United States Patent [19]

Clayton

[11] **3,851,293**

[45] **Nov. 26, 1974**

[54] **ELECTRICAL RESISTANCE ELEMENT AND METHOD OF MANUFACTURE**

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[22] Filed: **Aug. 15, 1972**

[21] Appl. No.: **280,809**

[52] **U.S. Cl.** **338/195,** 338/142, 29/620

[51] **Int. Cl.** **H01c 9/02**

[58] **Field of Search** 338/195, 89, 90, 91, 122, 338/138, 139, 142; 29/620

[56] **References Cited**

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Primary Examiner—J. V. Truhe
Assistant Examiner—David A. Tone

[57] **ABSTRACT**

A conductive plastic potentiometer with an electrical resistance element having two end terminations and comprising two resistance films applied on a single substrate. The two films are applied sequentially with the higher resistance film being first applied over the entire substrate surface, and then a second film of substantially lower resistance being applied over the first film such as to cover and contact approximately half of the higher resistance film, so that the wiper runs on the surface of the higher resistance film.

8 Claims, 5 Drawing Figures

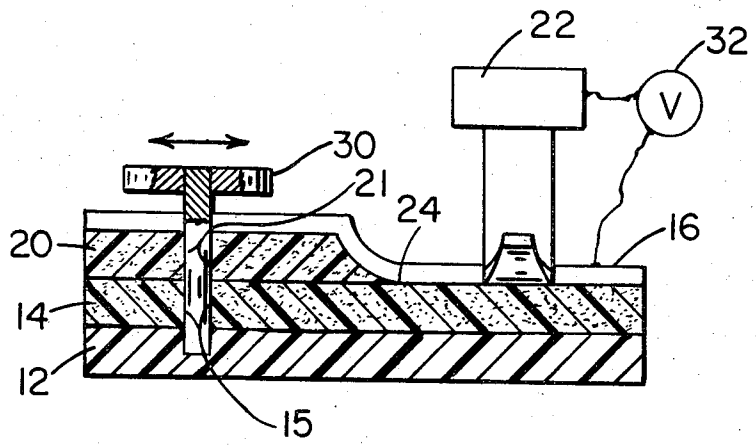


FIG. 1

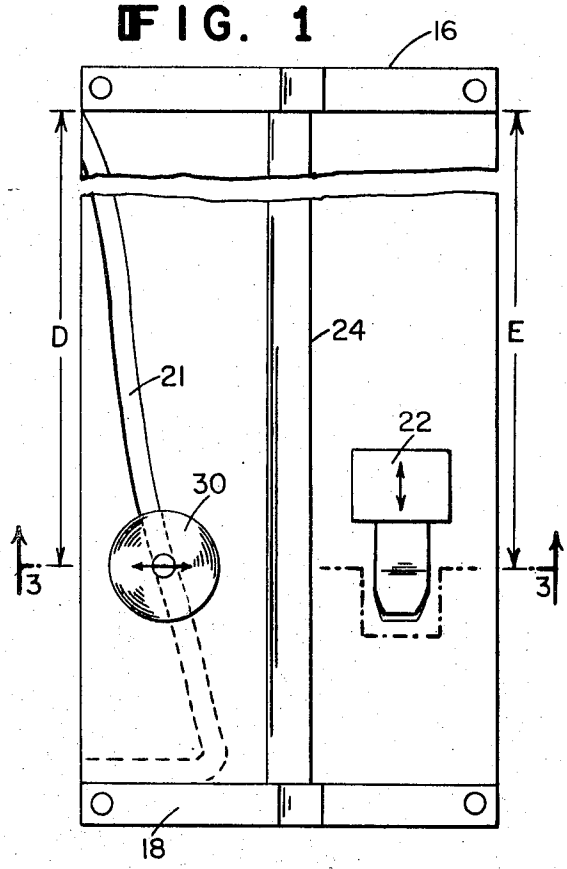
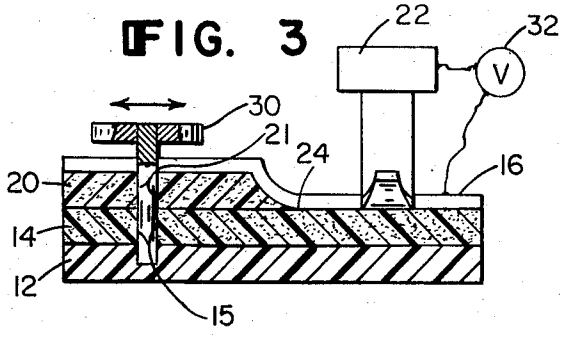


FIG. 3



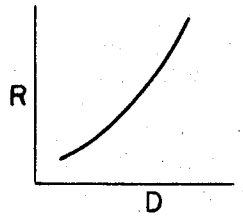


FIG. 5

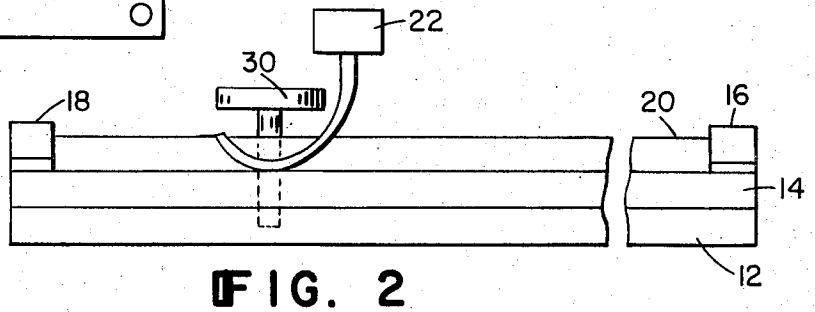


FIG. 2

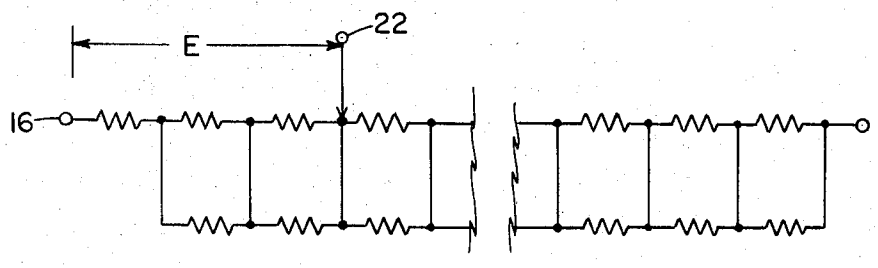


FIG. 4

ELECTRICAL RESISTANCE ELEMENT AND METHOD OF MANUFACTURE

This invention relates to precision non-linear and linear conductive plastic film potentiometers and methods of their manufacture.

Non-linear potentiometers are potentiometers which include an electrical resistance element of either plane or cylindrical configuration along which a wiper is moved to provide a voltage output value which varies non-linearly as a predetermined mathematical function of the distance from an end termination of the resistance element. In the case of certain functions, for example a logarithmic function, the rate of change of voltage output to distance causes the voltage output value near one end of the resistance element to be large compared to that near the other end of the resistance element. This is a serious problem in the design of resistance elements of the conductive film type, since it makes necessary the use of a longitudinal series of resistance elements of differing resistance values in order to keep the transverse dimensions of the resistance elements within practical limits while providing a minimum transverse dimension sufficient to be useful as a wiper path of travel.

In view of these problems, it is a major object of the present invention to provide a novel precision non-linear potentiometer of practical transverse dimension without the necessity of utilizing a longitudinally averaged series of resistance elements.

It is also an object of the invention to provide a novel precision linear potentiometer.

It is another object of the invention to provide a novel method of manufacturing such potentiometers.

According to the invention in its broadest aspect, there is provided a precision potentiometer having a predetermined function comprising a high resistance element, the slope of which approximates closely the maximum slope of the predetermined function, preferably a conductive plastic film on a suitable insulating base and having end terminations. The high resistance element provides a path of wiper travel between the end terminations for a wiper movable along the path. There is also provided a low resistance element, the slope of which approximates closely the minimum slope of the predetermined function, of varying transverse cross sectional dimension, preferably a film, in continuous electrical contact with the high resistance element, extending between the end terminations in continuous parallel electrical connection with the high resistance element, so that the high and low resistance elements together provide a voltage output value at the wiper varying as a predetermined function of distance from one end termination, either non-linearly or linearly. Slope ratios as high as 100,000:1 may be achieved by the invention.

Preferably, the low resistance element is spaced from the wiper path and has its edge remote from the wiper path at a varying distance from the adjacent edge to provide the varying transverse cross sectional dimension. Preferably, too, the edge of the low resistance element adjacent the path of wiper travel is diffused progressively transversely.

The novel method of the invention comprises the steps of providing a longitudinally extended high resistance element having end terminations, the high resistance element having a path of wiper travel between the end terminations. A longitudinally extended low resistance film is provided on the high resistance element in continuous parallel electrical connection therewith extending between the end terminations. The low resistance film is spaced from the wiper path. The transverse cross sectional dimension of the low resistance element is then progressively altered as a function of desired voltage output value and distance from the end termination by progressively sensing the voltage output value along the path of wiper travel and altering the transverse cross sectional dimension of the low resistance value responsively thereto. Preferably this is done by effectively varying the transverse dimension of the films on the side thereof remote from the path of wiper travel to provide a precision potentiometer element non-linearly varying as a function of distance from one end termination, or to provide a precision linear potentiometer.

For the purpose of more fully explaining the above and still further objects and features of the invention, reference is now made to the following detailed description of a preferred embodiment of the invention, together with the accompanying drawings, wherein:

FIG. 1 is a plan view of a precision potentiometer according to the invention;

FIG. 2 is a side view of the potentiometer of FIG. 1;

FIG. 3 is a cross sectional end view of the potentiometer of FIG. 1, taken on line 3—3 thereof and illustrating the method of the invention;

FIG. 4 is an equivalent circuit diagram of a potentiometer of the invention, and

FIG. 5 is a graph of a non-linear resistance function typical of a potentiometer of the invention.

Referring to the drawings, in which the thickness of the film layers has been greatly exaggerated for clarity, the potentiometer of the present invention comprises a suitable insulating base 12 having a longitudinally extended high resistance film 14 on it. Film 14 may be of any suitable material, such as a conductive plastic, for example, having a relatively high resistance value. Conventional end terminations 16 and 18 are provided on opposite ends of high resistance film 14.

A longitudinally extended low resistance film 20 is provided on high resistance film 14 for about half the transverse dimension thereof extending between end terminations 16, 18 in continuous parallel electrical connection with high resistance film 14. High resistance film 14 is thus exposed for about half its width to provide a path of travel between end terminations 16, 18 for a conventional wiper 22 movable along said path.

Low resistance film 20 may be of any suitable material, such as a conductive plastic, for example, having a relatively low resistance value, and preferably has its edge 24 adjacent the path of wiper 22 diffused progressively transversely to increase the resistance value thereof in a transverse direction toward said path and spaced from said wiper path.

In the preferred embodiment, base 12 is about 5 mils thick, high resistance film 14 is about 1 mil thick, and low resistance film 20 is about 1 mil thick.

In order to provide a voltage output value at wiper 22 varying as a predetermined function of distance between end terminations 16, 18, the edge 15 of high resistance film 14 and the edge 21 of low resistance film 20, that is, their opposite edges remote from the path

of wiper **22**, are at a varying distance from the low resistance film edge **24** adjacent the path of wiper **22** to provide a varying cross sectional dimension thereof. The equivalent circuit of the potentiometer of the invention is shown in FIG. **4** to consist of a network of two parallel series of resistors connected at indefinitely short intervals along their lengths.

In operation, the potentiometer of the invention, whether of the plane configuration as shown or of a conventional cylindrical configuration, has its wiper **22** moved along its path between terminations **16, 18** to provide the desired voltage output value, such as that of FIG. **5**, for example.

The method of making the potentiometer element of the invention comprises the previously described steps of providing on base **12** a longitudinally extended high resistance film **14** having end terminations **16, 18** on opposite ends thereof and providing a path of travel of wiper **22** between said end terminations with a longitudinally extended low resistance film **20** on high resistance film **14** in continuous electrical contact therewith extending between said end terminations in continuous parallel electrical connection with said high resistance film and spaced from said wiper path.

In order to alter progressively the transverse cross sectional dimension of at least the low resistance film **20** as a function of desired voltage output value and distance from the end terminations **16, 18** by effectively varying the transverse dimension of said film on the edge **21** thereof remote from the path of travel of wiper **22**, both low resistance film **20** and high resistance film **14** are cut by a suitable cutter **30**, such as an etching tool, responsive to the voltage output value E at the wiper **22** as it is moved along the wiper path in synchronism with cutter **30**. This may be accomplished by applying a constant voltage across end terminations **16, 18** and measuring the voltage value E at wiper **22** by a suitable voltmeter **32**, and simultaneously advancing cutter **30** and wiper **22** at equal longitudinal distance D from end termination **16** while simultaneously moving cutter **30** transversely in accordance with the desired function of voltage and distance, as illustrated, for example in the graph of FIG. **5**. As shown, the excess material of both the high and low resistance films is effectively removed from the potentiometer in an electrical sense, since cutter **30** extends into the insulating base **12**. Of course, the cut could be made through the base for physical removal of excess film material if so desired.

The invention can be equally applied to linear elements in that the use of the double film permits extension of the resistance range in the lower direction, since the lower resistance film becomes the resistance and shunt that controls the total resistance of the entire element. In many cases, too, the lower resistance film has a high metallic content and thus has a difficult surface condition that may affect adversely the linear factors of the sliding contact.

What is claimed is:

1. A potentiometer having a predetermined function comprising

a longitudinally extended conductive plastic high resistance film element having end terminations on opposite ends thereof,

said high resistance film element providing a path of wiper travel between said end terminations

a wiper movable along said path

a longitudinally extended conductive plastic low resistance film element superimposed on said high resistance film element in continuous electrical contact therewith extending between said end terminations in continuous parallel electrical connection with said high resistance film element,

said low resistance film element being spaced from said path of wiper travel and having an edge remote from said path of wiper travel of varying dimension from its opposed edge to provide a varying transverse dimension thereof

said high and low resistance film elements together providing a voltage value at said wiper varying as a function of distance between said end terminations.

2. A potentiometer as claimed in claim **1** wherein

the edge of said low resistance element adjacent to said path of wiper travel is diffused progressively transversely.

3. A potentiometer as claimed in claim **1** wherein

said high resistance element has a slope which approximates the maximum slope of said predetermined function and

said low resistance element has a slope which approximates the minimum slope of said predetermined function.

4. A potentiometer having a predetermined function comprising

an insulating base

a longitudinally extended conductive plastic high resistance film element on said base having end terminations on opposite ends thereof,

said high resistance film element providing a path of wiper travel between said end terminations

a wiper movable along said path,

a longitudinally extended conductive plastic low resistance film element superimposed on said high resistance film on the side thereof opposite said base and in continuous electrical contact therewith extending between said end terminations in continuous parallel electrical connection with said high resistance film element,

said low resistance film element being spaced from said path of wiper travel and having its edge adjacent said path of wiper travel diffused progressively transversely to increase the resistance value thereof in a transverse direction toward said path of wiper travel and spaced therefrom,

the opposite edges of said films remote from said wiper path being of varying dimension from said adjacent edge to provide a varying transverse dimension thereof

said high and low resistance elements together providing a voltage output value at said wiper varying as a predetermined function of distance between said end terminations

said high resistance film element having a slope which approximates the maximum slope of said predetermined function and

said low resistance film element having a slope which approximates the minimum slope of said predetermined function.

5. A potentiometer as claimed in claim **4** wherein said predetermined function is non-linear.

6. The method of making a potentiometer element having a predetermined function comprising the steps of

providing an insulating base
a longitudinally extended conductive plastic high resistance film element having end terminations on said base
said high resistance film element having a maximum voltage output slope that closely approximates the slope of said predetermined function
said high resistance film element having a path of wiper travel between said end terminations and
a longitudinally extended conductive plastic low resistance film element superimposed on said high resistance film element on the side thereof opposite said base and in continuous electrical contact therewith extending between said end terminations in continuous parallel electrical connection with said high resistance film element
said low resistance element having a slope which approximates the minimum slope of said predetermined function
said low resistance film being spaced from said path of wiper travel and
progressively altering the transverse cross sectional dimension of at least said low resistance film element as a function of desired voltage output value and distance from said end terminations by progressively sensing the voltage output value along said path of wiper travel and altering the transverse cross sectional dimension of said low resistance value responsively thereto by effectively varying the transverse dimension of said low resistance film element on the side thereof remote from said path of wiper travel,
to provide a potentiometer element varying as a function of distance from said end terminations.

7. The method as claimed in claim **6** wherein said predetermined function is non-linear.

8. A potentiometer having a predetermined function comprising
an insulating base
a longitudinally extended conductive plastic high resistance film element on said base having end terminations on opposite ends thereof,
said high resistance film element providing a path of wiper travel between said end terminations
a wiper movable along said path,
a longitudinally extended conductive plastic low resistance film element superimposed on said high resistance film on the side thereof opposite said base and in continuous electrical contact therewith extending between said end terminations in continuous parallel electrical connection with said high resistance film element,
said low resistance film element being spaced from said path of wiper travel and having its edge remote from said path of wiper travel of varying dimension from its edge adjacent said path of wiper travel to provide a varying transverse dimension thereof
said high and low resistance elements together providing a voltage output value at said wiper varying as a predetermined function of distance between said end terminations
said high resistance film element having a slope which approximates the maximum slope of said predetermined function and
said low resistance film element having a slope which approximates the minimum slope of said predetermined function.

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