification may be made with reference to such materials. It should be understood, however, that such electrically conducting materials as may have a high positive resistance-temperature coefficient, are not thereby excluded from the invention described and claimed.

It has been found that a thermistor may be made to exhibit a negative resistance characteristic. For example, the static voltage-current characteristic curve of a negative resistance-temperature coefficient thermistor rises to a voltage maximum and then falls off. This declining voltage-current curve is an indication of the negative resistance characteristic. If a sufficient direct current voltage is applied to such a thermistor to bias it beyond the voltage maximum point, the device will react to an applied alternating current as if its resistance were negative, provided the frequency of the alternating current is not too high. A thermistor so used may be made to oscillate. The frequency of oscillation depends upon the heating and cooling ability of the thermistor, i. e., its thermal inertia. If the device is constructed to have low thermal inertia it can be made to oscillate at relatively high frequencies.

It is an object of this invention to construct a thermistor having low thermal inertia.

A feature of this invention resides in a resistor device constructed to present a very small volume of thermistor material to the applied current.

Other and further objects and features of this invention will be understood more clearly and fully from the following detailed description with reference to the accompanying drawing in which:

Fig. 1 is a perspective view of one illustrative form of the device;

Figs. 2 and 3 are enlarged views showing in detail certain features of the device of Fig. 1; and

Fig. 4 is a plot showing static and dynamic characteristics of a typical thermistor.

Referring to the drawing, 10 is the thermistor device mounted in the envelope 11 and connected to terminal members or contact pins 12 by means of conductors 13, 14 and 15. The device is built around a rod 16 mounted on conductors 14 and 15. The rod 16 may be made of hardened steel, tantalum, tungsten or other suitable material. The conductors 14 and 15 are preferably secured, as by welding, to spaced portions of the rod 16 to inhibit twisting thereof. The rod 16 has a recess on one side adjacent its mid-portion to receive an element 17. The element 17 is of hard surface conductive material and may include material of high resistance-temperature coefficient.

As shown in the drawing, the element 17 comprises a fine wire, for example, of tantalum or tungsten, coated with a thin film of semiconductive material such as boron. The film should be thin with respect to the diameter of the wire so that the volume of metal is high as compared with the volume of semi-conductive material. The element 17 may be secured in the recess of rod 16 by any of several suitable methods of which welding has been found particularly satisfactory. To prepare the element 17 for welding, a small amount of the semi-conductive material may be removed from the wire adjacent its end or if the material is boron small spots of platinum boride may be provided thereon. A small amount of semiconductive coating may be removed from the ends of the wire by crushing as in a pair of pliers. Platinum boride spots may be made by playing a small flame on a platinum wire held against the boron coating. Another element 18, which may be similar to element 17, may have a conductive lead 20 welded or otherwise secured in electrical connection to one end thereof. Element 18 is oriented at an angle, preferably a right angle, to element 17 and held in contact therewith by means of a spring 21. The spring may be flat and of clock spring steel or equivalent material. Adjacent the ends of the spring are two elongated openings 22 and 23. In assembling the device the spring is bowed and the rod 16 is inserted in the openings 22 and 23. A bent over portion 24 of the spring 21 is secured to the rod 16, e. g., by welding. The element 18

may be insulated from the spring 21 by a member 25 of insulating material such as a small piece of mica. Lead 20 from the element 18 is connected to the conductor 13 which is in turn connected to one of the contact pins 12. Electrical connection to the element 17 is by way of rod 16 and conductors 14 and 15 or either of them.

The envelope 11 may be filled with helium to increase the cooling rate of the device. This may be done by evacuating the envelope to about 10^{-4} millimeters of mercury and baking it at about 200° C. for approximately fifteen minutes to remove absorbed gases, etc. The device is then cooled and the helium introduced, the final pressure being about atmospheric or slightly thereunder.

Various modifications may be made in the above-described structure to produce similar resistor devices. Each of the elements 17 and 18 may have a thin coating of hard, high resistance-temperature coefficient material or the coating may be provided on one only. For example, a bit of tungsten or tantalum wire may be welded in the recess of rod 16 as the element 17, or such a bit of wire may be used as the element 18. In either case the opposing element will have a thin coating of semiconductive material thereon. The recess in the rod 16 may be omitted and a semiconductively coated element 18 pressed directly against the rod. In such a case the rod should be of a material that does not react with the semiconductive material. For example, if the semiconductive material were boron the rod 16 might be of tungsten or tantalum but not of steel. Whatever the modification, the contact portions should present to each other relatively hard surfaces to inhibit deformation thereof, they should present contact surfaces to provide a very small area of contact and the layer of semiconductive material should be so thin that it is in contact with a relatively large mass of metal i. e., the metal core. The elements 17 and 18 or either of them may be made of other materials, such as tungsten wire coated with uranium oxide or with a mixture of nickel and manganese oxides, or other suitable high resistance-temperature coefficient materials. Instead of employing helium in the envelope it may be evacuated to from 1×10^{-5} to 5×10^{-6} millimeters of mercury. As another alternative, the envelope 11 may be filled with a liquid which will not react with the various elements and which will not decompose at the operating temperature, i. e., about 300° C. Mechanical stability, i. e., rigidity and freedom from twisting may be obtained by using a flat conductor in place of the two conductors 14 and 15. The rod 16 may be made of insulating material, such as glass or porcelain, with the element 17 or the equivalent thereof embedded in one side adjacent its mid-portion. Such a rod could be secured directly in the base of the envelope and connection made to the element 17 by means of a conductive lead like lead 20. If the rod 16 were made of insulating material it would not be necessary to insulate the element 18 from the spring 21.

An understanding of the operation of this device may be derived from a more specific discussion of the negative resistance or declining voltage current characteristic obtainable with thermistors. In Fig. 4 there is shown a voltage-current plot of the static and dynamic characteristics of a thermistor having a negative temperature coefficient of resistance. As may be

seen from an inspection of this figure, the curve of static characteristic rises to a voltage maximum E_m and then falls off. The static characteristic is obtained by subjecting the thermistor to increasing direct currents and measuring the voltage for each current.

Dynamically, the alternating current resistance is negative in the region beyond the voltage maximum E_m for sufficiently low frequencies. If a direct current of a value I_b greater than I_c (that current corresponding to E_m) be applied to the thermistor, a superposed alternating current of frequency approaching zero will trace out a curve aob , approximating the static characteristic. If the superposed current has a very high frequency, the thermal lag of the thermistor will prevent any change in temperature and hence in resistance from taking place during a single cycle. The voltage current trace therefore will be along the ohmic resistance line cod . At intermediate frequencies, the superposed current will produce traces as shown at e , f and g in the order of increasing frequency. At low frequencies, the effective alternating current resistance is negative, at high frequencies it is positive and at intermediate frequencies it may be either positive or negative; thus for some critical frequency it becomes equal to zero. This latter is the maximum frequency at which the device may be made to oscillate. In the devices of this invention, the thermal lag is very low so that the frequency at which the resistance is zero is very high. For example, devices having very thin boron films as the active thermistor material have been made to present a negative resistance to alternating current up to about 60 kilocycles per second.

The structure of a rapidly acting or high speed thermistor made in accordance with this invention provides a device in which the active volume of high resistance-temperature coefficient material is very small, but is in intimate thermal connection with larger bodies or masses of material having relatively high thermal conductivity. Thus the small volume subjected to electrical current is quickly heated and the heat is conducted away rapidly upon cessation of current flow. Such a device is capable of responding to rapidly fluctuating current and is therefore available for a rather wide field of use. These devices connected in suitable circuits may be used as oscillators, modulators, amplifiers or filters.

Although specific embodiments of this invention have been described and illustrated it is to be understood that modifications may be made therein within the spirit and scope of the appended claims.

What is claimed is:

1. A resistor device comprising a relatively stiff rod, a first member secured centrally of said rod, a second member, spring means secured to said rod and embracing said second member to hold it between the rod and spring and against said first member, said members being shaped and oriented to make substantially point contact with one another, both members having relatively hard surfaces, at least one member including a thin layer of high resistance-temperature coefficient material at the point of contact, and means for connecting each member to an electric circuit.

2. A resistor device comprising a stiff elongated body, a first member comprising a thin layer of high resistance-temperature coefficient material secured centrally of said body, a second member

also comprising high resistance-temperature coefficient material, a spring means secured to said body and embracing said second member to hold it against said first member, said members having convex portions oriented to make substantially point contact with each other, and means for connecting each member to an electric circuit.

3. A resistor device comprising a stiff metal rod having a recess centrally thereof, a fine tantalum wire having a thin coating of boron thereon, said wire secured in said recess, a thin, flat spring of metal secured at one end to said rod, which passes through an orifice adjacent the other end thereof, a second boron coated tantalum wire oriented substantially at right angles to the first wire and held in place by said spring, means for insulating the second wire from the spring, electrical connectors secured respectively to the rod and the second wire, an envelope enclosing the foregoing assembly, and a gas having a relatively high thermal conductivity within said envelope.

4. A resistor device comprising a conductive rod having a recess on one side thereof intermediate its ends, a first fine wire coated with a thin film of relatively hard, high resistance-temperature coefficient material secured in said recess and substantially parallel to said rod, a second fine wire coated with relatively hard, high resistance-temperature coefficient material, a flat spring having elongated openings adjacent its ends, said spring being bowed with the rod passing through the elongated openings, one end of the spring being secured to the rod, said second, coated, fine wire being between the rod and the central portion of the spring and urged toward the first wire by the spring, the wires being relatively oriented at such an angle that their coatings are in substantially point contact, an envelope having a plurality of conductors sealed therethrough, at least two of said conductors being secured in spaced, substantially parallel relation to said rod, and means for electrically connecting one other of said conductors to said second fine wire.

5. A resistor comprising a relatively rigid rod of conductive material, said rod having a recess on one side thereof, and intermediate its ends, a short section of cylindrical wire coated with a thin layer of a relatively hard resistance material secured in the recess and in electrical connection with said rod, a bowed, flat spring having spaced openings therein, the spring being secured at one end to said rod, which passes through said openings, a second cylindrical wire coated with a thin layer of hard resistance material, between the rod and the central portion of the spring and urged against the first coated wire, said wires being approximately at right angles to each other, whereby their coatings are in substantially point contact, insulating means between the second coated wire and the spring and current conductors secured respectively to the rod and to the second wire.

6. An impedance device comprising a relatively stiff rod, a member, spring means secured to the rod and embracing the member to hold it against the rod, said rod and member having portions shaped and oriented to make substantially point contact with one another, at least one of said portions including a thin layer of high resistance-temperature coefficient material at the point of contact, and means for connecting each of said portions to an electric circuit.

7. An impedance device comprising a body, a member, resilient means secured to the body and embracing the member for holding the member against the body, said body and member each having convex portions oriented to make substantially point contact with each other, at least one of said portions including a thin layer of high resistance-temperature coefficient material at the point of contact, and means for making electrical connection to each of said portions.

JOSEPH J. KLEIMACK.
GERALD L. PEARSON.