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PRODUCTION OF POTENTIOMETERS

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FIG. 1

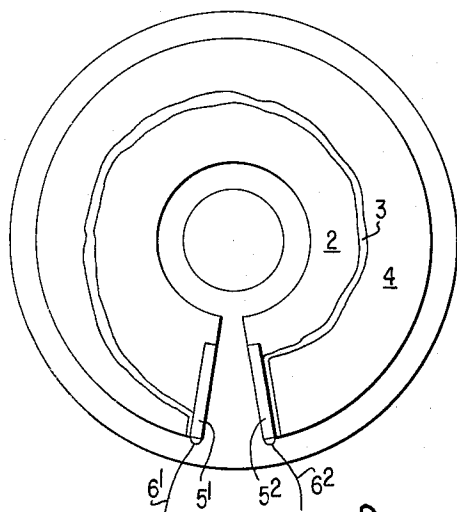
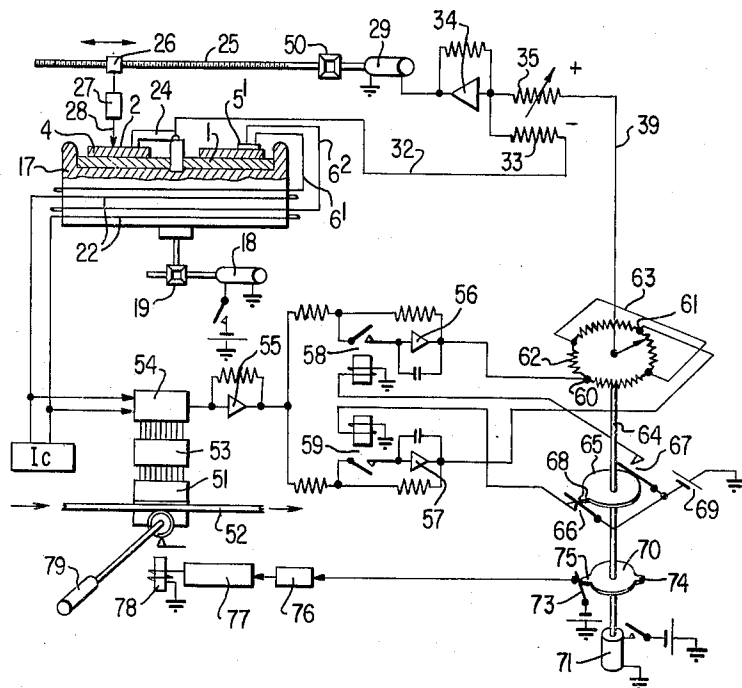


FIG. 2

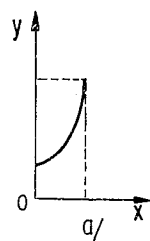


FIG. 3

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PRODUCTION OF POTENTIOMETERS

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6 Claims. (Cl. 83-5)

This invention relates to the production of potentiometers of high resolution and having a predetermined resistance-displacement characteristic of taper.

More particularly, the invention relates to potentiometers having a coating or film of resistance material on an annular surface of a flat dielectric ring. While the resistance film or coating may be formed of different materials, the present invention is specially useful in connection with coatings of certain metallic oxides and nitrides or mixtures thereof.

It is an object of the invention to adjust the parameters required for a potentiometer track by dividing a resistive coating into at least two sections which are electrically isolated from one another. This separation involves a mere cutting line or groove, made for instance with a diamond-pointed stylus.

It is another object of the invention to devise apparatus to perform a cutting operation automatically by controlling the path of the cutting tool by means of an error signal which results from the comparison of the electric signal taken, during operation, from a wiper bearing on the final useful portion of the coating and an electric reference signal which varies in accordance with a predetermined law to produce the desired resistance-displacement characteristic or taper.

It is still another object of the invention to control the cutting operation from a digitalized record of the predetermined law of taper to be produced in the final potentiometer.

Additional objects will become obvious upon consideration of the following detailed description taken in conjunction with the drawings wherein:

FIGURE 1 is a view shown somewhat diagrammatically of the apparatus necessary to carry out the present invention;

FIGURE 2 is a top plan view of a non-linear potentiometer track produced by the present invention;

FIGURE 3 is a non-linear law exemplatively plotted and corresponding to the taper of the track of FIGURE 2.

The track, when un-machined according to the present invention, comprises an annular carrier 1 coated with a thin film of oxides and/or nitrides. This coating is deposited on the annular disk 1 by any of the known methods, for instance by the method disclosed in co-pending application No. 636,410 filed January 25, 1957, now Patent No. 3,019,137, or the method disclosed in co-pending application No. 852,742, filed November 13, 1959, now Patent No. 3,008,447. While the production of this coating does not fall within the purview of the present invention, suffice it to say that the coating may be produced from halogenated components of at least two elements from the groups III to V of the periodic table. The material is deposited on the vitreous disk 1 in an amount whereby the total resistance between two end terminals is of the approximate overall value desired for the finally produced potentiometer. The disk 1 consists, for instance, of glass of high melting point, of type commonly known by the trademark "Pyrex." The annular resistive coating 2 leaves outer and inner areas uncoated on the glass. Furthermore, an additional sector is not coated on the glass. On each side of this sector, the coat-

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ing material ends in conductive terminals 5¹ and 5² which consist of coatings of good conductivity.

The invention contemplates, beginning with such a base as described above, the calibration or formation of the track so as to impart to it a predetermined resistance-displacement characteristic or taper between the terminals. By taper is meant that when the wiper or contact moves across the surface of the resistive coating in a clockwise manner, the resistance between terminal 5¹ and the wiper varies according to a predetermined law from the position of the wiper on terminal 5¹ to the position of the wiper on the terminal 5², with "infinite" resolution, that is to say, without discontinuity and with a predeterminedly variable "slope." The slope is, of course, the value of the derivative or the function $R(\theta)$ and therefore the value of the function $(dR/d\theta)$, R being the resistance and θ the angular position of the wiper along the entire useful path in question, i.e., from the terminal 5¹ to the terminal 5². In other words, the current tapped off by contact varies according to a predetermined law when the potentiometer is energized with a constant current between the terminals via the connecting wires 6¹ and 6² which are soldered to the said terminals.

In order to achieve such a condition, it is necessary to assure simple cutting, by a diamond cut, or the like, of the resistant film, dividing it into at least two parts or portions which are electrically isolated from each other by the cutting line, one of the parts which are thus separated being shaped to provide a required law of variation of resistance (taper) as a function of the angular position of a contact wiper, and doing this with the desired precision of taper at any point of the "track" which is thus established. In the example shown in FIG. 2, it is the inner portion of the film, 2, which is provided with a contour satisfying the required taper to the desired degree of precision, and the outer surface, 4, which is unconnected to the portion 2. This separation is made from two cutting lines which delineate another unused but small portion 3 between the active portion 2 and the inactive portion 4 of the film coating. Each of said lines is made in a separate operation. In this example, the taper follows a law which is $y=x^2$ as shown at (a), and of course any other required law may be set on the potentiometer track.

The film support 1 is mounted in a mounting unit 17 which can be driven in rotation at slow uniform speed by a motor 18 through gearing 19 which is provided with a crank for manual rotation when necessary. The disk 1 is wedged in the block 17 and its terminals 5¹ and 5² are connected by wires 6¹ and 6² to terminals of collector rings 22 carried by the support 17. A reference voltage for energizing the film during the cutting operation is applied between these rings by way of wipers. The reference voltage is supplied from an automatically regulated current source I_0 so that the film is fed a constant current for the duration of each track cutting pass.

A wiper 24 is held fast on its support so that during the rotation of block 17, this wiper remains below a feed screw 25 parallel to the wiper support. Mounted on this screw and driven thereby is a movable carriage 26 which supports a tool holder 27, on which there is mounted the cutting tool 28. It should be understood that this tool holder is of such a nature that the tool can be moved by the operator into and out of contact with the film when required.

The feed screw 25 can be driven by a motor 19 through gearing 50. An electric connection 32 is made between the wiper 24 and a summation or mixer resistor 33 at the input of a control amplifier 34 controlling the motor 29. To the other mixer resistor 35 of this amplifier, there is applied a reference current which varies during the rota-

tion of the unit 17 in accordance with a desired law of variation.

The current applied to the lead 39 to resistor 35 originates in source I_c and is controlled from the tape reader 51 which is driven in a step-by-step fashion from the rotation of a motor 79 each time a relay 78 is activated for permitting such a drive. The tape, punched or otherwise marked for an automatic read-out, carries a series of digital codes defining in their sequence the required law of variation of the taper. Each complete digital code is actually made of several characters on the tape 52 and, when readout from the tape in several steps, it is progressively stored in a store 53 from the accumulating therein of a predetermined number of elemental codes read-out in as many steps on the tape 52. The digital accumulator 53 may be of a kind automatically erasable after a predetermined number of times a code had been introduced therein. A digital-to-analogue converter 54 is controlled from the accumulator 53 and fed from the source I_c . The current issuing from the output of 54 passes through a polarity-changing amplifier 55, with high negative feedback stabilization, and reaches the inputs of two storing amplifiers 56 and 57. The voltage storing in said amplifiers may be assumed by condensers in shunt around the amplifier stages proper which, being of a high gain amplifier type, does not reverse the polarity of an input voltage to its output. In the inputs of said amplifiers 56 and 57 are inserted contact of relays 58 and 59. These relays will always be controlled so that only one of them is energized at a time, consequently one contact only closed at any time.

The outputs of the said amplifiers 56 and 57 are connected to diametrically opposed taps, 60 and 61, of a potentiometer track 62, the wiper of which is driven by a shaft 64. This potentiometer track has a linear taper and may comprise an oxide film track which has been previously adjusted to such a linear taper. Preferably, two diametrically opposed points of the track, at 90° from the taps 60 and 61 are connected by a wire 63 for decreasing the apparent impedance of the track.

On the shaft 64 are carried two cams 65 and 70. The shaft 64 is driven by a motor 71. Cam 65 presents an embossing 68 for the alternate closure of the contacts 66 and 67 fed by a battery 69, for the alternate activation of relays 59 and 58 in each complete turn of the shaft. Said contacts 66 and 67 are arranged at 180° and in angular registration with the positions of the taps 60 and 61 of the track 62. Consequently, relays 58 and 59 are alternately energized, relay 58 when the contact 67 closes and the wiper of 62 passes over 61, relay 59 when the contact 66 closes and the wiper of 62 passes over 60.

The cam 70 is provided with two embossings at 180° in order to close, twice in a revolution of the shaft 64, a contact 73 supplied by a battery 71. Each time the embossing 74 or the embossing 75 closes 73, the battery 71 is connected to a pulse shaper 76 which starts a step-by-step pulse generator 77. Each step of 77 temporarily closes the contact of relay 78 and the tape 52 consequently advances by one step. When, for instance, a complete digital core comprises four characters on the tape, the step-by-step member 77 delivers four activation pulses to the relay 78 and comes back to its rest condition. At each operation of 77 consequently, a digital code is substituted in 53 to the next preceding code read-out from the tape, and the output current from 54 varies for storing a fresh voltage value in the condenser of 56 or 57 according to the one of the relays 58 and 59 which is then energized.

The speed of rotation of 70 is such that the shaft 64 completes a revolution during the time motor 18 rotates the potentiometer track 1 by, say, two degrees. The curve at (a) has been cut into 360 portions, each defining a quantized value of ordinate, the digital code of which is carried in four characters on the tape 52 for the control of the cutting of the track 4.

The operation of the device may then be explained as follows: at the start, the motor 71 is started with the embossing of cam 70 closing the contact 73, and this embossing being, for instance 75. The embossing of the cam 65 then closes the contact 66 and the relay 59 is energized. The first digital code is introduced into 53, decoded at 54 and stored as an analog voltage in storing amplifier 57. The inputs of both 56 and 57 are then cut off from the output of 54. The wiper of 62 being driven at a constant speed, in a clockwise direction for instance, from 60, zero voltage, the current fed to 39 will linearly increase up to the maximum value reached for the passage of the wiper at point 61, value U_1 for instance, corresponding to the electric charge of the condenser in the storing amplifier 57. Slightly prior to the instant when the wiper of 62 reaches 61, the cam 70 has modified the content of the accumulator 53 from the read-out of a fresh digital code from the tape. The analog voltage from 54 has not been stored since no input of amplifiers 56 and 57 was available. When the wiper of 62 reaches 61, the cam 65 activates the relay 58 and the voltage from the decoder 54 is stored in the condenser of storing amplifier 56, and voltage U_2 is applied to the tap 60. The potential at 61 does not significantly vary, hence the continuity of the signal fed to 39 which follows the interpolation law from 62 until the wiper reaches 60; at this time instant, a further fresh digital code has been introduced in 53 and is substituted, in its analog voltage representation, to the previous voltage stored in the condenser of the storing amplifier 57. The fresh voltage U_3 is substituted to U_1 on the tap 61 of 62; and so on, from degree of rotation to degree of rotation of the unit 17, wherein the track 2 is progressively cut according to the required taper law as set on the read-out tape. It may be of advantage, once a first pass completed for the cutting, to provide a renewed pass, from the same tape, in order to obtain a better approximate of the taper law on the oxide film 2.

Prior to an automatic pass, it is required that the cutting of a radial portion to be made for separating the terminal 5¹ from the part 4 of the oxide film coating, and another cutting is made after the pass to separate 4 from 5². These may be manual steps of operation wherein motor 18 is stopped and carriage 26 manually driven.

What I claim is:

1. Apparatus for forming a desired taper on a potentiometer track formed of an elongated film of resistive material applied to one face of a dielectric base and having a terminal at each end, said apparatus comprising: a tool for cutting a groove through the film onto the base; first driving means producing relative movement between the base and said tool longitudinally of the strip; second driving means for moving said tool transversely of the track during the operation of said first driving means; means for connecting a constant source of current to the end terminals of the track during operation of said driving means; means for detecting the potential difference between the point of cutting and one of said end terminals of said strip; a digitally coded store, reader means for periodically reading-out digital codes from said store, and for generating and periodically varying an analog voltage in accordance with said read-out codes; means for comparing said potential difference and said analog voltage; and means connecting the output of said voltage comparing means to control said second driving means.

2. Apparatus according to claim 1, wherein said voltage varying means from said read-out codes comprise means for interpolating the values of said analog voltage between each pair of successive variations of the voltage from the digital codes.

3. Apparatus for forming a desired taper on a potentiometer track formed of an elongated film of resistive material applied to one face of a dielectric base and having a terminal at each end, said apparatus comprising: a tool for cutting a groove through the film onto the base; first driving means producing relative movement between the

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base and said tool longitudinally of the film; second driving means for moving said tool transversely of the film during the operation of said first driving means; means for maintaining a constant current through the film; a wiper contacting the film in registration of position with said cutting tool; a digital coded tape; means for periodically reading-out digital codes from said tape during the operation of said first driving means; a digital-to-analog converter connected to said read-out means; interpolating means for deriving a continuously varying voltage between any changes of values of said analog voltage; means for deriving a difference signal between the output current from said wiper and the output current of said interpolating means; and means for controlling said second driving means from said difference signal.

4. Apparatus according to claim 3, wherein said interpolating means comprise two intermediate stores and means for alternately routing the successive values of said analog voltage to each one of said stores; a potentiometer track having diametrically opposed taps connected to the output voltages from said stores; means for driving the wiper of said interpolation potentiometer during the operation of said first driving means; and means for reading-out said tape each time said wiper nears one of said diametrically opposite taps.

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5. Apparatus according to claim 4, wherein said routing means comprise relays alternately disabling the inputs of said stores and means for alternately and temporarily actuating said relays each time the said wiper passes over one of said taps.

6. Apparatus according to claim 5, wherein said means for reading-out digital codes from the tape and said means for actuating the said relays comprise cams mounted for rotation with said wiper and switch means connected to said tape reader and said relays.

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