Dec. 6, 1966 G. V. A. MALMROS 3,290,495

ELECTRICAL RESOLVER MEANS

Filed Dec. 31, 1962

FIG. 1b

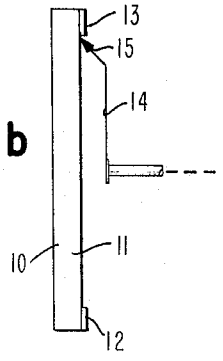


FIG. 1a

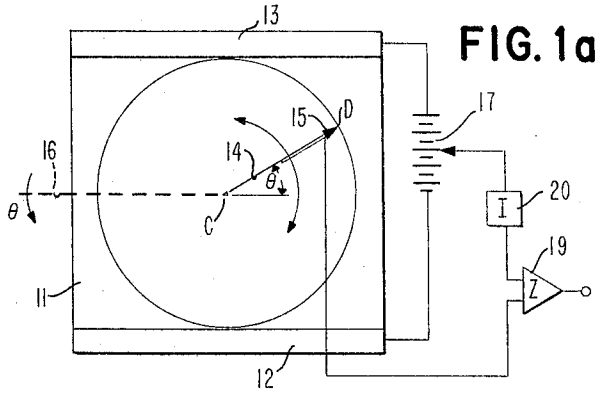


FIG. 1c

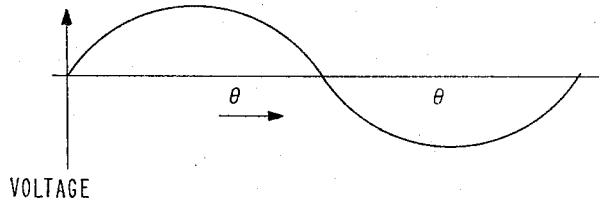


FIG. 2a

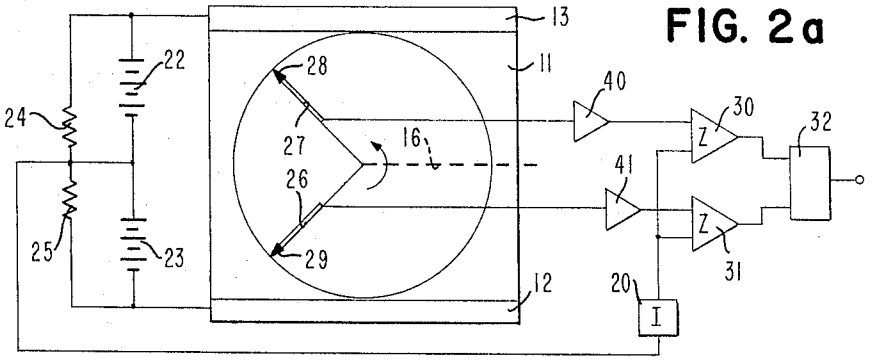
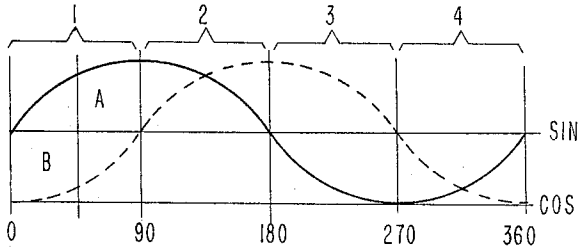


FIG. 2b



	1	2	3	4
SIN	−	+	+	−
COS	+	+	−	−

FIG. 2c

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ELECTRICAL RESOLVER MEANS

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The present invention relates generally to an electro-mechanical potentiometer and trigonometric resolver devices, and more particularly to a new and improved resistance type electrical resolver utilizing a flat resistively coated surface.

In the electrical analog and industrial control field, wide use is made of electro-mechanical potentiometers and trigonometric resolvers. The electrical resolvers in use vary in construction over a wide range. Some of the considerations with respect to the selection of a particular resolver for use are related to its mechanical simplicity, its high resolution in the derivation of variable voltages and the uniform torque loading of the shaft which is driving the resolver for various shaft angles. One type of electrical resolver known in the prior art is one which is classified as a resistance resolver in that it resolves a shaft angle position into trigonometric voltage functional relationships by reason of variations of resistance which result from variations in the shaft angle positions. Such prior art resistance resolvers tend to be complicated mechanically, have poor resolution and present irregular torque loading to the shaft driver.

It is the variable resistance electrical class to which the teachings of the present invention are related. In recent years, technology has advanced to the point that it is now possible to deposit or otherwise apply resistive coatings on substrates. Patent Number 2,542,478, issued February 20, 1951, is illustrative of the state of the art in the utilization of resistive coatings on flat surfaces. In keeping with the state of the art capability in the manufacture of resistance coatings on substrates, it is now possible to make substantial strides in the design of electrical resistive type shaft angle trigonometric resolvers. One of the requirements of electrical resolvers used in analog computers and industrial control fields, however, is that it be operative over 360 degrees of angular rotation of a shaft. It is, therefore, a primary object of the present invention to provide a new and improved resistive electrical shaft angle resolver which is rotatable through 360 degrees of shaft angle.

It is still another object of the present invention to provide a new and improved shaft angle resistive electrical resolver which provides both sine and cosine trigonometric functional relationships in response to 360 degrees shaft rotation.

It is still another object of the present invention to provide a new and improved resistive electrical resolver which will derive functional trigonometric signals commensurate with shaft angle position through 360 degrees and at the same time provide electrical signal polarity information commensurate with the quadrant through which the shaft angle is being rotated.

The foregoing and other objects of the present invention are obtained by constructing a shaft angle electrical resolver to include a shaft rotatable through 360 degrees driving at least one wiper arm pivotally mounted at one extremity relative to a flat surface having a resistive coating placed thereon so that a wiper contact mounted on the other extremity of each of the wiper arms maintains slidable conductive contact on the resistive coating and at the same time is positioned as to its pivotal mounting and the length of the wiper arm such that the wiper contact makes physical conductive alternate contact with the two parallel electrodes at 180 degree angular positions of the shaft.

The resistive coating is energized by applying a voltage source across the two parallel electrodes.

The foregoing and other objects, features and advantages of the invention will be apparent from the following more particular description of preferred embodiments of the invention, as illustrated in the accompanying drawings.

In the drawings:

FIGURES 1*a*, 1*b* and 1*c* illustrate the mechanical construction and the electrical output of a resistive resolver according to one embodiment of the teachings of the present invention; and

FIGURES 2*a*, 2*b* and 2*c* illustrate the mechanical construction and the electrical output of a second embodiment of an electrical resolver built according to the teachings of the present invention.

Referring to FIGURES 1*a* and 1*b*, there is shown a flat surface 10 consisting of a substrate material of an insulating type having deposited thereon a uniform film or coating 11 of resistive material. For example, this uniform film or coating of resistive material may have a resistance of 10,000 ohms per square (unit area). This coating or film can be done in several ways now known to those skilled in the art. For example, the film 11 may be the result of the deposition of metallic salts which are fired in a manner to provide a reasonable wearing resistive surface. As shown, located at opposite extremities of the resistive coating 11 are two conductive strips or electrodes 12 and 13. These conductive strips are substantially parallel and should provide highly conductive connections to the resistive surface. These conductive strips or electrodes can be made by depositing or plating, etc., such materials as gold or copper, etc.

Mounted for pivotal rotation adjacent the resistive surface 11 is shown a non-conducting wiper arm 14. Mounted on the non-pivoting extremity of the arm 14 is a wiper contact 15 which is designed to conductively cooperate with the resistive surface 11 as the wiper arm 14 is rotated by shaft 16. As the shaft 16 is rotated through 360 degrees, the wiper contact 15 will make contact with the resistive surface 11 along a path shown therein as a circle. The position at which wiper arm 14 pivots with respect to the resistive surface 11 and the length of wiper arm 14 are selected so that wiper contact 15 will effectively conductively contact electrodes 12 or 13 at 180 degrees diametrically opposite shaft positions for shaft 16.

FIGURE 1*b* shows a simplified side view of the resolver of FIGURE 1*a* (with the wiper arm at a different position) and identical reference numerals are used for clarity. The resistive coating is shown energized via electrodes 12 and 13 by a voltage source 17. Although the voltage source 17 is shown as of the D.C. type, it should be clear that following the teachings of the present invention the source could also be of the A.C. type.

Wiper contact 15 is connected to one input of a summing amplifier 19 and another input of that same summing amplifier is shown connected to voltage source 17 in a manner such that the summing amplifier would be receiving a voltage of approximately one-half that which is applied across electrodes 12 and 13. Assuming uniformity in the resistive coating 11, this will be equal in magnitude to the voltage adjacent the pivot point C of wiper arm 14. When this voltage is inverted by conventional inverter 20 and applied to summing amplifier 19, the output of amplifier 19 will have a sine voltage variation for a given rotation of shaft 16 as that shown in FIGURE 1*c*.

The cooperation of the resistive coating 11 with the wiper contact 15 while shaft 16 is being rotated will be such that a relatively high resolution is obtained in the voltage variation for a given shaft rotation. Moreover, the mechanical construction of the resolver is very simple and the torque loading on shaft 16 is uniform throughout 360 degrees.

For a particular position of the wiper contact **15** as shown in FIGURE 1*a*, the resistance measured at point D between point D and a horizontal line through point C divided by the resistance from the edge of coating surface **11** to point C will be proportional to the sine of the angle θ. As indicated hereinabove, it is also important in an electrical resistance resolver to be able to obtain a cosine function of the shaft angle of the shaft driving that resolver. It is a further teaching of the present invention that a second wiper arm and wiper contact can be oriented at 90 degrees from the first wiper arm described in connection with FIGURE 1*a*. FIGURE 2*a* shows such an arrangement.

In order to simplify the explanation, identical reference numerals are utilized in FIGURE 2*a* as that utilized in FIGURE 1*a* whenever possible to illustrate identical functional elements. Identical wiper arms **26** and **27** are mounted to rotate about the same pivot point in a manner such that they are displaced by 90 degrees. Assuming that the wiper arms **26** and **27** are rotating counter-clockwise as a unit, wiper contact **29** will have a voltage derived thereon which is a sine function and wiper contact **28** will have a voltage derived thereon which is a cosine function of the shaft angle of shaft **16**. Parallel connectors or electrodes **12** and **13** are shown energized by connecting therebetween to voltage sources **22** and **23** in series. Voltage sources **22** and **23** are oriented polarity-wise to be additive. Assuming a uniform density of resistive coating **11**, the voltage at the common junction of voltage sources **22** and **23** will be equal to the voltage level in the resistive coating **11** immediately adjacent the pivot means. Accordingly, this voltage can be utilized in the same manner via inverter **20** to provide one of the inputs to each of two conventional summing amplifiers **30** and **31**.

The construction of these conventional summing amplifiers is well known in the prior art and may be considered to include a summing resistor network. Accordingly, the voltage derived on wiper contact **29** may be applied to summing amplifier **31** via one of its inputs and compared with the reference voltage for deriving a voltage shaft angle characteristic such as shown in FIGURE 2*b* as waveform A which is commensurate with the sine function of the rotation of shaft angle. Similarly, the voltage derived on wiper contact **28** may be applied to one of the inputs of summing amplifier **30** and compared with the reference voltage provided by inverter **20** for deriving a voltage which varies in accordance with the cosine of the varying shaft angle. Waveform B of FIGURE 2*b* shows this functional voltage variation. Resistors **24** and **25** connected parallel with voltage sources **22** and **23** are for balancing purposes. Linear amplifiers **40** and **41** connected to wiper contacts **28** and **29** are for the purpose of preventing current loading problems inherent in potentiometer type devices.

Not only will the outputs of summing amplifiers **31** and **30** provide sine and cosine functional voltage relationships with variations of shaft angle driving wiper arms **26** and **27**, but the polarity of the output signals will be indicative of the quadrant through which the wiper assembly is passing. FIGURE 2*c* shows four possible polarity combinations which will be usable to determine the quadrant as the practical applications of the teachings of the present invention require such information in system usage. Moreover, since both sine and cosine functional voltage relationships are available for various shaft angles, the application of this analog information into a conventional analog division circuit **32** is all that is necessary to derive a tangential type functional voltage relationship, such as may be required in a system application. While the voltage analog division circuit **32** may take various forms, one such circuit suitable for use in practicing the present invention is described and explained in detail on page 124 et seq. in the publication titled "Introduction to Analogue Computers" by C. A. A. Wass, 1955 edition, published in the United States by McGraw-Hill Inc.

As those skilled in the art will recognize, the tangent function may be obtained by dividing a sine functional voltage by a cosine functional voltage and the co-tangent functional relationship may be obtained by an inversion of that analog process. Maximum use of the known trigonometric identities plus conventional analog computing circuits can provide for substantial system application of a resistive resolver of a type built according to the teachings of the present invention.

While the voltage sources described hereinabove in the specification and drawings have been of the D.C. type, it should be clear that in either of the embodiments an A.C. voltage supply might be used as required for a practical application. Obviously, the summing and amplifier circuits would have to be modified to accommodate this modification.

While the invention has been particularly shown and described with reference to preferred embodiments thereof, it will be understood by those skilled in the art that the foregoing and other changes in form and details may be made therein without departing from the spirit and scope of the invention.

What is claimed is:

1. A shaft angle electrical resolver for deriving electrical signals commensurate with trigonometric functions of a shaft angle comprising a shaft rotatable through 360 degrees, a flat surface having a resistive coating placed thereon of a predetermined uniform resistivity per unit area, a pair of spaced parallel conductive electrodes fastened to and conductively cooperative with said resistively coated surface, a first wiper arm pivotally mounted at one extremity in pivotal relationship with the plane of said resistively coated surface and rotatable through 360 degrees in accordance with the angular position of said shaft, a second wiper arm pivotally mounted at one extremity in pivotal relationship with the plane of said resistively coated surface and rotatable through 360 degrees in accordance with the angular position of said shaft, said first and second wiper arms being displaced 90 degrees with respect to each other, a wiper contact mounted at the other extremity of each of said wiper arms for maintaining a slidable conductive contact on said resistive coating, the position of said pivotal mounting of each of said wiper arms and the length of said wiper arms being selected so that each of said wiper contacts makes physical conductive contact alternately with said parallel electrodes at 180 degree angular positions of said shaft, means for applying a voltage across said parallel conductive electrodes, the wiper contact of said first wiper arm having a voltage derived thereon commensurate with the sine function of the angle of rotation of said shaft, the wiper contact of said second arm having voltage derived thereon which is a cosine function of the angular rotation of said shaft, a first and second summing amplifier, each amplifier having at least two summing inputs, said first summing amplifier having its first summing input connected to the wiper contact on which is derived the sine voltage functional variation and its other summing input connected to a voltage source which is equal in magnitude and opposite in polarity to the voltage level present in the resistive coating immediately adjacent the pivotal mounting of the wiper arms, the second summing amplifier having its first summing input terminal connected to the wiper contact on which is derived the cosine function of the rotation of said shaft angle, the other of said summing inputs of said summing amplifier being connected to a voltage source equal in magnitude and opposite in polarity to the voltage level in the resistive coating point immediately adjacent the pivotal mounting of said arms, the output voltages of said first and second summing amplifiers being indicative of the magnitude of the shaft angle and the quadrant through which said shaft angle is being rotated.

2. A shaft angle electrical resolver for deriving electrical signals commensurate with trigonometric functions of a shaft angle comprising a shaft rotatable through 360

degrees, a flat surface having a resistive coating placed thereon of a predetermined uniform resistivity per unit area, a pair of spaced parallel conductive electrodes fastened to and conductively cooperative with said resistively coated surface, a first wiper arm pivotally mounted at one extremity in pivotal relationship with the plane of said resistively coated surface and rotatable through 360 degrees in accordance with the angular position of said shaft, a second wiper arm pivotally mounted at one extremity in pivotal relationship with the plane of said resistively coated surface and rotatable through 360 degrees in accordance with the angular position of said shaft, said first and second wiper arms being displaced 90 degrees with respect to each other, a wiper contact mounted at the other extremity of each of said wiper arms for maintaining a slidable conductive contact on said resistive coating, the position of said pivotal mounting of each of said wiper arms and the length of said wiper arms being selected so that each of said wiper contacts make physical conductive contact alternately with said parallel electrodes at 180 degree angular positions of said shaft, means for applying a voltage across said parallel conductive electrodes, the wiper contact of said first wiper arm having a voltage derived thereon commensurate with the sine function of the angle of rotation of said shaft, the wiper contact of said second arm having voltage derived thereon which is a cosine function of the angular rotation of said shaft, a first and second summing amplifier, each amplifier having at least two summing inputs, said first summing amplifier having its first summing input connected to the wiper contact on which is derived the sine voltage functional variation and its other summing input connected to a voltage source which is equal in magnitude and opposite in polarity to the voltage level present in the resistive coating immediately adjacent the pivotal mounting of the wiper arms, the second summing amplifier having its first summing input terminal connected to the wiper contact on which is derived the cosine function of the rotation of said shaft angle, the other of said summing inputs of said summing amplifier being connected to a voltage source equal in magnitude and opposite in polarity to the voltage level in the resistive coating point immediately adjacent the pivotal mounting of said wiper arms.

3. A shaft angle electrical resolver as set forth in claim **2** wherein there is also included an analog division circuit connected to receive voltage inputs from said first and second summing amplifiers for the purpose of deriving a tangential type trigonometric voltage variation with respect to changes of the angular rotation of said shaft.

4. A shaft angle electrical resolver for deriving a portion of a trigonometric function of a given shaft angle comprising a shaft, a flat surface having a resistive coating placed thereon of a predetermined uniform resistivity per unit area, a pair of spaced parallel conductive electrodes fastened to and conductively cooperating with said resistive coated surface, a wiper arm pivotally mounted on said resistive coated surface and electrically insulated therefrom and rotatable in accordance with said shaft angle, a wiper contact mounted on the end of said wiper arm for maintaining a slidable conductive contact on said resistive

coating, the position of said pivotal mounting and the length of said wiper arm being selected so that said wiper contact makes effective conductive contact alternately with the two parallel electrodes at 180 degrees angular positions of said shaft, said shaft driving said wiper being rotatable through 360 degrees, a source of electrical energy being conductively connected across said pair of electrodes, a summing amplifier having at least two summing inputs, one of said summing inputs being conductively connected to said wiper contact, the other of said summing inputs being connected to an electrical energy source equal in voltage and opposite in polarity to that present in the resistive coating immediately adjacent said shaft position of said wiper arm, the output of said summing amplifier means providing an electrical signal which is a sinusoidal function of the angular position of said shaft.

5. A shaft angle electrical resolver for deriving electrical signals commensurate with trigonometric functions of a shaft angle comprising a shaft rotatable through 360 degrees, a flat surface having a resistive coating placed thereon of a predetermined uniform resistivity per unit area, a pair of spaced parallel conductive electrodes fastened to and conductively cooperative with said resistively coated surface, at least one wiper arm pivotally mounted at one extremity in pivotal relationship with the plane of said resistively coated surface and rotatable through 360 degrees in accordance with the angular position of said shaft, a wiper contact mounted on the other extremity of each of said wiper arms for maintaining a slidable conductive contact on said resistive coating, the position of said pivotal mounting of each of said wiper arms and the length of each of said wiper arms being selected so that each of said wiper contacts effectively makes physical conductive contact alternately with the two parallel electrodes at 180 degrees angular positions of said shaft, said pair of spaced parallel directive electrodes having applied thereacross a voltage source, a summing amplifier having at least two summing inputs, one of said summing inputs being conductively connected to a wiper contact, the other of said summing inputs being connected to an electrical energy source equal in voltage and opposite in polarity to that present in the resistive coating immediately adjacent said shaft position of said wiper arm, the output of said summing amplifier means providing an electrical signal which is a sinusoidal function of the angular position of said shaft.

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