Aug. 15, 1967 A. J. WRIGHT 3,336,558

NON-LINEAR RESISTANCE ELEMENT

Filed Dec. 10, 1964 2 Sheets-Sheet 1

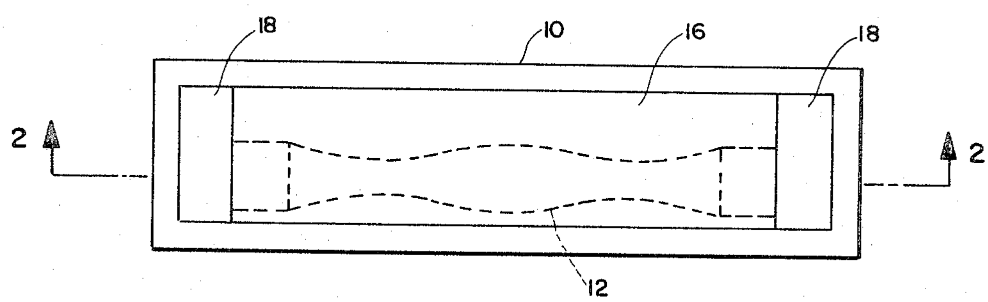

FIG. 1

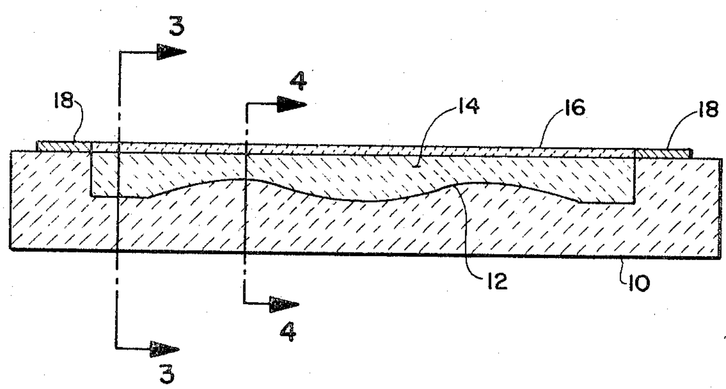

FIG. 2

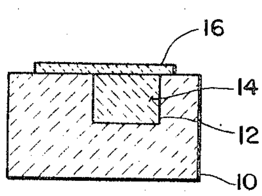

FIG. 3

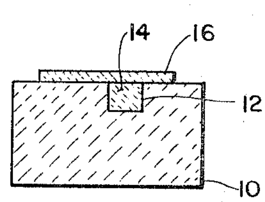

FIG. 4

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NON-LINEAR RESISTANCE ELEMENT

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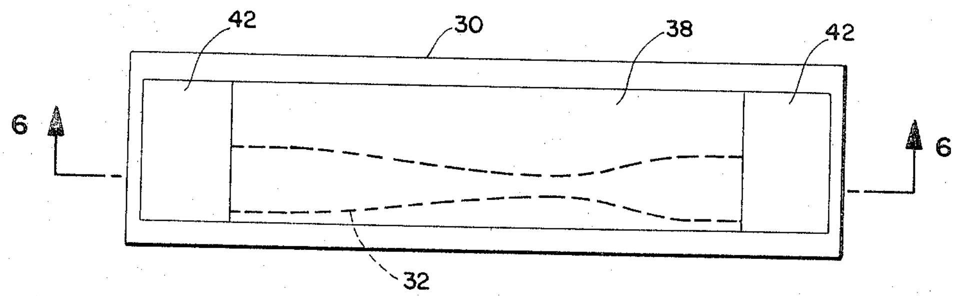

FIG. 5

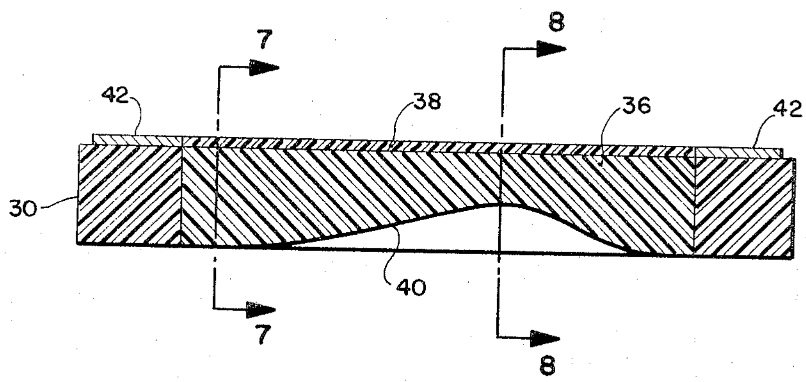

FIG. 6

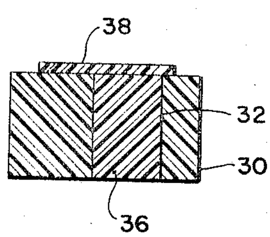

FIG. 7

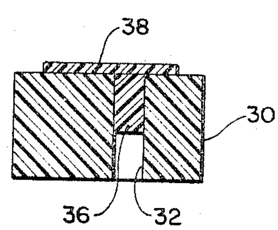

FIG. 8

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NON-LINEAR RESISTANCE ELEMENT

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ABSTRACT OF THE DISCLOSURE

A non-linear resistance element in the form of a base member having an elongated cavity with a resistance material deposited in the cavity, the resistance material having cross-sectional variations along its length in accordance with a predetermined function.

This invention relates to resistance elements of the type applied to a base as a thin layer and which are employed in variable resistance devices such as potentiometers, rheostats, and the like.

The resistance elements with which the present invention is concerned typically comprise a thin stratum or layer of an electrically resistive composition applied to an insulating base. One such composition, commonly called "cermet," comprises a finely divided mixture of noble metals and glass frit. Cermet is deposited upon a support made of an insulating refractory material such as steatite which has been previously fired to form a solid base structure. The assembly is fired at high temperatures, yielding a hard, glossy, electrically resistive layer bonded to the base.

Another composition which exhibits resistive properties, and which may be applied to an insulating base in the form of a thin layer, is "conductive plastic." This composition includes finely divided conducting particles, such as carbon, dispersed in an insulating, organic binder. The conductive plastic layer may be comolded with, or mounted on, the insulating base which may be fabricated of a suitable plastic.

The layer of resistance material is normally applied to the base structure in the form of a "track" of given width, thickness and length. These dimensions, along with other factors such as composition of the resistance material, determine the electrical resistance properties of the track.

A resistance element of the type described above, whose composition is uniform and has been applied so that the width and thickness of the layer do not vary along its length, will exhibit "linear" resistance properties. That is, the resistance varies as a straight line function with respect to the distance from either extremity of the track or, in other words, the "slope," or resistance-per-unit-length (ohms per inch) is constant.

Functions other than linear, that is, those with slopes which vary along the length of the resistance element, have heretofore been achieved by varying the width or composition or both along the length of the element. Thus, almost any desired non-linear variation of resistance with respect to distance from one of the ends of the resistance element track can theoretically be created.

Certain limitations are imposed by the prior art methods of obtaining non-linear resistance functions. Predominant among these is a limitation in the change of the slope or resistance-per-unit-length which can be effected. For example, for a particular application, if a slope of 1 ohm per inch is required at one end of the resistance element and a slope of 1,000 ohms per inch is required at the other end and if only the width is varied, the first end would have to be a thousand times wider than the other end. The construction of such an element for use in a miniaturized potentiometer, for example, in which there are extreme space limitations, is highly impractical.

Varying the composition of the resistance element either singly, or in combination with varying the width, also introduces several problems. Since it is not feasible to control the percentages of the different ingredients of the composition along the length of the element in order to achieve a smoothly varying function such as an exponential function, several sections of resistance material, having different resistance-per-unit-length slopes, are joined together in series. As a result, only an approximation of the desired function is obtained, and the actual variation of resistance along the length of the element as compared to the desired variation may, at certain points, fall outside the permissible tolerances which have been established for particular applications. In addition, when a number of resistance element segments are serially joined, the surface over which the potentiometer wiper or slidable contact moves is no longer smooth since bumps or depressions will appear, either during fabrication or eventually during use, at the junction of the segments. Therefore, the force required to move the wiper will not be uniform over the length of the resistance element. Further, since resistance element sections having different compositions exhibit different surface characteristics, the wiper drive force may be expected to vary along the length of the element for this reason also when segments are mounted in series. Additionally, the wear characteristics of the various segments may differ, eventually contributing still further to irregularities in the force required to drive the wiper. Another problem associated with serially joining resistance element segments of different composition is the variation in the electrical temperature coefficient between the segments.

Substantial variations in the spectrum of electrical noise generated between the wiper contact and the surfaces of resistance elements having different compositions is yet another problem associated with serially joining a number of resistance element segments. Elimination of a wider noise spectrum requires more elaborate filtering.

Accordingly, it is an object of the present invention to provide a resistance element capable of producing smooth, accurate resistance-per-unit-length slope changes which may vary greatly over the length of the element.

It is another object of the present invention to provide a resistance element capable of producing smooth, accurate resistance-per-unit-length slope changes which may vary greatly over the length of the element, yet which has a smooth, uniform surface over which the wiper contact travels and a uniform composition and temperature coefficient throughout.

It is a further object of this invention to provide a resistance element capable of producing large resistance-per-unit-length slope changes, which resistance element may comprise segments of different compositions in series but which has a smooth surface of uniform characteristics over which the slidable wiper contact travels.

According to the present invention, there is provided a novel resistance element which may be varied not only in width and/or composition, but also in depth. The control of the additional dimension of depth results in a resistance element whose cross-sectional area may be so widely varied over relatively short distances that it makes available resistance-per-unit-length slope changes heretofore not possible.

In accordance with a specific, exemplary embodiment of the invention shown and described herein, there is provided an insulating base having a cavity in the form of a longitudinal groove or channel the width and depth of which vary along the channel's length. The channel is filled flush with the top surface of the base with a resistance material such as cermet or conductive plastic. The resistance material may be of uniform composition throughout the entire length of the channel or may comprise two or more serially connected segments of resistance material having different compositions and therefore, different electrical resistance properties. A thin layer of resistance material of uniform width, thickness and composition, applied to the top surface of the base, covers the channel and provides a smooth surface for the sliding wiper contact. The variations in the width and depth of the channel and composition of the resistance material are designed and selected so as to obtain the desired resistance-per-unit-length slope values along the length of the element.

According to another, specific, exemplary embodiment of the invention shown and described herein, the base member is provided with a cavity in the form of a slot extending through the entire thickness of the base. The width of the slot may be varied as in the case of the first embodiment described above. The slot is entirely filled with resistance material such as cermet or conductive plastic, the outer surfaces of which are made flush with the top and bottom surfaces of the base. The composition of the material may be uniform or varied along the length of the slot. As in the first embodiment, a thin layer of resistance material of uniform width, thickness and composition is bonded or otherwise affixed to the top surface of the base member to provide a smooth contact surface for the wiper. Additional shaping or "tailoring" of the resistance material may be accomplished by suitably cutting or grinding away, according to a predetermined pattern, the bottom surface of the resistance material within the slot.

The novel features which are believed to be characteristic of the invention are set forth with particularity in the appended claims. The invention itself, however, together with further objects and advantages thereof, can best be understood by reference to the following description taken in connection with the accompanying drawings in which:

FIG. 1 is a plan view of a first embodiment of the invention;

FIG. 2 is a section view taken along plane 2—2 of FIG. 1;

FIG. 3 is a section view taken along plane 3—3 of FIG. 2;

FIG. 4 is a section view taken along plane 4—4 of FIG. 2;

FIG. 5 is a plan view of a second embodiment of the present invention;

FIG. 6 is a section view taken along plane 6—6 of FIG. 5;

FIG. 7 is a section view taken along plane 7—7 of FIG. 6; and

FIG. 8 is a section view taken along plane 8—8 of FIG. 6.

It is to be understood that the detailed description of FIGS. 1–8 which follows is applicable not only to the miniaturized rectilinear resistance elements depicted in the drawings, but to resistance elements of any shape and size. Further, the detailed description of FIGS. 1–8 which follows is applicable not only to cermet and conductive plastic types of resistance elements but to any type resistance element of this general nature.

Referring now to the drawings, there is shown in FIGS. 1–4 a first embodiment of the present invention. A rectangular base **10**, preferably fabricated from a refractory material such as steatite, has a longitudinal groove or channel **12** cut or molded therein. The width and depth of channel **12** are appropriately shaped along the length of the channel in accordance with a desired resistance-per-unit-length function. A particular channel shape may be obtained by casting the base in a suitable mold or die, or by cutting or grinding, after the base is fabricated, in accordance with a master pattern. A comparison of FIGS. 3 and 4 indicates the variation in cross-section area of the resistance material between two points along the length of the resistance element.

Channel **12** is filled, flush with the top surface of the base **10**, with a resistance material **14** such as cermet, having a single value of resistivity, or, if required for a particular application, having a multiplicity of resistance values along the length of the channel. Overlaying the top surface of the base member **10** and in contact with the resistance material **14** in channel **12**, is a thin layer **16** made of the same resistance material as that in the channel. The layer **16** is of uniform width, thickness and composition and has a smooth top surface adapted to be engaged by a sliding wiper contact which longitudinally traverses the resistance element.

A pair of terminals **18** are provided at the ends of the layer **16** for connecting the resistance element with an external circuit in which it is to be used. The terminals **18** are typically made of a noble metal which is applied as a paste and fired to yield a continuous, adhering, metallic strip. Electrical connections may be made to the terminals **18** by soldering or welding lead-in wires or ribbons to the terminals.

In FIGS. 5–8, there is shown an alternative embodiment of the present invention. A rectangular insulating base **30** has formed in it a through-slot **32**, the sides of which may be shaped so that the width of the through-slot varies along its length in accordance with a predetermined function.

Initially, the entire slot is filled with a resistance material. For exemplary purposes, the device of FIGS. 5–8 is shown to be filled with conductive plastic resistance material **36**. The top surface of the resistance material fill is made flush with the top surface of the base member **30**. A thin layer **38**, of uniform width, thickness and composition throughout its entire length, overlays the top surface of the base member **30** and is in contact with the top surface of the resistance material filling the slot **32**. As in the first embodiment, it is upon the upper, smooth surface of this layer that the wiper contact slidingly moves.

After assembly of the device, the bottom surface of the material **36** in the slot **32** may be cut away in accordance with a predetermined function. FIG. 6 of the drawings more clearly shows the cutaway portion of the material held in the slot **32**. As indicated by FIG. 6, the resistance material in the slot has been cut away to form a smoothly curved surface **40**. FIGS. 7 and 8 show the difference in total cross-section area of the resistance material which exists between two points along the length of the element.

Elements **42** represent the metallic end terminals of the resistance element. The terminals **42** may be inserts molded along with the rest of the assembly, or they may be metallic paste strips similar to terminals **18** in FIG. 2.

As in the first embodiment, the composition of the resistance material in the slot may be varied along the length of the element in order to produce abrupt variations in the resistance-per-unit-length curve.

It will be evident that this invention provides a variable resistance element capable of furnishing large variations in the resistance-per-unit-length slope along the length of the element by varying width, depth and if necessary, composition. Additionally, a smooth, uniform, wear-resistant surface is presented to the wiper contact thus assuring that the wiper drive force remains substantially constant throughout the entire excursion of the wiper.

It will be obvious to those skilled in the art that various modifications may be made to the specific, exemplary embodiments of the invention described. While particular embodiments have been discussed, it will be understood that the invention is not limited thereto and that it is contemplated to cover any such modifications as fall within the true spirit and scope of the invention by the appended claims.

What is claimed is:

1. A resistance element comprising:

an insulating base member having top and bottom surfaces;

an elongated cavity extending into said base member from said top surface;

resistance material, having known electrical resistance properties, deposited in said cavity; said material having cross-sectional dimensions varying along the length of said cavity in accordance with a predetermined function;

said resistance material disposed within said cavity flush with said top surface of said base member; and

a thin layer of resistance material affixed to and overlaying the top surfaces of said base member and said resistance material disposed within said cavity, said thin layer having a width substantially greater than the width of the top surface of said resistance material in said cavity.

2. A resistance element comprising:

an insulating base member having top and bottom surfaces;

an elongated channel extending into the interior of said base member from said top surface, the width and depth of said channel varying along its length in accordance with a predetermined function;

a resistance material, having known electrical resistance properties, filling said channel flush with said top surface of said base member; and

a thin layer of resistance material affixed to and overlaying the top surfaces of said base member and said resistance material filling said channel, the width of said thin layer being substantially greater than the width of said resistance material in said channel.

3. A resistance element comprising:

an insulating base member having top and bottom surfaces;

an elongated cavity in the form of a through-slot passing through the top and bottom surfaces of said base member;

resistance material, having known electrical resistance properties filling said through-slot flush with said top surface of said base member and to a depth which varies along the length of said slot in accordance with a predetermined function; and

a thin layer of resistance material affixed to and overlaying the top surfaces of said base member and said resistance material filling said slot, said thin layer of resistance material having a width substantially greater than the width of the top surface of said resistance material filling said slot.

4. A resistance element comprising:

an insulating base member having top and bottom surfaces;

an elongated cavity in the form of a through-slot passing through the top and bottom surfaces of said base member;

a resistance material, having known electrical resistance properties, filling said cavity to a depth which varies along the length of said cavity in accordance with a predetermined function;

a thin layer of resistance material affixed to and overlaying the top surfaces of said base member and said resistance material filling said slot; and

terminals mounted on the ends of said overlaid layer.

5. A method of making a resistance element comprising the steps of

forming a base member with top and bottom surfaces and an elongated channel extending from the top surface into the interior of said base member;

shaping the walls of said channel along its length in accordance with a predetermined function;

filling said channel, substantially flush with said top surface of said base member, with a resistance material having known resistance properties overlaying the top surfaces of said base member and said resistance material filling said channel with a thin layer of resistance material having a uniform width and composition along its entire length.

6. The method of making a resistance element which comprises the steps of

forming a base member with top and bottom surfaces and an elongated through-slot passing through said top and bottom surfaces of said base member, the width of said slot varying along its length in accordance with a predetermined function;

filling said slot with resistance material of known resistance properties flush with said top and bottom surfaces;

shaping the bottom surface of said resistance material in said slot in accordance with said predetermined function overlaying the top surfaces of said base member and said resistance material filling said slot with a thin layer of resistance material having a uniform width and composition along its entire length.

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