Nov. 5, 1957 E. A. WILLIFORD 2,812,408

IMPROVED ELECTRICAL POTENTIOMETER

Filed June 10, 1955

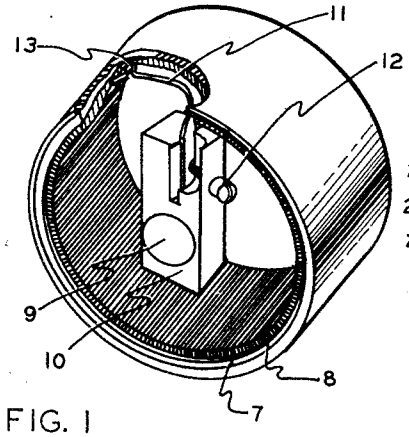

FIG. 1

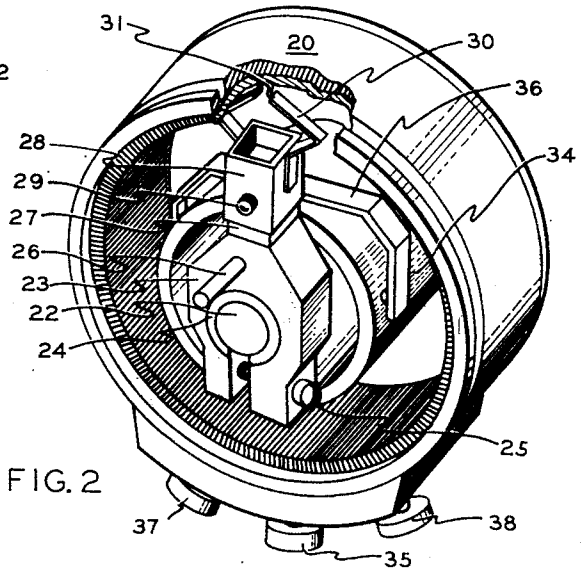

FIG. 2

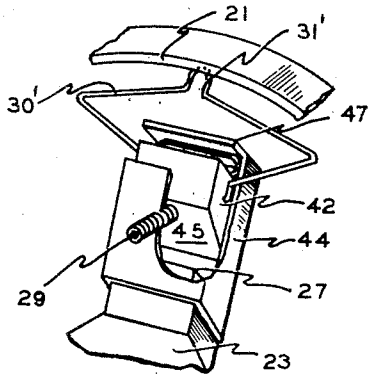

FIG. 4

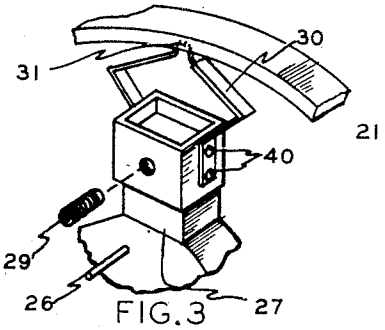

FIG. 3

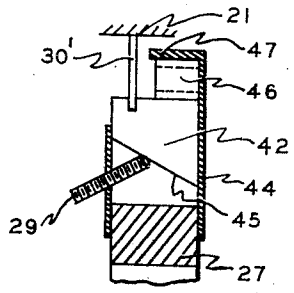

FIG. 5

FIG. 5a

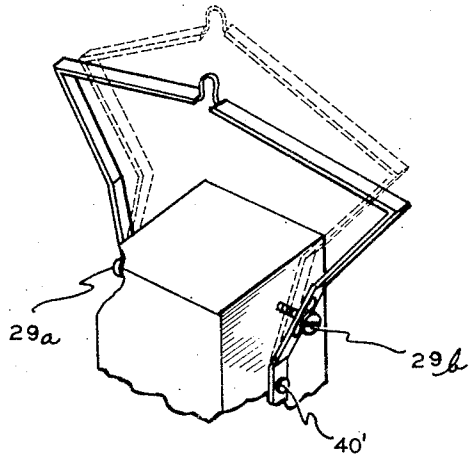

FIG. 6

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IMPROVED ELECTRICAL POTENTIOMETER

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4 Claims. (Cl. 201—56)

This invention relates to improvements in variable potential dividers, and more particularly to improved resilient contact means for providing a reversibly variable contact which is completely free from backlash, which maintains constant contact pressure to avoid electrical noise, and which assures good electrical contact with a wire-wound conductive element while requiring a minimum of torque for its operation.

In the electronic instrumentation, communication and computation arts, high-precision variable resistance potentiometers are employed to derive electrical potentials which vary in accordance with predetermined mathematical functions. As employed in analog computers, a plurality of such potentiometers are frequently coupled to common drive shafts and operated by reversible electric motors, or sometimes by selsyns, to derive voltages representing functions of angular shaft rotation. Where a number of such potentiometers ganged to a common shaft may be required to be operated by a small servo or selsyn motor, it is necessary that the friction of the moving parts in the potentiometers be held to a minimum in order that the low torque of the servo or selsyn may accurately position the contact wipers. It is also necessary that uniform electrical contact be maintained between the resistance element of each potentiometer and its movable wiper to avoid generation of electrical noise.

To meet all of these requirements, and to keep the movable contactor mechanism entirely within the cylindrical shell of the potentiometer resistance element, potentiometers of the prior art have commonly employed a resilient cantilever arm comprised of, or at least plated with, precious metal at the point of contact. It has been discovered, however, that such forms of construction invariably cause different forces to be exerted on the wiper element when rotated in opposite directions, resulting in sliding of the wiper when it is rotated in one direction and stubbing of the wiper when rotated in the opposite direction. This leads to such undesirable functioning as unequal torque in opposite directions of rotation, and a degree of electrical "backlash" which may introduce serious errors in an electrical computer. Stubbing or vibration of the contact alters contact pressure and contact resistance, causing high frequency noise in many circuits. When a plurality of such prior art potentiometers are connected in cascade, as in a computer system, small positional errors due to this backlash in the cantilever contactors are additive and may produce much larger errors in the output circuits of the system, and noise introduced by a prior art potentiometer in one portion of a computer system may be greatly amplified in the computer so as to cause faulty operation.

It is therefore an object of the invention to provide a precision variable potentiometer having virtually no backlash in the movable contact member and having substantially uniform contact resistance and pressure regardless of direction of operation.

Another object of the invention is to provide improved

low torque variable potentiometers suitable for ganged operation from a common drive means.

Another object of the invention is to provide a precision variable potentiometer reversibly operable in either direction by the application of equal torque or force without the introduction of variable functional performance.

A further object of the invention is to provide such improved precision potentiometers with means for readily adjusting the contact pressure between the movable elements and the stationary conductors.

Other objects of the invention will in part be obvious and will in part appear hereinafter.

The invention accordingly comprises the features of construction, combination of elements, and arrangement of parts, which will be exemplified in the construction hereinafter set forth, and the scope of the invention will be indicated in the claims.

For a fuller understanding of the nature and objects of the invention reference should be had to the following detailed description taken in connection with the accompanying drawing, in which:

Fig. 1 represents a conventional potentiometer of the prior art;

Fig. 2 represents a perspective view of an improved potentiometer embodying the invention;

Fig. 3 is an enlarged view in perspective of the contact wiper element of the potentiometer shown in Fig. 2, embodying features of the invention;

Fig. 4 illustrates in perspective an alternative embodiment of adjustable contact wiper element suitable for use with the potentiometer shown in Fig. 2;

Fig. 5 is a detailed side view in section of the structure shown in Fig. 4;

Fig. 5*a* is a perspective view showing in detail one form of compression spring suitable for use in the structure of Fig. 4 and Fig. 5;

Fig. 6 is a perspective view of an alternative arrangement which may be used in adjusting contact pressure.

Referring first to the prior art type of potentiometer illustrated by Fig. 1 of the drawings, a cylindrical card of insulating material **7** has wound upon it a multiplicity of evenly spaced coils of fine resistance wire, forming a helical conductive element **8**. Although other forms of conductive element may be employed in some types of potentiometers, as for example a coating of carbonized material, high precision potentiometers as used in electrical computers generally require a resistance element of metallic wire. A rotatable shaft **9**, which is coaxial with the helix **8**, is coupled to a rigid arm **10** which is rotatable within the cylindrical enclosure of the helix **8**. Arm **10** carries a resilient contact or wiper element **11** formed as a cantilever, which may be secured to arm **10** by soldering, riveting or by means of a set screw **12**. An arcuate portion **13** of the wiper element **11** bears against a portion of the inner surface of the wire helix **8**, being urged into conductive engagement with the resistive element **8** by the spring tension of cantilever **11**.

Numerous variations of this basic construction have been employed in precision potentiometers of the prior art, but all known prior forms of wiper construction result in different forces appearing to be exerted on the wiper **11** for different directions of rotation. As viewed in Fig. 1, the wiper arm **11** may deflect slightly to the left as the shaft **9** is rotated in a clockwise direction and "dragging" the arm **11**, and in general the arm **11** will deflect an even greater distance to the right when the shaft **9** is rotated in a counter-clockwise direction, "pushing" the wiper ahead of the arm and causing it to "stub." Any deflection in either direction results in failure of the contact portion **13** to accurately follow the angular rotation of shaft **9**, and unequal deflection in opposite direc-

tions of rotation results in more than doubling the positional errors between the shaft 9 and the contact portion 13 as the direction of rotation is reversed. Such errors may become cumulative in complex systems where a plurality of potentiometers are connected in cascade, and they impose an undesirable limitation to the accuracy which has heretofore been possible in electrical analog computer systems.

Reference is now had to Fig. 2 and Fig. 3 of the drawings which disclose one embodiment of my invention whereby errors in potentiometer wiper deflection are obviated. A substantially cylindrical casing 20 encloses a wirewound resistance card 21 which may be held in position within the casing 20 by any suitable means. A centrally disposed coaxial shaft 22 is channeled through a bearing (not shown) in the end wall of the casing 20. A rigid arm member 23, which may contain a coaxial ring collar 24 for engaging the shaft 22, is clamped on to the rotatable shaft 22 by means of a clamping screw 25. The opposite end of rigid arm 22 may carry a fixed pin 26 adapted to engage a cooperative socket of an adjacent potentiometer when two or more potentiometers are coaxially ganged for simultaneous operation by a single rotatable shaft. The end 27 of arm 22 is polyangular in cross-section and carries a slidable collar member 28 which may be secured to the end 27 by means of a set screw 29. Affixed to opposite sides of collar 28 is a resilient spring contactor element 30 having a tip portion 31 which may be of precious metal and which is in conductive engagement with the inner cylindrical wall of the resistance element 21. As shaft 22 is rotated in either direction, the conductive tip portion 31 is moved through an arc of a circle, contacting corresponding portions of the resistance element at each different position to which the shaft 22 may be rotated.

Although the rotatable contactor arm 23 is normally fixed to a rotatable shaft 22, whereby rotational motion is imparted to the contactor tip portion 31, in some embodiments of the invention it may be desirable to rotatably mount the arm 23 on a fixed concentric shaft 22, and to impart rotational motion to the contactor arm 23 by suitable coupling to the pin 26. In such arrangements the collar 24 may be of bearing metal adapted to engage an annular groove in the fixed rotational shaft 22. This form of construction may be particularly useful in potentiometers intended to be coaxially ganged for multiple operation.

An annular slip ring 34 of conductive material is mounted on the end wall of the casing 20, within the cylinder formed by the resistance card 21, and is electrically connected to an external terminal 35. A brush wiper 36, which may be formed of Phosphor bronze or other suitable spring material, is fastened to the slidable collar 28 and wipes upon the annular ring 34 to maintain electrical contact at all times between the fixed external terminal 35 and the movable spring loop contactor 30. External terminals 37 and 38 are connected to opposite ends of the resistance element 21. Additional terminals (not shown) may also be provided for connections to fixed taps (not shown) which may be made to various portions of the resistance element 21.

The spring contactor 30 may be formed of thin strips of Phosphor bronze, or other suitable spring material, or this element may be formed of spring wire which is substantially circular in cross-section. As illustrated in greater detail in Fig. 3, the opposite ends of spring contactor 30 are fastened to the slidable collar member 28 by riveting, soldering or spot welding, as shown at 40 in Fig. 3. The spring contactor 30 is formed substantially as an elongated loop with its major axis extending in a direction at right angles to the axis of shaft 22 and its minor axis located on a radial line from the axis of shaft 22 through the tip portion 31 of the contactor 30, which is the mid-portion of the loop in engagement with the resistance element 21. Good electrical contact between the contactor tip portion 31 and the conductive element 21 is assured by compressional stress on the arms of loop 30. Any desired degree of compression of loop 30 may be obtained by loosening set screw 29 and sliding collar 28 radially along the end 27 of rotatable arm 23.

Reference is now had to Figs. 4 and 5 of the drawings which disclose an alternative embodiment of the invention wherein one end 27 of the rotatable arm 23 may be capped by a polyangular channel-like member 44, and the spring loop contactor 30′ is affixed to a slidable block 42 within the hollow portion of the channel 44. In Fig. 4, the contactor loop 30′ is formed entirely of spring wire having a substantially circular cross-section, while an arcuate contactor tip portion 31′ on the minor axis of loop 30′ may be coated with precious metal to assure good electrical contact with the resistance element 21.

The lower surface 45 of the slidable block 42 forms an angular cam, as clearly shown in Fig. 5, and the set screw 29 is threaded through a side wall of the hollow channel 44 in a position to engage the inclined cam surface 45 of block 42. As the set screw 29 of Fig. 4 and Fig. 5 is tightened, it exerts a force upon the inclined cam surface 45 of block 42 causing the block 42 and the spring loop 30′ to move radially outward, compressing the spring loop 30′ and increasing contact pressure between the resistance element 21 and the contact tip portion 31′. Conversely, as the set screw 29 is loosened, block 42 is allowed to move inwardly, within the confines of channel arm 44, thereby reducing compressional stress on loop spring 30′, and correspondingly reducing contact pressure between the tip portion 31′ and the resistance coil 21. If desired, a portion of the outer end of channel 44 may be folded over as shown at 47, and a compression spring 46 may be placed between the outer end of slidable block 42 and the folded end 47, to urge the spring loop 30′ inwardly as set screw 29 is loosened. By this means the contact pressure between contact tip portion 31′ and the conductive element 21 may be adjusted to a very low value and still assure positive contact free from chatter as the wiper arm is rotated. A form of compression spring suitable for this purpose is illustrated by Fig. 5*a*. It will be understood, however, that either a leaf spring, a helical spring, or any other suitable form of compression spring may be employed at 46 if desired.

Shown in Fig. 6 is an alternative embodiment of the invention utilizing different means to vary contact pressure. In Fig. 6 the wiper loop is rigidly affixed at each end to the end portion 27 of rotatable arm 23 by means of welding, soldering, or by means of rivets or screws 40′. Nearer the end of the rigid arm, each side of the loop is adjustably compressed, as for example by means of adjustable screws 29*a* and 29*b*, which thread into the end of the rigid arm. In Fig. 6 the resilient contact loop is shown in full lines in an uncompressed condition, and in dashed lines in a compressed condition. As screws 29*a* and 29*b* are threaded into the rigid arm, the contact loop is resiliently deformed, with the major axis of the loop decreasing and the minor axis increasing. As will be evident, such deformation urges contact tip portion 31 radially outward, increasing the pressure between tip 31 and a potentiometer resistance element. It will be seen that independent adjustment of screw 29*a* or of screw 29*b* would serve to tilt or cock the loop. For example, tightening of screw 29*b* without an equal tightening of screw 29*a* would serve to rotate the axes of the wiper loop counter-clockwise as viewed in Fig. 6. In practice of the invention, both screws may be adjusted approximately equal amounts so that desired contact pressure is obtained, after which differential adjustment of the screws may be made to insure identical wiping action for both directions of wiper travel.

It will be appreciated that by the above described constructions, a potentiometer is provided with a spring contactor element which is continually under controlled compressional stress in engagement with the conductive resist-

ance element. As opposite ends of the contactor loop element **30** are securely anchored to a rigid rotatable arm, virtually no angular deflection or backlash can occur between the rigid arm and the contacting portion **31** of the contactor tip element, regardless of the direction of shaft rotation. It will also be appreciated that as the friction between the movable contactor tip portion **31** and the resistance element **21** is dependent entirely upon the compressional stress applied to spring loop **30**, and is wholly unaffected by direction of rotation, the potentiometer may be operated in either direction by application of equal values of minimum torque. The contact pressure may be readily adjusted by means of set screw **29** to obtain good electrical contact with a minimum of friction between the contactor tip **31** and the conductive element **21**.

It will thus be seen that the objects set forth above, among those made apparent from the preceding description, are efficiently attained and, since certain changes may be made in the above constructions without departing from the scope of the invention, it is intended that all matter contained in the above description or shown in the accompanying drawing shall be interpreted as illustrative and not in a limiting sense.

It is particularly noted that although the invention has been disclosed as embodied in a variable potentiometer of the wire-wound resistive type, the structure of the invention is equally applicable to variable inductive apparatus, as for example variable auto-transformers, or to other forms of variable potential dividers, or wherever it is desired to obtain a low torque resilient contact free from angular backlash. Furthermore, while I have shown the invention as applied to a rotary potentiometer, the novel wiper contact of the invention may also be applied to linearly-actuated potentiometers.

It is also to be understood that the following claims are intended to cover all of the generic and specific features of the invention herein described, and all statements of the scope of the invention which, as a matter of language, might be said to fall therebetween.

Having described my invention, what I claim as new and desire to secure by Letters Patent is:

1. In variable potential divider apparatus having an annular conductive element and a rotational shaft concentric therewith, low-torque variable contact means comprising a resilient spring contact member substantially formed in an elongated loop, a conductive portion of said contact member on the minor axis of said loop and in electrical contact with the conductive element, the minor axis of said loop substantially normal to the point of contact with the conductive element, a rigid arm mounted on the rotational shaft, a movable member slidably mounted on said arm, means fastening opposite ends of said spring contact member to said movable member, said fastening means positioning the loop of said spring contact member symmetrically about a radial line extending from the axis of the rotational shaft to the point of contact between said conductive portion and the conductive element, and adjustable means for fixing the position of said movable member on said arm to vary the compressional tension of said spring contact member.

2. In variable potential divider apparatus having a conductive element of substantially cylindrical form and a rotational shaft concentric therewith, low-torque variable contact means comprising, a resilient spring contact member substantially formed in an elongated loop, the minor axis of said loop substantially normal to the inner cylinder wall of the conductive element, a conductive portion of said contact member on said minor axis and in electrical contact with the inner wall of the conductive element, means fastening opposite ends of said spring contact member to a movable member, said fastening means positioning the loop of said spring contact member symmetrically about the minor axis thereof, a rigid arm member extending radially within the cylinder of the conductive element, means on said rigid arm member slidably engaging said movable member, a set screw on said arm member for adjustably fixing the position of said movable member with respect to said arm, further spring means between said arm and said movable member, said further spring means cooperating with said set screw to determine the radial position of said movable member on said arm, and means mounting said arm on the rotational shaft of the potential divider apparatus whereby said arm and said contact member may be rotated as a unit.

3. A rotatable electrical contact engageable with the cylinder wall of annularly disposed conductive elements comprising, a shaft concentric with the conductive elements, a rigid arm rotatably mounted on said shaft and extending radially therefrom within the cylinder formed by the elements, one end of said arm of polyangular cross-section, a polyangular collar slidably mounted on said end, a set screw on said collar for adjustably fixing the position thereof on said ram, a resilient spring member formed substantially in a loop, opposite ends of said loop rigidly fastened to opposite sides of said collar, and a mid-portion of said spring loop adapted to conductively engage the inner cylindrical surface of said annularly disposed elements.

4. A rotatable electrical contact engageable with a plurality of annularly disposed conductive elements comprising, a shaft concentric with the conductive elements, a rigid arm rotatably mounted on said shaft and extending radially therefrom in a direction toward the conductive elements, one end of said rigid arm comprising a polyangular channel portion, a polyangular member slidably mounted within said channel portion, one end of said polyangular member comprising an inclined cam surface, a resilient spring member formed substantially in a loop, opposite ends of said loop fastened to opposite edges of said polyangular member at one end thereof, a mid-portion of said spring loop adapted to conductively engage successive conductive elements as said arm is rotated, and a set screw mounted on said channel portion and engaged with said cam surface whereby the compression of said spring loop may be varied to adjust the contact pressure of said mid-portion on the conductive elements.

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