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POTENTIOMETER OR THE LIKE

Original Filed Jan. 24, 1966

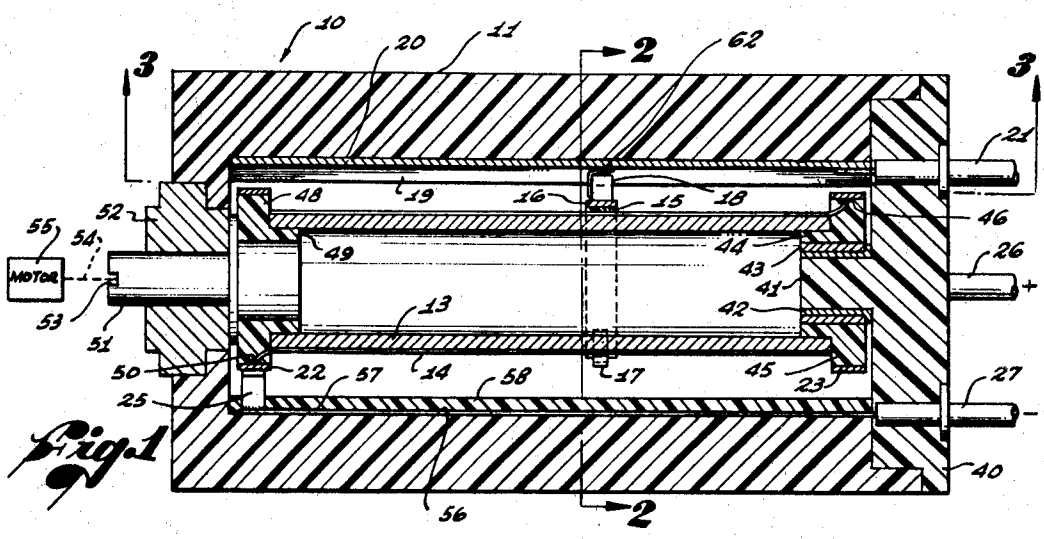


Fig. 1

Fig. 5

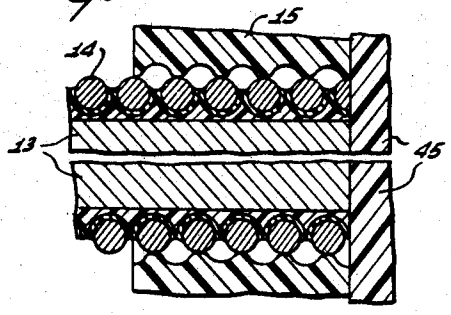


Fig. 2

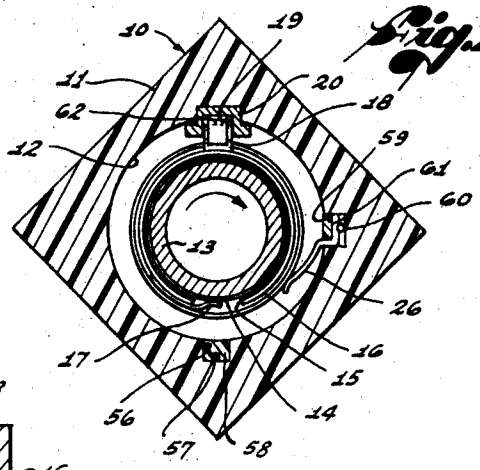
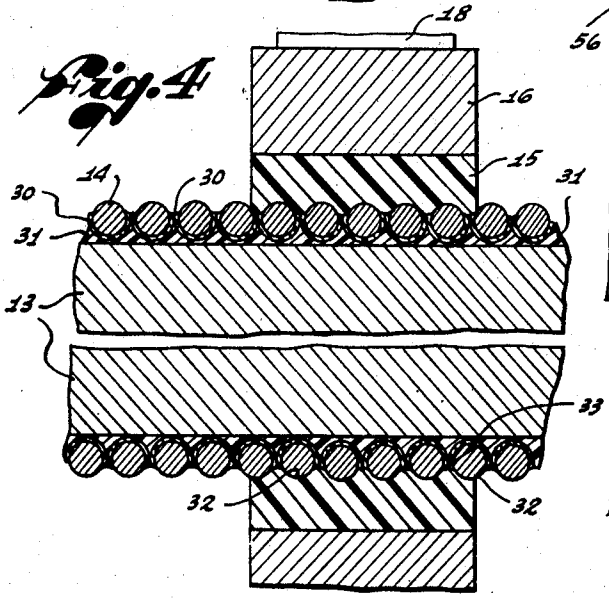


Fig. 4



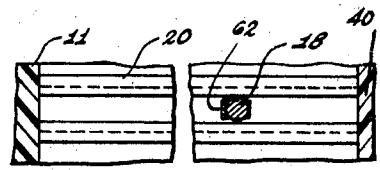


Fig. 3

INVENTORS
WILLIAM I. ELLIOTT
JACK L. RANDALL
BY Fulwider, Patton, Rieber, Lee, and Utecht
ATTORNEYS

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POTENTIOMETER OR THE LIKE

William I. Elliott, 5172 Dumont Place, Woodland Hills, Calif. 91364, and Jack L. Randall, 27 Malibu Colony, Malibu, Calif. 90265

Original application Jan. 24, 1966, Ser. No. 522,736, now Patent No. 3,399,368, dated Aug. 27, 1968. Divided and this application Dec. 14, 1967, Ser. No. 703,814
Int. Cl. H01c 1/14
U.S. Cl. 29—619 5 Claims

ABSTRACT OF THE DISCLOSURE

A method of making a potentiometer, including the steps of:

(1) Winding an insulation-coated resistance wire onto a cylindrical support with adjacent turns in abutment;
(2) securing the confronting portions of the insulation and the support together;
(3) removing the insulation along the outer portion of each turn between the portions of insulation separating adjacent turns;
(4) forming a split plastic ring having a smooth inner surface of an axial length sufficient to span a plurality of turns of the wire;
(5) placing the plastic ring around the wire;
(6) deforming the inner surface of the plastic ring to form alternate grooves and ribs, wherein the grooves conform to the contour of the exposed wire of the turns and the ribs nest between adjacent turns, the turns and ribs being in mesh so as to coact, upon rotating the support while holding the plastic ring against rotation, to effect longitudinal movement of the plastic element;
(7) and attaching an electrical contact element to the plastic ring, with a portion of such element in wiping engagement with the exposed wire on at least one turn.

This application is a division of application Ser. No. 522,736, filed Jan. 24, 1966, now Patent No. 3,399,368.

This invention relates to apparatus using variable resistance devices, and more particularly to a unique construction for potentiometers and the like with which to obtain infinite resolution with a wire-wound resistor.

It has long been known to apply a voltage across the terminals of a resistor element formed of many turns of resistance wire, and to move an electrical wiper contact, or pick-off, from turn to turn to change the voltage between either terminal and the wiper. The greater the number of turns, the smaller is the increment of change in voltage from turn to turn. Thus, a resistor may be formed of 2,500 turns per inch of wire wound on a mandrel, in which case movement of the wiper along the mandrel between adjacent turns effects a change of $\frac{1}{2500}$, or 0.0004 of the total voltage across either terminal of the resistor and the wiper. But this is the smallest voltage change that can be effected, or detected, with this arrangement.

However small the wire, and however large the number of turns, it has not heretofore been possible with such wire-wound resistors to obtain infinite resolution, i.e., to effect as small a voltage change as desired. In many complex electronic systems, it is often desirable to change a voltage applied to a circuit by as little as a millionth of the applied voltage.

Variable resistors with which infinite resolution can be obtained have been made with powdered resistive and ceramic materials mixed together and sintered to form a monolithic element. In some, the proportions of ingredients in the mixture are the same throughout the length of the element, but the thickness of the element varies

from end to end. In others, the element is of uniform thickness along its length, but the quantity of resistive material varies gradually from end to end. In either case, the wiper can be moved to any desired position on the element to effect any desired voltage change.

However, there are certain disadvantages in the use of such resistor elements. Due to their particulate structure, they manifest relatively high electrical noise levels and temperature coefficients of resistance, which are greatly improved by resistors wound with wire of solid metal.

It is an object of our invention to provide wire-wound resistor apparatus with which to achieve infinite resolution.

It is another object of our invention to provide a unique wire-wound resistor and wiper therefor which function both as electrical elements and as cooperative threaded means to make the wiper follow the turns of the resistor.

A further object of our invention is to provide a potentiometer or like structure having a minimum number of component parts of simple design and dugged construction.

The above and other objects and advantages of our invention will become apparent from the following description taken in conjunction with the accompanying drawing of an illustrative embodiment thereof, in which:

FIGURE 1 is a longitudinal sectional view of a potentiometer of our invention, wherein the windings of the resistor element constitute threads for mating engagement with threads of an element which functions both as the wiper and a traveling nut;

FIGURE 2 is a sectional view taken along the lines 2—2 of FIGURE 1, showing more clearly the arrangement of the wiper-nut element;

FIGURE 3 is a fragmentary sectional view taken along the lines 3—3 of FIGURE 1, to aid in explaining the movement of the wiper-nut along the resistor element;

FIGURE 4 is an enlarged fragmentary sectional view of a portion of the resistor element encircled by the wiper-nut, to aid in explaining the method of our invention in forming the cooperative threads; and

FIGURE 5 is an enlarged fragmentary sectional view of the wiper-nut at one end of the resistor element at which further linear movement thereof is prevented, to aid in explaining the operations of the mating parts to prevent stripping of the threads thereof.

Referring to FIGURES 1 and 2, a potentiometer **10** in accordance with our invention employs a housing **11** having a central opening **12** therein, in which a mandrel **13** is adapted to rotate. The mandrel **13** carries a resistance winding **14** on its outer surface, the turns of which form mating threads with a plastic nut **15**, which is formed as a broken ring, and which is supported in a spring clip **16** which at one end forms a conductive wiper contact **17** engaging the winding **14**. The spring clip **16** is provided with a projection **18** that rides in the groove or keyway **19** formed in an elongated channel-shaped member **20**. The channel **20** is of conductive material, and is electrically connected at one end to an external pin **21**, and the ends of the winding **14** are connected to conductive slip rings **22**, **23** which rotate with the mandrel **13**, and which, through respective wiper contacts **24**, **25**, are electrically connected to external pins **26**, **27**.

In this manner, rotation of the mandrel **13**, and hence the resistor winding **14**, effects longitudinal movement of the nut **15**, the direction of travel of the nut depending upon the direction of rotation of the mandrel **13**. In this manner, the wiper **17** is caused to follow the turns of the winding **14** as it moves from one to the other thereof. Accordingly, any desired adjustment in the position of the nut **15** can be made to effect any desired change in voltage at the pin **21**.

For example, assume the winding **24** to be one inch

long, and to comprise 2500 turns of wire, the ends of which are connected, via terminal pins **26, 27**, to a source of voltage (not shown). One revolution of the mandrel **13** causes the wiper **17** to traverse the length of wire which accounts for $\frac{1}{2500}$ or 0.0004, of the total applied voltage. However, inasmuch as the wiper engages such turn throughout such a revolution, a fraction of the revolution effects a corresponding fractional change in the portion of the voltage represented by a complete turn. Thus, moving the mandrel **13** through an angle of one degree effects a change of $\frac{1}{360}$ of the 0.0004 fraction of the applied voltage, or approximately one-millionth of such applied voltage. Movement of the mandrel through a fraction of a degree effects a correspondingly smaller fractional change of the applied voltage.

It will be appreciated that it is impossible by conventional methods to make a threaded element with threads of as slight a pitch as above indicated. Even by engraving methods, it would be next to impossible to form threads of the order of a 0.0004 inch pitch with accuracy. Referring to FIGURE 4, in our invention we utilize the resistor winding **14** for forming the internal threads of the nut **15**. To this end, we first wind the resistance wire on the mandrel **13**, it being understood that such wire, however small it is in diameter, is coated with insulation **30**. The turns of the winding **14** are attached to the mandrel **13**, as by a coating **31** of plastic material, such as an epoxy resin, which forms a bond between the mandrel **13** and the confronting portions of the insulation **30** around the wire.

In this latter connection, the winding may be attached to the mandrel in any desired manner. For example, the thin coating of the plastic material may be applied to the mandrel before winding the wire thereon. The wire is wound on the mandrel so that the insulation coatings on adjacent turns are in abutment. If the plastic coating **31** is hardened at the time the winding is wound thereon, the assembly is placed in an oven and heated to cause the plastic material to flow and fill the helical groove that is defined by the diverging portions of the insulation **30** and the outer surface of the mandrel. If the coating **31** is wet when the wire is wound on the mandrel, the plastic material fills such groove, whereupon subsequent curing of the plastic material causes the winding to be firmly bonded to the mandrel.

Further, the winding may be wound on a dry, i.e., uncoated, mandrel. The ends of the mandrel are plugged, and it is immersed in a container of liquid material to be used for bonding. The contaner is then placed in a vacuum chamber, and a vacuum is drawn to cause the liquid to be drawn between the mandrel and the winding, and to fill all interstices therebetween. The assembly is then removed from the vacuum and the bonding material is allowed to harden.

After the winding **14** is bonded to the mandrel **13**, the outer portion of the insulation **30** around each turn of wire is removed. Removal of the insulation from the wire can be effected by any known technique, as by soda buffing, wherein an abrasive of finely divided particles of soda are applied to the external portions of the insulation by a sand blasting technique. Alternatively, the insulation may be removed by simply rubbing it off with a soft eraser.

For purposes of a precision potentiometer, the mandrel **13** is of sufficiently large diameter as to avoid undue stress in the wire by virtue of wrapping it around a cylinder. As will be appreciated, winding any wire on a mandrel that is too small in diameter requires that the wire follow such a short radius as to set up stresses therein, which would be greatest where the wire engages the mandrel. The effects of such stresses become pronounced over wide temperature variations, and result in marked changes in the temperature coefficient and the resistance of the wire in different temperature ranges. Where such changes cannot be tolerated, we employ a mandrel that is of sufficient outside diameter as to substantially eliminate this possibility. For example, in one application using wire of 0.0004 inch diameter, we employ a mandrel having an outside diameter of approximately 0.25 inch.

Also, where the apparatus is subjected to a wide range of temperatures, the material used for the wire preferably has a temperature coefficient which is as nearly like that of the mandrel as possible. The mandrel may be made of brass, which has an extremely low temperature coefficient, in which case the material used for the wire of the winding **14** should be made of alloys of metal having a comparable coefficient of expansion and contraction.

As previously mentioned, the nut **15** is formed of plastic material. If the material of the nut **15** is one that is capable of being deformed by the application of pressure alone, e.g., Teflon, the spring clip **16** surrounding the material is utilized for this purpose. Since the elements forming the wiper and the nut are split rings, the constant inward pressure of the spring clip **16** results in grooves **32** (FIG. 4) which conform to the exposed portions of the wire, and ribs **33** formed of the portion of the material that is forced inwardly toward the portions of insulation **30** between adjacent turns of the wire.

As will be seen, this arrangement results in the formation of internal threads for the nut **15** which matingly engage the turns of the winding, so that rotation of the mandrel **13** effects linear travel of the nut **15** in a manner conventional for linear actuators.

Where the nut **15** is to be formed of a plastic material which is extremely hard and has long-wearing qualities, e.g., a nylon molding compound, the force exerted by the clip **16** is insufficient to deform the internal surface of the nut to provide the desired internal threads therefor. In such case, the split ring for the nut is molded, and then inserted in the clip **16** and bonded thereto with a suitable plastic material. Such bonding may be facilitated by roughening the outer surface of the molded ring, as by etching, before bonding it to the spring clip **16**. The clip **16** and the plastic ring therein are snapped onto the exterior of the winding **14**. We then heat the internal surface of the plastic ring to a sufficient temperature to cause the material to flow, whereupon the pressure exerted by the spring clip **16** forces the material into the grooves between adjacent turns of the wire, thereby to form the internal threads for the nut as previously described in connection with FIGURE 4.

The application of heat for molding the threads in the inner surface of such a hard plastic element may be effected in a variety of ways. One technique is to apply a heating current through the wires of the winding **14** of sufficient magnitude to heat the internal surface of the element. Due to the continuing inward pressure exerted by the clip element **16**, the softening of the inner surface of the element forces it inwardly to form the grooves and ribs **32, 33** as shown in FIGURE 4.

Another technique for carrying out this heating step is to place the entire assembly in an oven and heat to a sufficient temperature to effect the desired molding of the threads.

Molding of the threads on the nut **15** may be accomplished on a volume basis. To this end, we employ a master mandrel wound with a resistance winding as described herein, and position a plurality of assembled plastic rings in spring clips around the winding. The heating step previously described thus forms internal threads on all of the plastic nut elements simultaneously. After such molding, each of the wiper-nut assemblies is removed from the master unit and placed on a respective wire-wound mandrel, on which wire of the same diameter has been wound.

For a fuller understanding of the operation of the potentiometer of our invention, reference is made again

to FIGURES 1–3. As shown, the housing **11** is formed as an elongated cylinder having an end cap **40** bonded in place as by a suitable plastic adhesive coated on the confronting surfaces of the cylinder and the end cap. The housing parts may be formed of any desired material, e.g., metal or plastic.

As shown at the right-hand end of the housing in FIGURE 1, the end cap **40** has an inner cylindrical projection **41** which is surrounded by a metallic sleeve **42** forming a sleeve bearing. Surrounding the bearing **42** is a metallic sleeve **43**, which is press-fit into a cylinder **44** which extends into the end of the mandrel **13**. The confronting surfaces of the mandrel **13** and the cylinder **44** are bonded together, as with a suitable epoxy cement. The flange **45** of the cylinder **44** abuts the ends of the mandrel **13**, and extends radially a substantial distance beyond the winding **14**. As shown, the slip ring **23** is mounted on the periphery of the flange **45**, to which it is bonded. The adjacent end of the winding **14** is suitably connected to the slip ring **23**, as by extending it through a groove in the radial face of the flange **45**, and soldering or welding it at **46** to the inner surface of the slip ring **23**.

At the opposite end of the mandrel **13**, the slip ring **22** is mounted on the periphery of the flange **48** of a cylinder **49** that extends into and is bonded to the interior surface of the mandrel **13**, in the manner of the cylinder **44**. The outer diameter of the flange **48** is the same as that of the flange **45**, and the slip ring **22** is the same size as the slip ring **23**. As in the case of the terminal of the winding connected to the slip ring **23**, the end of the winding adjacent the flange **48** is similarly connected at **50** to the slip ring **22**.

The cylinder **49** is press-fit on the inner end of a stub shaft **51** that extends to the exterior of the housing **11**. As shown, the stub shaft **51** is rotatably mounted in a bushing **52** which is secured in the left end of the housing. The outer end of the stub shaft **51** may be provided with a screwdriver slot **53** through which to rotate the mandrel manually, or the stub shaft may be adapted as at **54** for operation by a motor **55**. Thus, it will be seen that the shaft **51**, the mandrel **13** with the winding **14** thereon, and the slip rings **22, 23** are arranged for unitary rotation.

As seen in FIGURES 1 and 2, the wiper contact **25** extends into a groove **56**, where it is soldered or welded to one end of a wire **57** extending the length of the groove from the inner end of the terminal pin **27**. As shown, the wire **57** is laid in the bottom of the groove **56**, and is potted in place, by filling the groove with a suitable plastic material, indicated at **58**. At the right end of the housing, the wiper contact **26** extends into a similar groove **59**, where it is soldered or welded to a wire **60** extending from the inner end of the terminal pin **26**, as in the case of the wire **57** and terminal pin **27**. Also, as in the case of the potting material **58** in the groove **56**, the groove **59** is filled with potting material **61**.

To aid in maintaining the desired electrical contact between the winding **14** and the terminal pin **21**, a short metallic leaf spring **62** is soldered or welded to the projection **18**. As shown, the leaf spring **62** is soldered to the radially extending portion of the projection **18**, and is bent over the upper end of the projection. The spring **62** is self-biased outwardly from the end of the projection **18**, so as to be maintained in continual engagement with the inner surface of the web portion of the channel **20**.

The wiper-nut construction in our invention offers the unique advantage that when the nut engages either of the flanges **45, 48** at the ends of the mandrel, continued rotation of the mandrel in the same direction will not result in damage to the cooperating threads of the winding **14** and the nut **15**. In other words, our invention dispenses with the requirement in prior art linear actuators for mechanical slip clutches and/or electromagnetic clutches operated by switches disposed in the paths of the traveling elements.

Referring to FIGURE 5 along with FIGURE 1, when the nut **15** is brought to bear against the flange **45**, the split ring configuration of the clip **16** and the nut **15** permit the threads constituted of the winding **14** to cam the nut **15** and clip **16** outwardly during those portions of the revolution in which the threads would, with a nut formed of a solid ring, result in stripping of the threads or alternately, causing the interfering threads to bind and thereby place an overload on the motor **55**. By this means, if the mandrel **13** continues to turn in the same direction, the nut **15** simply opens and closes as long as the mandrel is turned, but without damage to any of the parts of the potentiometer or the actuating means therefor. As soon as the direction of rotation of the mandrel is reversed, the threads of the nut immediately resume mating engagement with the turns of the winding, to cause travel of the nut in the opposite direction.

To facilitate the above-described operation of the wiper-nut arrangement, and to avoid any short-circuiting problems, we make the axial length of the nut and clip **16** greater than the axial dimensions of the projection **18** and the portion of the spring wiper **62** that is welded or soldered thereto. Additionally, the outer diameter of the metal clip **16** is smaller than the inner diameter of the slip rings **22, 23**. Thus, when the nut reaches the end of its travel at either end of the mandrel, none of the metal parts associated with the clip **16** can engage a slip ring.

It will be noted that we have illustrated the nut as spanning several turns of the winding **14**. For a nut of given axial dimension, the number of turns of the winding spanned thereby, i.e., the number of threads formed in the nut, will depend upon the size of the wire. For wire of the order of 0.0004-in. diameter, a nut of 0.080-in. axial length spans of the order of 200 turns of the winding **14**. For a winding **14** wound with wire of 0.016-in. diameter, a nut of such axial dimension spans five (5) turns. Correspondingly, of course, the wiper portion **17** of the clip **16** spans a number of turns of the winding, the number of which also depends upon the size of the wire used. We find that this arrangement is beneficial, in that it insures mechanical stability of the nut, i.e., by preventing tilting thereof as it is moved along the mandrel.

From the foregoing, it will be apparent that various modifications can be made in the method and apparatus as illustrated and described herein, without departing from the spirit and scope of our invention. Accordingly, we do not intend that our invention be limited, except as by the appended claims.

We claim:

1. The method of making variable resistance apparatus comprising the steps of:

winding an insulation-coated resistance wire onto a cylindrical support with adjacent turns in abutment;

securing the confronting portions of the insulation and the support together;

removing the insulation along the outer portion of each turn between the portions of insulation separating adjacent turns;

forming a split plastic ring having a smooth inner surface of an axial length sufficient to span a plurality of turns of the wire;

placing the plastic ring around the wire;

deforming the inner surface of the plastic ring to form alternate grooves and ribs, wherein the grooves conform to the contour of the exposed wire of the turns and the ribs nest between adjacent turns, said turns and ribs being in mesh so as to coact, upon rotating the support while holding the plastic ring against rotation, to effect longitudinal movement of the plastic element;

and attaching an electrical contact element to the plastic ring, with a portion of such element in wiping engagement with the exposed wire on at least one turn.

2. The method of claim **1**, wherein the deforming step includes applying pressure radially inwardly on the plastic

ring, the material of the ring being deformable by the application of pressure alone.

3. The method of claim 1, wherein the material of the plastic ring is deformable upon application of heat and pressure, and wherein the deforming step includes heating the inner surface of the plastic ring, and applying pressure radially inwardly on the ring while the inner surface thereof is heated.

4. The method of claim 3, including passing an electric current through the wire to heat the inner surface of the plastic ring.

5. The method of claim 4, including forming a split ring clip of conductive spring metal:

inserting the plastic ring within and securing it to the clip prior to placing it around the wire, the clip exerting inward radial pressure on the plastic ring, the ends of the clip and the plastic ring being flush and spaced apart;

and securing a spring wiper contact to the clip, with one end of such contact extending between the ends of the slip and slidably contacting the wire on the support.

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JOHN F. CAMPBELL, Primary Examiner

U.S. Cl. X.R.

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