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E. J. GOEPPINGER ET AL

2,711,463

TAPPED POTENTIOMETER ELEMENT AND ASSOCIATED NETWORK

Filed Oct. 5, 1951

2 Sheets-Sheet 1

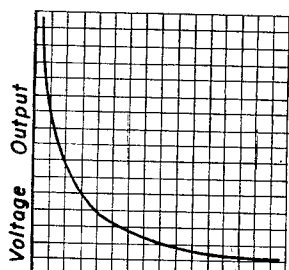


FIG. 1

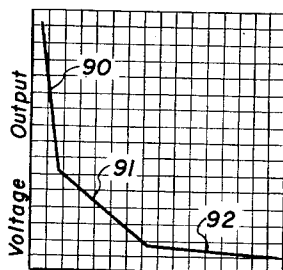


FIG. 2

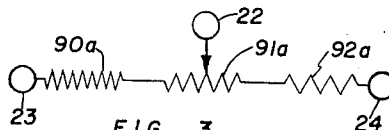


FIG. 3

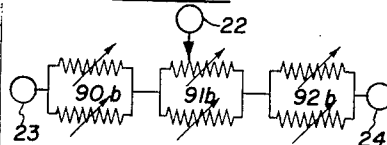


FIG. 4

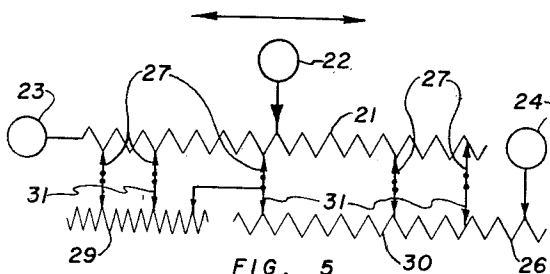


FIG. 5

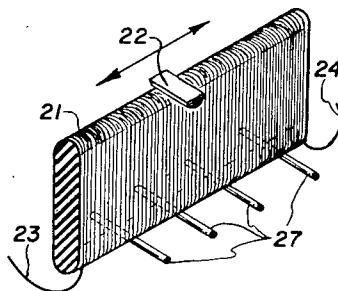


FIG. 6

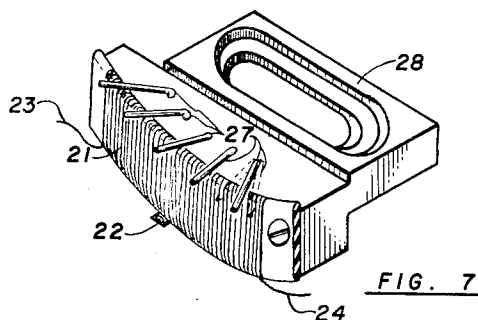


FIG. 7

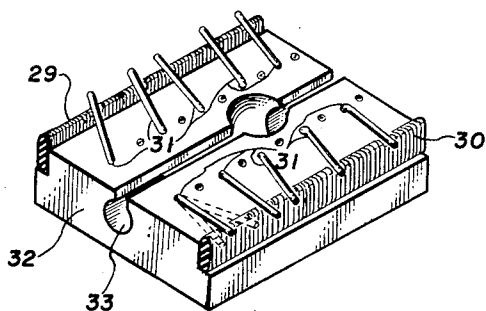


FIG. 8

INVENTORS

Marlan E. Bouma

Edward J. Goepfinger

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E. J. GOEPPINGER ET AL

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2 Sheets-Sheet 2

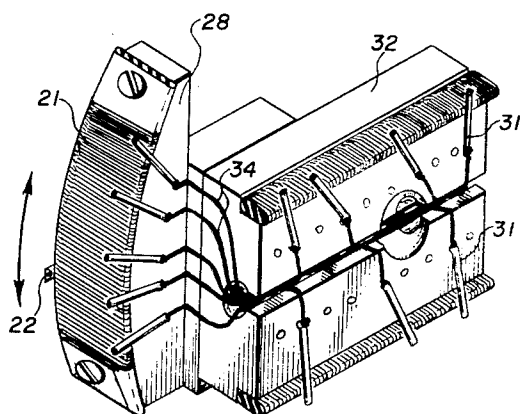


FIG. 9

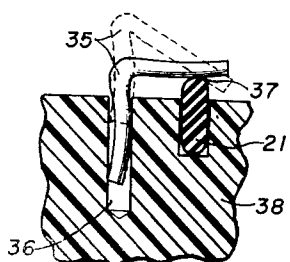


FIG. 12



FIG. 13

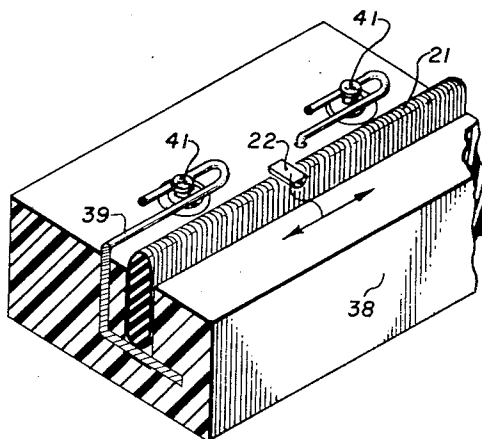


FIG. 10

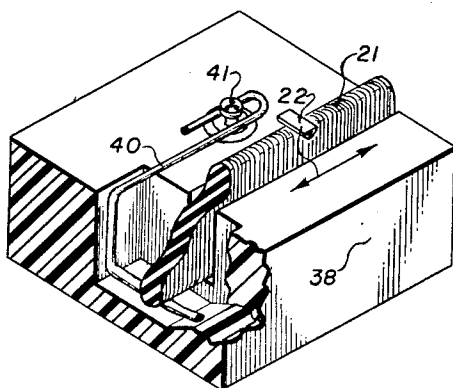


FIG. 11

INVENTORS

Marion E. Bourne

Edward J. Goepfinger

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TAPPED POTENTIOMETER ELEMENT AND ASSOCIATED NETWORK

Edward J. Goeppinger and Marlan E. Bourns, Riverside, Calif.; said Goeppinger assignor to said Bourns

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15 Claims. (Cl. 201—62)

This invention relates to a new and useful tapped potentiometer element and associated network which may be used for many purposes including the production of an output voltage having a desired functional relationship to the position or movement of an electrical contact, or to quantities being measured by the position or movement of the electrical contact.

In many applications, particularly in the control, guidance, and servo-systems of guided missiles and aircraft, and in electrical computer circuits, it is desirable to use potentiometer-type instruments of negligible wiper drain having electrical outputs which follow desired functions when plotted against the quantity being measured. The desired output may be a line with fixed end points and a high degree of linearity or any degree of non-linearity. To date, several methods have been employed to achieve the desired non-linearity in the electrical output of potentiometer-, or voltage divider-type instruments. These methods include non-linear spring loading, non-linear linkages, wire-wound elements using forms of special shapes, and/or changes in wire diameter, and/or variation in wire spacing and other methods of depositing or shaping composition-type electrical elements to produce the desired effect. All of these methods have certain limitations and disadvantages as compared to the method of the subject invention.

An object of this invention is to provide an electrical element and associated network for use in voltage divider-type instruments which may have any desired output within physical limitations.

A further object of this invention is to provide such an electrical element and associated network with means of adjusting the shape of the voltage output curve to fit a desired function, thereby compensating for deviations of the various components of the instrument, including the electrical element itself.

A further object of this invention is to provide taps on the electrical element which may be used for any desired purpose including that of producing a voltage output curve to meet a desired requirement.

Another object of this invention is to provide electrical adjusting taps which are readily locked in any desired position.

A further object of this invention is to simplify the construction of potentiometer-type instruments by means of tap and shunt arrangements so that linearity or total resistance of the main resistance element will not be critical, and standardized resistance elements can be used for all instruments. In the event wire-wound resistance elements are used, the smallest wire consistent with the life requirements and fabrication techniques would preferably be used in the interest of improved resolution.

A further object of this invention is to provide an instrument constructed in such a manner that its voltage output curve may be altered to correspond with any of several desired curves by merely adjusting electrical resistors or taps, or by exchanging electrical assemblies comprising sets of resistors having predetermined values.

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This may be facilitated by use of multiple contact plug and socket assemblies or switches in common use.

A further object of this invention is to provide an instrument constructed in such a manner that its calibration curve may be corrected to correspond with the desired curve after the instrument has been subjected to severe operating conditions, aging, accelerations, or other factors which may have changed its calibration from that desired.

In accordance with these objects and other objects which will become apparent in the following specifications, a potentiometer element, main element, electrical element, or wire-wound element having a moving contact, wiper, or probe, is provided with electrical taps. The electrical taps, adjusting tap, spring taps, spring clips, or spring contacts are made of conductive material in the form of wires or springs and contacting one edge of the electrical element, said edge being different or opposite from the edge used for the normal moving contact of the instrument. The construction of the preferred taps is such that they may readily be adjusted to the desired locations and will permanently maintain good electrical contact with the electrical element. The taps may also be made by means of spot welding or by pulling off turns of wire at the desired tap locations while the electrical element is being wound. Connections from these taps may be used outside the instrument for any desired purpose, or they may be used internally or externally for the purpose of producing an output voltage which will follow a desired function by means of shunt resistors or shunt and series resistors connected and adjusted in an appropriate manner. The resistance of the shunting resistors and series resistors may be determined by calculations and suitable individual resistors, called shunts, parallel resistors or shunt resistor strips, may then be connected between the desired taps. A method of providing shunts, which has proved to be very satisfactory and convenient, is the use of shunting resistance elements, also called shunt elements or parallel elements, upon which taps are placed at desired locations and electrically connected with the taps on the main electrical potentiometer element. The shunt element taps are similar in design to those on the main electrical element and may be adjusted in the proper sequence to provide the desired voltage output curve. An advantage of this method, in addition to the easy adjustments and simplicity, is the fact that the actual resistance of shunt-element segments need not be determined; only the resistance of the parallel combination of the shunt element segment and the corresponding segment of the main element need be determined. Also, for still further simplicity, the adjustment can actually be made by physically locating the moving contact on the main element in certain desired positions and then adjusting the shunt element taps to produce the desired electrical output readings at these points. Thus, this method gives a completely universal means of providing adjustable taps on the main electrical element and adjustable means of producing an electrical output which will follow a desired function.

In certain applications, it may be desired that the output of the instrument with the electrical wiper at the extreme end of the element be some value other than zero. In this event, a segment of the same element used for the shunts can also be used as a series resistor between the end of the main element and one of the external terminals of the potentiometer instrument. This, then, provides a means of adjusting the end setting of the instrument by moving the electrical tap on the series resistor in a manner similar to that mentioned above. In the case of dual instruments, i. e., instruments having two entirely separate electrical circuits actuated by the same

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mechanical means, this series element arrangement is particularly convenient inasmuch as the lengths of the main elements are not critical and variations therein can be compensated for by means of these adjustable series resistors and other correlations between the two elements can be made. The principles described can be used advantageously in many types of instruments, such as, Bourdon tube- or bellows-type instruments for measuring differential, gauge, or absolute pressures; linear motion instruments; angular motion instruments, including such units as vane potentiometers for measuring angle of attack; accelerometers and many other potentiometer-type instruments. Embodiments of this invention are considered in two general potentiometer applications. In one, the wiper travels in an arc, while in the other, the wiper travels in a straight line.

Figure 1 indicates a representative functional output which may be approximated with an electrical element and associated network of the type described above.

Figure 2 shows an approximation to the desired curve of Figure 1 accomplished by means of a series of straight lines.

Figure 3 is a schematic diagram of a series of electrical elements which could be used to produce the voltage output curve of Figure 2.

Figure 4 is a modification of Figure 3 wherein parallel combinations of variable resistors are substituted for the fixed resistors shown in Figure 3.

Figure 5 is a schematic electrical diagram of an element and associated network similar to that shown in Figure 4 but with certain components advantageously combined or added for mechanical, electrical, and physical reasons.

Figure 6 shows a potentiometer element with the moving contact and electrical adjusting taps.

Figure 7 shows the design of an element block with the main potentiometer element, wiper, and taps in place.

Figure 8 shows a shunt element block with two shunting elements and taps in place.

Figure 9 is a perspective view showing parts related to this invention as assembled in an instrument.

Figure 10 shows an alternate design of the element block with an adjusting tap located in a cavity.

Figure 11 shows an alternate design of the element block with fixed taps molded in predetermined positions.

Figure 12 shows the details of an adjustable spring tap in the adjusting position and in the locked position.

Figure 13 shows an alternate configuration for a spring tap.

Referring to Figure 1, the output curve shown is somewhat representative of those obtainable with the features of this invention. However, outputs varying from an extremely straight line to a curve having a greater degree of non-linearity than the curve shown, may also be accomplished.

In Figure 2, three straight line segments 90, 91, and 92 are shown. These lines are a close approximation to the curve shown in Figure 1. A closer approximation may be obtained by the use of a greater number of straight line segments. In actual practice, the lines may be somewhat curved as a result of the characteristics of certain components of the instrument in which the element and associated network are used. Referring to the circuit shown in Figure 3, the straight line segments shown in Figure 2 may be produced by a combination of three resistors 90a, 91a, and 92a, having different resistance per unit length; the slope of the output voltage curve is related to the resistance per unit length of the element.

If a battery is connected across potentiometer terminal 23 and 24, a voltmeter connected between terminal 22 and 23, the meter will show an output voltage such as that of Figure 2 when plotted against the movement of the moving contact 22 as it wipes across the three electrical elements, assuming the ends of the three elements

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should be closely butted against one another. The segment of the curve 90 of Figure 2 corresponds to the high resistance segment 90a of the electrical circuit; segment of the curve 91 of Figure 2 corresponds to segment 91a of the electrical circuit; segment 92 of Figure 2, which is most nearly horizontal, corresponds to the voltage produced as the wiper 22 moves across the low resistance segment 92a of the electrical circuit of Figure 3.

In Figure 4, the three elements of Figure 3 have been replaced by adjustable parallel elements 90b, 91b and 92b connected in series so that the resistance of each element segment may readily be varied. Again, the output is similar to that shown in Figure 2.

Figure 5 shows the schematic circuit diagram of a typical arrangement of the main electrical element 21 connected to an end terminal 23 and having a moving electrical contact 22. The taps 27 make contact with the main electrical element 21 at various desired locations which may readily be adjusted. Shunting resistors are provided across each element segment. It has been found convenient to use two separate shunt resistor strips, one having high resistance per unit length 29 and one having lower resistance per unit length 30. The reason for preferring two resistance strips having different resistance per unit length is that high resistance shunts are required when adjusting one end of the curve, whereas, lower resistance shunts are required at the other end. The values of the shunt elements are selected to give optimum adjustability. Taps 31 make contact with these shunt element strips and provide the desired shunt resistance across each segment of the main electrical element. A series resistor 26 is formed from a part of the shunt resistor 30 and is used to provide a desired end resistance between the physical end of the main potentiometer element 21 and the terminal 24 in the event it is desired that the electrical output of the instrument be some value other than zero when the wiper is at the end of the main electrical element. The resistance of the resistor 30 may be zero if this desired electrical output is zero.

In Figure 6, 21 is an electrical element in the form of a high resistance wire wound on an insulating card, its output being linear in itself. Moving electrical wiper 22 rides on said element, and electrical taps 27 make contact with the main element on a side other than that used by the wiper 22.

Figure 7 shows the electrical element of Figure 6 mounted on an arcuate block 28 made of insulating material and with the taps 27 mounted in position and located in holes in the block 28 in such a manner as to be readily adjustable.

In Figure 8, two shunting element strips, 29 and 30, are mounted on a block of non-conductive material 32. Electrical taps 31 make contact with the shunt element strips in such a manner as to provide several individual shunt element segments of desired values. The cavity 33 provides a convenient place for the leads which run between the taps of the main electrical element and the shunt elements in the final assembly.

Figure 9 shows the main element assembly of Figure 7, and the shunt element assembly of Figure 8 mounted and connected with electrical conductors 34 as used in one application. Thus, these shunt resistor circuits as actually used, in effect, produce a number of segments on the main element which have different resistance per unit length, thereby producing an output voltage which consists of a series of relatively straight lines such as is shown in Figure 2 to approximate the curve such as is shown in Figure 1.

Figure 10 shows an electrical element 21 fixed in an insulating block 38, said block having taps 39 molded in predetermined locations and exposed in such a fashion as to make contact with the electrical element held in

the cavity. Ends of the taps are accessible for soldering or otherwise fastening to terminals 41.

Figure 11 shows an electrical element 21 fixed in an insulating block 38, said block having a cavity, hole or depression of suitable form to accommodate a spring type tap. The tap 40 is so fastened to a soldering post, screw terminal or molded insert 41 that the tap position may be readily adjusted.

Figure 12 is a cross-sectional view of the adjusting tap, placed in a suitable electrical insulator. The spring tap 35 is inserted in a cavity such as a hole 36 until contact is made on the electrical element at 37. The spring tap is adjusted to some desired setting by rotating the spring in hole 36. When the correct position is achieved, the spring is advanced to its maximum depth to provide increased force on the element 21 and to lock the spring in position. The locking action occurs whenever a bending moment, such as that produced by loading the spring on the element, is applied to the portion of the shaft that is inserted in the hole. Additional holding strength is obtained by burring the spring, cementing, or securing the spring wire assembly in an electrical potting compound.

Adjusting spring wire 42 of Figure 13 is an alternate spring form adapted to this application.

In this instrument, the movement of the electrical wiper is accomplished by means of mechanical displacement which is applied by a bellows, Bourdon tube, or other actuating device. Many desired functional relationships between various parameters, such as pressure, angular displacement, and voltage output, may be achieved in this instrument by means of the arrangement of taps and shunts as described above.

Instruments constructed in accordance with the above description have been found to be rugged, reliable, precise and readily adjusted to produce functional outputs in accordance with many desired curves.

What we claim is:

1. A potentiometer component comprising an elongated main resistance element, a pair of input terminals, one of said terminals being connected to one end of said main resistance element, a variable resistor connected in series between the other end of said main resistance element and the other of said terminals, a plurality of taps connected to said element at spaced intervals along the length thereof, a movable contact slidably engaging said element and having connection with an output terminal, and a plurality of shunt resistors, each connected to a pair of adjacent taps, said shunt resistors having the effect of varying the resistance of said main element per increment of length between pairs of taps, and said variable series resistor providing means for adjusting the voltage output of said contact at the extreme end of said element.

2. A potentiometer component comprising an elongated main resistance element, a pair of input terminals, one of said terminals being connected to one end of said main resistance element, a variable resistor connected in series between the other end of said main resistance element and the other of said terminals, a movable contact slidably engaging said element and having connection with an output terminal, a plurality of taps connected to said element at spaced intervals along the length thereof, and a plurality of variable shunt resistors connected to pairs of said taps, said shunt resistors providing an adjustable variation in the rate of change in voltage output per increment of travel of said contact along the length of said element, and said variable series resistor providing means for adjusting the voltage output of said contact at the extreme end of said element.

3. A potentiometer component comprising an elongated main resistance element having input terminals connected to the ends thereof, a movable contact slidably engaging said element and having connection with an

output terminal, a plurality of movable taps adjustably engaging said element at spaced intervals along the length thereof, and a plurality of shunt resistors, each connected to a pair of taps, said shunt resistors having the effect of varying the resistance of said main resistance element per increment of length between pairs of taps.

4. In an electrical component having a body and a resistance element mounted thereon, an adjustable tap comprising a length of conductive spring material having two angularly related legs, said body having a hole formed therein into which one of said legs is inserted, the other of said legs extending across and bearing on said resistance element, said one leg being forced into firm frictional engagement with the sides of said hole when pushed down into said hole to a depth such that said other leg is pressed firmly against said resistance element.

5. In an electrical component having a body of non-conductive material and a resistance element mounted thereon, an adjustable tap comprising a generally L-shaped length of conductive spring wire, one of the legs of said tap being inserted into a hole in said body, and the other leg extending across and bearing on said resistance element, said tap being rotatable within the hole in said body so as to adjust the position of said other leg along the length of said resistance element, and said one leg engaging the sides of said hole with a firm frictional engagement serving to hold said tap in place.

6. In an electrical component, a body of non-conductive material having a channel formed therein, a resistance element mounted within said channel, a tap of conductive strip material, said tap including a portion extending transversely of and underneath said element and making electrical contact therewith, said portion being movable along the length of said element, and a terminal connected to said tap.

7. In an electrical component, a body of non-conductive material having a channel formed therein, a resistance element mounted within said channel, a tap of conductive strip material, said tap including a portion extending transversely of and underneath said element and making electrical contact therewith, another portion of said tap extending parallel to said resistance element, and a terminal mounted on said body to be slidably engaged by said other portion of said tap, said tap being shiftable bodily along the length of said resistance element to adjust the point of contact therewith.

8. In an electrical component, a body of non-conductive material having a channel formed therein, a resistance element mounted within said channel, a cavity formed within said body and intersecting said channel, a tap of conductive spring wire, said tap including a first portion extending parallel to said resistance element on the outside of said body, a second portion extending down into said cavity, and a third portion extending transversely of and underneath said element and making electrical contact therewith, said third portion being supported above the bottom of said cavity and being deflected downwardly by pressure of said resistance element thereagainst, and a terminal mounted on said body to be slidably engaged by said first portion of said tap, said tap being shiftable bodily along the length of said resistance element to adjust the point of contact therewith.

9. A potentiometer component comprising an elongated main resistance element having input terminals connected to the ends thereof, a movable contact slidably engaging said element and having connection with an output terminal, a plurality of taps connected to said element at spaced intervals along the length thereof, and an elongated shunting resistance element having a plurality of taps connected thereto at spaced intervals, said taps on said shunting resistance element being connected to the corresponding taps on said main resistance element, whereby sections of said shunting resistance element function as individual shunt resistors to vary the resistance

of said main resistance element per increment of length between pairs of taps.

10. A potentiometer component comprising an elongated main resistance element having input terminals connected to the ends thereof, a movable contact slidably engaging said element and having connection with an output terminal, a plurality of taps connected to said element at spaced intervals along the length thereof, a high resistance shunting element and a low resistance shunting element associated with said main resistance element, a plurality of taps connected to each of said shunting resistance elements at intervals along the length thereof, the taps on said high resistance element being connected to corresponding taps at one end of said main resistance element, and the taps on said low resistance element being connected to corresponding taps at the other end of said main resistance element, whereby sections of said shunting resistance elements between pairs of taps function as individual shunt resistors to vary the resistance of said main resistance element per increment of length between pairs of taps.

11. A potentiometer component comprising an elongated main resistance element having input terminals connected to the ends thereof, a movable contact slidably engaging said element and having connection with an output terminal, a plurality of taps connected to said element at spaced intervals along the length thereof, a high resistance shunting element and a low resistance shunting element associated with said main resistance element, a plurality of taps connected to each of said shunting resistance elements at intervals along the length thereof, the taps on said high resistance element being connected to corresponding taps at one end of said main resistance element, and the taps on said low resistance element being connected to corresponding taps at the other end of said main resistance element, one of the end taps on said high resistance element being connected to an end tap on said low resistance element to connect said shunting elements in series with one another, sections of said shunt resistance element between pairs of taps functioning as individual shunt resistors to vary the resistance of said main element per increment of length between pairs of taps.

12. A potentiometer component comprising an elongated main resistance element having input terminals connected to the ends thereof, a movable contact slidably engaging said element and having connection with an output terminal, a plurality of taps connected to said element at spaced intervals along the length thereof, an elongated shunting resistance element, a plurality of movable taps adjustably engaging said shunting element at spaced intervals along the length thereof, the taps on said shunting element being connected to corresponding taps on said main element so that sections of said elements between pairs of taps function as individual variable resistors to vary the resistance of said main element per increment of length between pairs of taps.

13. A potentiometer component comprising an elongated main resistance element having input terminals connected to the ends thereof, a movable contact slidably engaging said element and having connections with an output terminal, a plurality of movable taps adjustably engaging said main element at spaced intervals along the length thereof, an elongated shunting resistance element, a plurality of taps connected to said shunting element at spaced intervals along the length thereof, and means connecting the taps of said shunting element to corresponding taps on said main element so that sections of said shunting element between pairs of taps function as individual variable resistors to vary the resistance of said main element per increment of length between pairs of taps.

14. A potentiometer component comprising an elongated main resistance element having input terminals connected to the ends thereof, a movable contact slidably engaging said element and having connection with an output terminal, a plurality of movable taps adjustably engaging said main element at spaced intervals along the length thereof, an elongated shunting resistance element, a plurality of movable taps adjustably engaging said shunting element at spaced intervals along the length thereof, and means connecting the taps of said shunting element to corresponding taps on said main element so that sections of said shunting element between pairs of taps function as individual variable resistors to vary the resistance of said main element per increment of length between pairs of taps.

15. An electrical component comprising a body having a cavity formed therein, an elongated resistance element mounted on said body within said cavity, a movable contact wiping on said resistance element, and a termination tap of conductive spring material having a portion disposed within said cavity and projecting into the space normally occupied by said resistance element, said portion of said tap being engaged and deflected by said resistance element when the latter is positioned within said cavity so that said portion is stressed to exert spring pressure on said resistance element to make electrical contact therewith.

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