Feb. 24, 1970 C. A. NORRIS 3,497,858

POTENTIOMETER

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FIG. 1

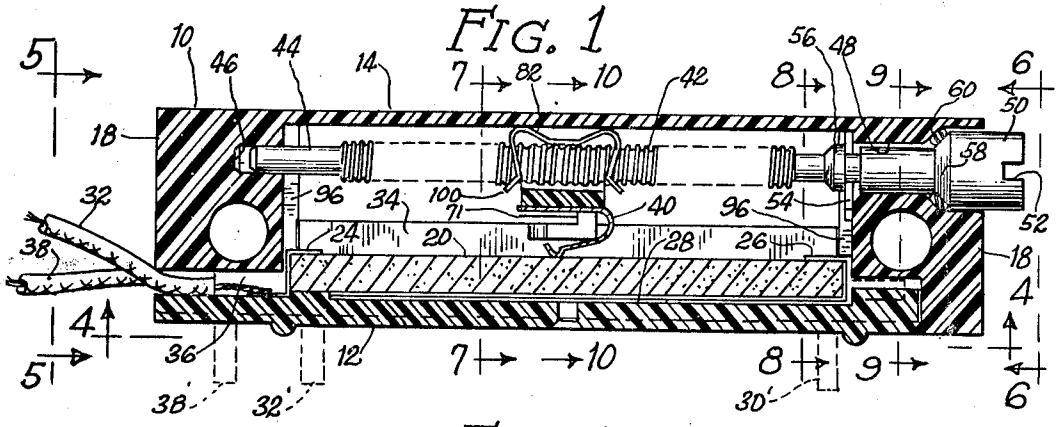


FIG. 2

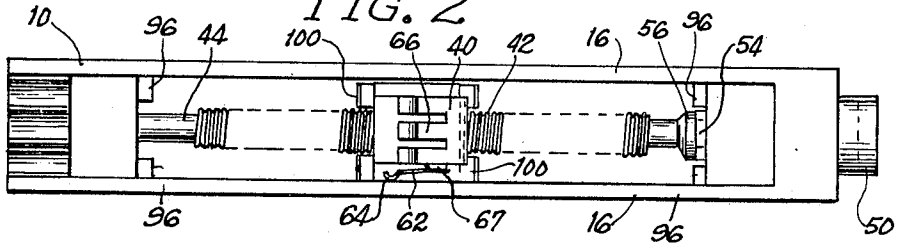


FIG. 3

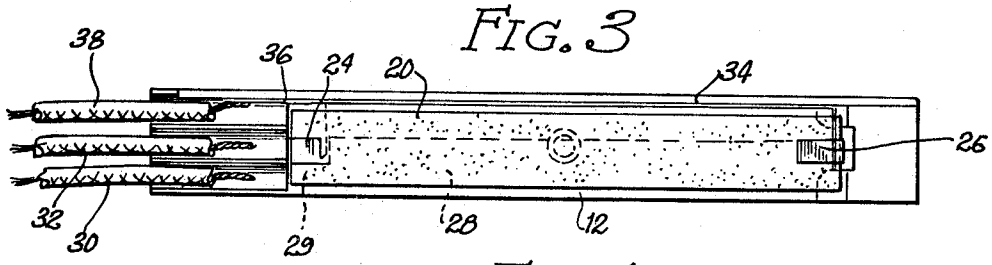


FIG. 4

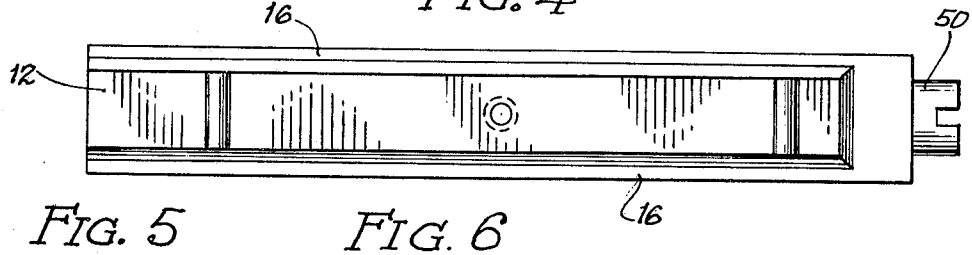


FIG. 5

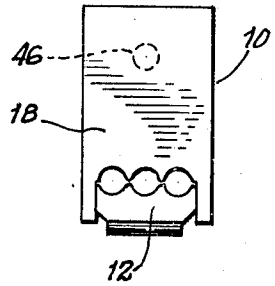
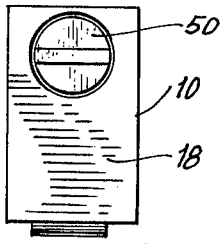


FIG. 6



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FIG. 7

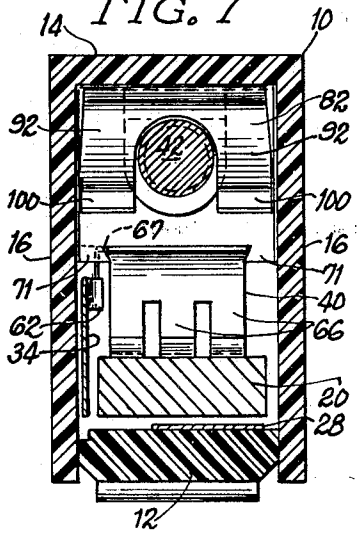


FIG. 8

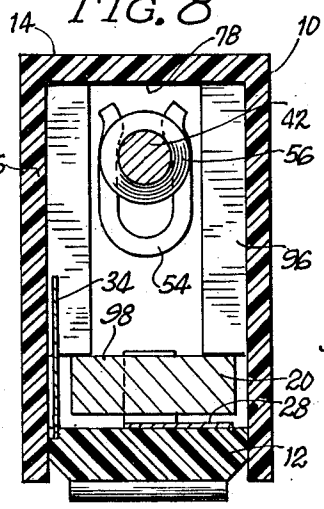


FIG. 9

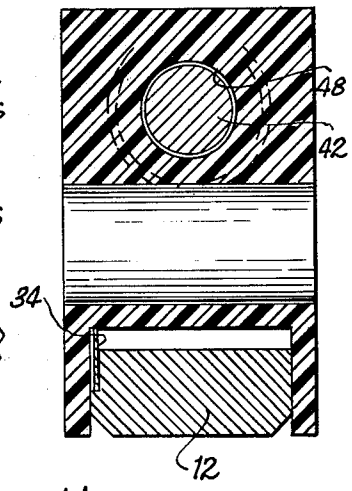


FIG. 10

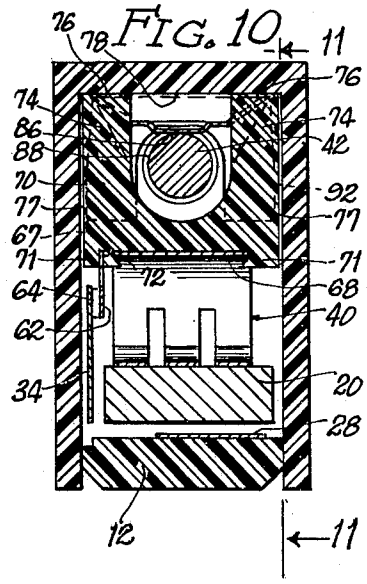


FIG. 11

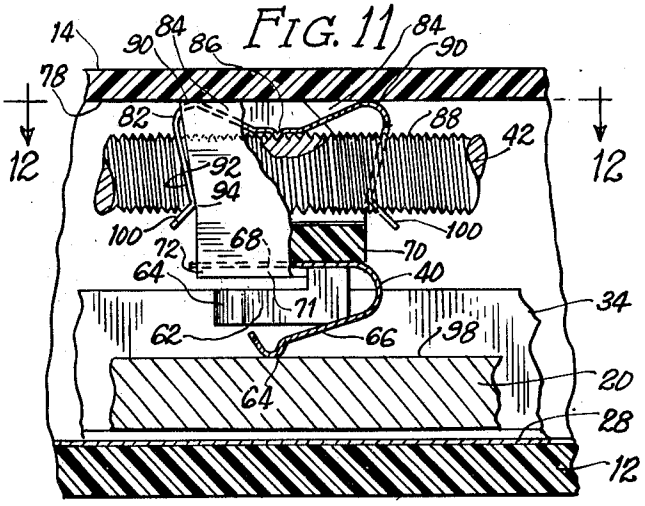
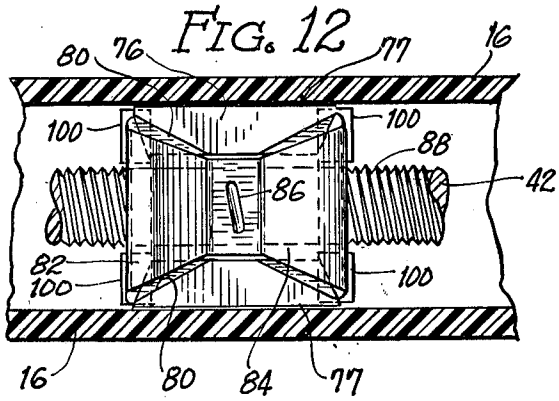


FIG. 12



United States Patent Office 3,497,858 Patented Feb. 24, 1970

3,497,858

POTENTIOMETER

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Filed Feb. 5, 1968, Ser. No. 703,023
Int. Cl. H01c 5/02
U.S. Cl. 338—180 15 Claims

ABSTRACT OF THE DISCLOSURE

A potentiometer construction of the type having a resistance element, a collector strip, a movable contact for engaging the element and the strip, and contact driving means. The improvements include a supporting structure for the contact comprising a carrier block and a carrier block spring. The contact is attached to the carrier block, and the carrier block spring is directly connected to the driving means. The carrier block is maintained out of contact with the driving means.

The carrier block and carrier block spring ride directly on the surface of the housing for the structure and means are provided for precisely spacing the resistance element relative to the carrier block. A high degree of uniformity can then be maintained.

This invention relates to a potentiometer construction, and the invention will be specifically described with respect to devices of the so-called "trimmer potentiometer" type. The invention is specifically concerned with the interior structure of the potentiometer and the invention is particularly directed to supporting means for the movable contact and resistance element employed in the construction whereby a device characterized by reliable operation, accuracy and durability can be efficiently and economically produced.

The internal components of potentiometers comprise a resistance element and a collector strip with terminals connected to both the element and the strip. A movable contact is provided for engaging both the element and the strip whereby a circuit will be completed between terminals connected to the element and strip. As the position of the contact changes, the amount of resistance included within a particular circuit will increase or decrease.

The mechanical design of potentiometers can greatly affect the electrical characteristics, particularly in instruments which require a high degree of accuracy. The problems are magnified where miniaturized instruments are involved. Thus, even slight tendencies toward vibration of parts, irregularities, loose fitting parts, or other mechanical deficiencies can result in significant changes in resistance due to the fact that only very small distances need be traversed by a movable contact in order to effect such changes. In addition to significant changes in resistance which occur as a result of mechanical deficiencies rather than as a result of intended movement of contacts, the mechanical design of potentiometers can effect various other performance characteristics. Specifically, the resolution at low resistance values and such other characteristics as the temperature coefficient of resistance and noise generation can be adversely affected through failure to achieve uniform and consistent contact pressure during operation.

The prior art provides for the production of potentiometers of desired characteristics, however, the cost of producing these is extremely high. Where production costs are kept low, inferior quality results.

It is a general object of this invention to provide a trimmer potentiometer design which will provide a high degree of reliability in performance, even in miniature form, while having only a relatively few parts of a relatively uncomplicated design whereby the potentiometer can be produced without undue expense.

It is a more specific object of this invention to provide a design for a trimmer potentiometer, which can be efficiently produced while still being characterized by substantially infinite resolution even at low resistance values while at the same time providing a low temperature coefficient of resistance and negligible generation of noise during the normal operation of the unit.

It is a further object of this invention to provide a potentiometer of the type described which is characterized by a mechanical design which permits uniform and consistent contact pressure during operation to thereby provide accuracy and reliability, and which can also be assembled by means of relatively simple techniques.

These and other objects of this invention will appear hereinafter, and for purposes of illustration, but not of limitation, specific embodiments of the invention are shown in the accompanying drawings in which:

FIGURE 1 is a vertical, sectional view of a potentiometer design characterized by the features of this invention;

FIGURE 2 is a bottom plan view of the potentiometer with the base portion removed;

FIGURE 3 is a plan view of the potentiometer with the main housing portion removed;

FIGURE 4 is a bottom plan view taken about the line 4—4 of FIGURE 1;

FIGURE 5 is an end view taken about the line 5—5 of FIGURE 1;

FIGURE 6 is an end view taken about line 6—6 of FIGURE 1;

FIGURES 7 through 10 each comprise vertical, sectional views taken about the line 7—7, 8—8, 9—9, and 10—10, respectively of FIGURE 1;

FIGURE 11 is a fragmentary vertical, sectional view taken about the line 11—11 of FIGURE 10; and,

FIGURE 12 is a horizontal sectional view taken about the line 12—12 of FIGURE 11.

The potentiometer design of this invention includes a housing having the usual elements located therein. Thus, a resistance element and a collector strip are mounted within the housing with a movable contact being provided for engagement therewith. Terminals are connected to the element and the strip, and a driving means is provided for adjusting the position of the contact to thereby vary the resistance included within the circuits between the terminals.

The specific improvements of the invention generally relate to the means for supporting the various elements within the construction. One particularly important aspect of the invention involves the supporting structure for the movable contact, said structure including a carrier block and a carrier block spring. The carrier block spring is in direct driving engagement with the driving means, and this spring in turn drives the carrier block. The carrier block does not have physical contact with the driving means. However, the contact which is attached to the carrier block is moved by the driving means since the carrier block spring will transmit the desired driving action.

The carrier block spring includes a portion which engages the housing. This engagement serves to resiliently hold the carrier block spring in driving engagement with the driving means. For example, where the driving means comprises a screw, a detent is formed on the carrier block spring for interfitting relationship with the threads of

this screw. The carrier block spring is pressed between the housing and the screw to provide positive driving engagement.

The carrier block itself is in engagement with the housing, and this block is, therefore, precisely positioned with respect to the housing. The resistance element is supported by pillars formed in the housing and the pillar position and carrier block size can be very accurately controlled so that a precise spaced relationship is provided between the surface engaged by the carrier block and the surface of the resistance element. The contact pressure on the resistance element is then precisely controlled.

The design is also of importance from the standpoint of ease of assembly. The carrier block and contact spring are easily put into position as a unit just prior to the placement of the resistance element on the pillars. The use of the pillars to locate the resistance element eliminates any critical operation in this regard.

The accompanying drawings illustrate the above noted features as well as other features of the invention. In describing the illustrated structure, and in the appended claims, reference is made to "upper" and "lower" surface, and to "downwardly" and "upwardly" extending portions, etc. It will be understood that this terminology is used solely for convenience in describing the relative location of the parts, and that the orientation of the potentiometer is not to be considered to be limited in any respect.

The potentiometer construction comprises a main housing portion **10** and a base portion **12**. The main housing includes a top wall **14**, downwardly extending side walls **16** and end walls **18**. The base portion is substantially rectangular, and includes various cut-outs and protruding areas having functions which will be later described.

The base portion supports a resistance element **20** which may be of any conventional configuration. A conductive strip **24** is secured at one end of the resistance element, and a conductive tab **26** which includes conductive extension **28** is secured at the other end of the resistance element. Lead wires **30** and **32** are connected to the end portion **29** of the extension **28** and the tab **24**, respectively.

A collector strip **34** is mounted on one side wall **16**. The collector strip includes an extension **36** which is connected to lead wire **38**. The contact **40** bridges between the collector strip and the resistance element. In accordance with conventional potentiometer operation, a circuit is thus provided between the lead wire **38** and each of the lead wires **30** and **32**. As the contact is moved, the resistance in one of these circuits will be increased while the resistance in the other circuit will be decreased.

Instead of lead wires, printed circuit board terminals **30'**, **32'** and **38'** can be secured to the base. This represents an important advantage of the design since the different connecting means can be provided without any material change in the other components of the potentiometer.

The contact **40** is moved back and forth by means of lead screw **42**. One end **44** of the lead screw is journalled in the bore **46** defined by one end wall **18** of the housing. The opposite end of the lead screw extends through the bore **48** in the opposite end wall of the housing. The operating head **50** of the lead screw includes a slot **52** whereby rotation of the lead screw, and consequently adjustment of the potentiometer, can be undertaken by means of a screwdriver or other mechanical means. Obviously, direct manual adjustment is also possible.

The lead screw is maintained in position by means of retainer spring **54** which engages the shoulder **56** defined by the lead screw. The head **50** defines a shoulder **58** and a compressible O-ring **60** is located for engagement with this shoulder.

The contact **40** consists of a formed spring which includes contact arm **62** for engagement with the collector strip **34**. A cylindrical section **64** is formed at the end of the contact arm to provide the desired contact.

The second contact portion of the contact **40** comprises three arms **66** which engage the resistance element **20**. The contact design provides better resolution, complete assurance of contact, and maximum resiliency while minimizing longitudinal deflection during operation. With respect to the latter point, the individual arms **66** are only formed in the contact for approximately half the flexural length of the contact. Therefore, the area at the bend where flexing takes place is relatively strong to minimize longitudinal deflection while each of the individual fingers will have a relatively high degree of resilience.

The arm **62** in contact with the strip **34** is, as a practical matter, separated from the arms **66**, and, therefore, irregularities in the movement of the arm **62** will not influence the arms **66**. It will also be noted that the upper arm portion **67** serves as a means for properly aligning the contact **40** with respect to carrier block **70**. Thus, this upper arm portion engages a protruding portion **71** of the carrier block to provide for accurate alignment.

The intermediate portion **68** of the contact **40** interfits with carrier block **70**. As best shown in FIGURE 10, the carrier block portions **71** define a dovetail groove **72** for receiving the contact portion **68**. An adhesive may be employed for preventing longitudinal shifting of the contact relative to the block. The contact is, however, completely confined against lateral movement by the arrangement shown.

The carrier block **70** comprises upstanding sections **74** defining a well therebetween. It will be noted that the opening between the arms **74** is greater than the diameter of the lead screw **42** so that there is no physical contact between the carrier block and the lead screw. The upper surface **76** of the carrier block sections **74** engage the inner surface **78** of the top wall **14** of the housing.

As best shown in FIGURE 12, the top surfaces **76** define flared edges **80** which extend outwardly from the mid-section of the carrier block. It has been found that this arrangement provides an ideal cleaning action during operation of the potentiometer. Thus, the flared edges **80** tend to drive foreign material which might collect on the surface **78** toward the center of this surface. Accordingly, the foreign material is moved to locations which are not traversed by the carrier block. This, therefore, insures a clean path for the carrier block thereby providing smooth operation. This design for the surface **76** also provides minimum contact between this surface **78** to thereby reduce friction. It will be noted that the surface **76** is in intimate contact with the surface **78** while the side surfaces **77** of the block are confined by the side walls of the housing to provide substantially complete stability for the carrier block.

A carrier block spring **82** is associated with the carrier block primarily within the well defined by the block. The carrier block spring includes an upper portion **84** which, as best shown in FIGURE 12, fits within the well without contact with the edges **80**. The opposed edges defined by the mid-section of the portion **76** of the block restrict lateral movement of the spring so as to completely avoid contact of the spring with portions of the enclosure.

The portion **84** also defines a detent **86** for engagement with the threads **88** of the lead screw **42**. The detent **86** is angularly disposed to correspond with the pitch of the threads on the lead screw.

Beyond the portion defining the detent **86**, the spring extends upwardly to points **90** which contact the upper surface **78** of the top wall **14**. The spring **82** is initially assembled so that the detent is pressed into engagement with the threads when the housing is assembled with the lead screw to thereby provide positive driving engagement between the carrier block spring and the lead screw.

The spring **82** includes four downwardly depending arms **92** which define bends **94** having only a small area

of contact with the carrier block to provide the necessary driving force while avoiding build-up of significant friction between the contacting surfaces. It will be apparent that as the lead screw turns, movements imparted to the spring **82** will be directly transmitted to the carrier block to thereby achieve movement of the contact **40** relative to the strip **34** and resistance element **20**.

The housing **10** defines four pillars **96** which are provided for purposes of supporting the resistance element. As best shown in FIGURE 8, the upper surface **98** of the resistance element is in direct contact with the lower face of the pillars **96**. Since the housing **10** can be manufactured by precision molding techniques, it will be apparent that the extent of the pillars **96** can be precisely controlled. Therefore, the distance between the surface **78** of the top wall **14** and the surface **98** can be precisely controlled.

The carrier block **70** is also a molded part and can be precisely dimensioned. Therefore, the distance between the bottom surface of the carrier block and the surface **98** can be precisely controlled since the carrier block is in direct contact with the surface **78**. The thickness of the resistance element, which is more difficult to control, is not a factor in determining the spacing since only the upper surface of the resistance element is a factor, and the position of this surface is determined solely by the pillars **96**. Since the critical spacing is precisely controlled, the contact fingers will have a positive relationship to the surface **98** of the resistance element. The deflection applied to the contact fingers can be controlled to a very close tolerance resulting in uniform contact pressure which contributes to reliable performance and low noise generation.

Isolation provided to the contact **40** and the carrier block **70** by the carrier block spring **82** also contributes to the ideal performance of the potentiometer. Thus, the carrier block is completely out of contact with the lead screw, and, therefore, irregular motions of the lead screw due to clearance tolerances at its ends or due to distortions throughout its length are not transferred to the contact assembly. The carrier block spring may be affected by such motions, particularly of the lateral variety, however, this may only cause shifting of the points **94** of the spring on the surface of the carrier block without imparting any actual movement thereto. In this connection, the four contact points of the carrier block spring with the carrier block are approximately an equal distance between the enclosure surface **78**, and the top surface of the element **98**, such that pressure applied to move the carrier block and contact assembly by the carrier block spring, is applied to the median point between the two surfaces.

The potentiometer design is characterized by many advantages from the standpoint of assembly steps. During assembly, the carrier block spring **82** and the lead screw **42** are associated with the housing **10** before the carrier block **70** and contact **40** are put into place. Accordingly, the most difficult assembly operations are accomplished while the carrier block and contact **40** are out of the way so that there is no danger of distortion of the contact or pick up of dirt by the contact during these assembly operations.

The contact **40** is secured to the carrier block outside of the housing, and this assembly can then be snapped into place as a unit. The collector strip, resistance element, and base portion **12** can be quickly and easily located so that there is a minimum possibility of any damage to any of the critical elements occurring. It will also be apparent that the critical spaced-relationship between the carrier block **70** and the resistance element **20** is very easily accomplished so that a high performance construction is provided even though assembly costs are quite low.

The base portion **12** can be secured to the main housing portion **10** by the use of adhesives between mating surfaces thereof, preferably in areas of the base which are beyond the ends of the element **20**. The application of the adhesives is not in any way critical since the critical spacing referred to above will not be in any way affected by the thickness of the adhesive coating applied.

The contact **40** is designed so that maximum resilience will be provided in the three contact arms. The resilience is achieved by providing a relatively large radius at the point where the arms are connected to the bridging portion of the contact. The effective length of the arms is also relatively long thereby adding to the resilience which can be achieved.

The provision of the collector strip **34** on a side wall **16** of the enclosure, and the use of a thin material for this strip, represents a further desirable feature of the invention since a large area is available which can be utilized by the total resistance element surface itself—and as a result provide a maximum of area on the element surface for keeping the temperature of this surface as low as possible. The collector strip is preferably formed of a combination comprising a gold inlay over a brass base to provide an extremely smooth surface, low contact resistance, and a surface which is compatible with precious metals which are preferably used in the contact **40**.

In considering the carrier block spring **82**, is will be noted that the extremities **100** of the arms **92** extend outwardly toward the outward ends of the housing. In practice, a potentiometer is often adjusted to the extent that the contact is driven to an extreme position at either end of the housing. In the case of the design illustrated, the extremities **100** will engage the pillars **96** when the assembly is moved to an extreme position. It will be appreciated that continued rotation of the lead screw will cause the extremities **100** to press against the pillars. As a result of this contact, there is a tendency for the arms to rotate about a line passing through the points of contact of the carrier block spring to the carrier block. This will cause movement to occur in the carrier block spring with the result that the detent **86** will tend to be lifted away from the threads **88**. This relieves pressure on the lead screw and assures that a more reliable overriding action will be provided.

This design feature serves an additional function in that as soon as the lead screw is rotated in the opposite direction to move the contact away from an extreme position, the extremities of the arms in contact with the pillars will immediately tend to force the contact assembly in the opposite direction. This tendency provides almost immediate engagement of the lead screw with the detent **86** to virtually eliminate lost motion during turning of the lead screw.

The design of this invention virtually eliminates backlash between the screw movement and contact movement. The contact **40** exerts pressure on the carrier block and holds the carrier block against the surface **78** of the top wall **14**. The arms **92** and the sloping surface of the carrier block adds somewhat to this pressure. As the carrier block rides across this surface, it will do so in a smooth manner with no tendency to rock or rotate about an axis at right angles to the direction of motion.

The manner in which the lead screw is mounted in the construction is also important insofar as the invention is concerned. The O-ring **60** is preferably of the conventional type so that the pressure exerted on the O-ring by the lead screw can be varied by varying the thickness of the retainer clip **54**. This provides a convenient means for adjusting the torque which must be applied to the lead screw to achieve rotation.

Trimmer potentiometers are often used in high quality military electronic equipment where excessive vibration is an important consideration. The design described provides a minimum of mass in the contact assembly, particularly because the carrier block spring is supported by the lead screw and does not contribute to the mass of the contact assembly which is therefore only the carrier

block and the weight of the contact itself. This is highly important from a vibration standpoint since under certain types of abnormal motion, for example, as experienced in shock or vibration testing, movement of the contact may be avoided. To provide minimum weight, all unnecessary material is eliminated, and material with a relatively low specific gravity is used where possible, as in the design of the carrier block.

It should also be noted that the O-ring seal at the end of the screw is under reasonable compression under normal circumstances, and it is not inconceivable that very small movements of the lead screw can occur upon application of longitudinal shock. However, these small movements may not cause movement of the carrier block even under severe vibration, since these movements of the lead screw would be of a very short pulse duration. Since the carrier block spring does have resilience, a time delay is involved before any movement of the mass of the contact and carrier block assembly can occur. Very instantaneous pulses applied through the carrier block spring will dissipate quickly and will not, in effect, cause movement of the carrier block and contact. This is, of course, due to the fact that the carrier block will only be moved when a sustained longitudinal force is applied by the spring.

The potentiometer of this invention comprises a unit which provides precision mechanical design while overcoming deficiencies in existing designs. The design also provides a simple method of production from the standpoint of consistent assembly practices which involve a minimum of skilled labor and expensive tools and gauges. Furthermore, from unit to unit close tolerance is provided in the critical areas of the trimmer potentiometer from a performance standpoint.

It will be understood that various changes and modifications may be made in the construction described which provide the characteristics of this invention without departing from the spirit thereof particularly as defined in the following claims.

That which is claimed is:

1. In a potentiometer construction including a housing and means located within the housing comprising a resistance element, a collector strip, terminals electrically connected to said element and said strip respectively, a movable contact having contact arms individually engaging said element and said strip, said contact also having an intermediate portion bridging said arms whereby a circuit is provided between terminals connected to the element and strip respectively, and contact driving means supported in said housing for varying the position of said contact relative to said element and strip, the improvement comprising a supporting structure for said contact including a carrier block, said carrier block defining an opening dimensioned whereby said contact driving means can be received in said opening without physical contact with the carrier block, and a carrier block spring having a first portion in driving engagement with said driving means, a second portion engaging the carrier block for transmitting drive thereto, and a third portion engaging said housing, the engagement of said third portion with said housing serving to resiliently hold the carrier block spring in driving engagement with said driving means.

2. A construction in accordance with claim **1** wherein said driving means comprises a screw, and wherein said first portion of said carrier block spring comprises a detent for engagement with the threads of said screw.

3. A construction in accordance with claim **1** wherein said second portion of said carrier block spring comprises downwardly extending arms straddling said carrier block, said arms defining bent-in portions contacting said carrier block.

4. A construction in accordance with claim **1** wherein said carrier block is dimensioned to engage said housing, and wherein said contact is attached to said carrier block on the side opposite the side of the block engaging said housing, said contact comprising a spring member operating to force the block against the housing.

5. A construction in accordance with claim **1** including pillars located within said housing for supporting said resistance element, said pillars extending between the surface of the housing engaged by the carrier block and that surface of the resistance element which is engaged by said contact.

6. A construction in accordance with claim **5** wherein said pillars are engaged by said carrier block spring when the spring is moved to the extreme end of the housing by said drive means, and wherein said spring is caused to rotate by a minor amount upon engagement with said pillars to thereby assist in releasing the first portion of the spring from driving engagement with said driving means to thereby avoid damage as the driving means continues to rotate after the carrier block has stopped in said extreme position.

7. A construction in accordance with claim **1** wherein said element is mounted on one wall of said housing with said collector strip being mounted on a wall which is perpendicular to said one wall, said contact including one portion extending downwardly and defining a first contact surface for engagement with said element, and a separate portion defining a second contact surface located at right angles to said first surface, said second surface engaging said collector strip.

8. A construction in accordance with claim **7** wherein said one contact portion includes three fingers, each of said fingers individually engaging said resistance element.

9. A construction in accordance with claim **1** wherein said driving means comprises a screw having an operating head at one end for rotation of said screw, and including an O-ring formed of compressible material located in engagement with a shoulder defined by said head, and a snap ring located forwardly of said O-ring for securing said screw in place, the torque required for turning of said screw being dependent upon the thickness of said snap ring.

10. A construction in accordance with claim **4** wherein said carrier block defines a pair of upstanding sections located on either side of said driving means, the upper surfaces of said sections engaging said housing, said surfaces defining interior edges which flare outwardly from the mid section of the block and wherein said sections exert a cleaning action with the flared edges forcing foreign material from the housing surface to interior locations on the surface which are outside the area traversed by the surfaces of the carrier block.

11. A construction in accordance with claim **4** wherein said carrier block defines a groove extending longitudinally of the housing and having a dovetail configuration, and wherein said bridging portion of said contact is positioned in said groove.

12. In a potentiometer construction including a housing and means located within the housing comprising a resistance element, a collector strip, terminals electrically connected to said element and said strip respectively, a movable contact having contact arms individually engaging said element and said strip, said contact also having an intermediate portion bridging said arms whereby a circuit is provided between terminals connected to the element and strip respectively, and contact driving means supported in said housing for varying the position of said contact relative to said element and strip, the improvement comprising a supporting structure for said contact including a carrier block, said carrier block defining an opening dimensioned whereby said contact driving means can be received in said opening without physical contact with the carrier block, and a carrier block spring having a first portion in driving engagement with said driving means, and a second portion engaging the carrier block for transmitting drive thereto, the opening in said carrier block extending completely through one wall of the block where-

by the block comprises a closed base and two side walls, said side walls straddling said driving means after assembly whereby the carrier block and contact can be put into place after said drive means and carrier block spring are assembled, and wherein said second portion of said carrier block spring comprises opposed pairs of downwardly extending, spaced apart spring arms, the lengthwise spacing between the opposed arms being normally less than the length of said carrier block whereby the opposed arms resiliently engage the outside end surfaces of said carrier block, the arms in each pair being laterally spaced apart by an amount sufficient to permit receipt of said driving means in the opening defined between the ends of the arms without engagement of the arms with said driving means.

13. A construction in accordance with claim **12** including resistance element locating means formed within said housing in spaced apart relationship with respect to the surface of the housing engaged by the carrier block, and wherein said resistance element is located in said housing by positioning of the element in contact with said locating means, and wherein said housing and carrier block comprise precision molded parts whereby the position of the resistance element locating means and the size of the carrier block are precisely maintained.

14. In a potentiometer construction including a housing and means located within the housing comprising a resistance element, a collector strip, terminals electrically connected to said element and said strip respectively, a movable contact having contact arms individually engaging said element and said strip, said contact also having an intermediate portion bridging said arms whereby a circuit is provided between terminals connected to the element and strip respectively, and contact driving means supported in said housing for varying the position of said contact relative to said element and strip, the improvement comprising a supporting structure for said contact including a carrier block, said carrier block defining an opening dimensioned whereby said contact driving means can be received in said opening without physical contact with the carrier block, and a carrier block spring having a first portion in driving engagement with said driving means, and a second portion engaging the carrier block for transmitting drive thereto, the opening in said carrier block extending completely through one wall of the block whereby the block comprises a closed base and two side walls, said side walls straddling said driving means after assembly whereby the carrier block and contact can be put into place after said drive means and carrier block spring are assembled, and wherein said second portion of said carrier block spring comprises opposed pairs of downwardly extending, spaced apart spring arms, the lengthwise spacing between the opopsed arms being normally less than the length of said carrier block whereby the opposed arms resiliently engage the outside end surfaces of said carrier block, the arms in each pair being laterally spaced apart by an amount sufficient to permit receipt of said driving means in the opening defined between the ends of the arms without engagement of the arms with said driving means.

15. A construction in accordance with claim **14** wherein said carrier block is maintained in engagement with a wall of said housing directly opposite said surface of the resistance element, and wherein said carrier block and said resistance element locating means comprise precision molded parts whereby the spacing between said surface of the resistance element and the carrier block can be precisely maintained.

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