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L. A. ROSENTHAL
SINE-COSINE GENERATOR

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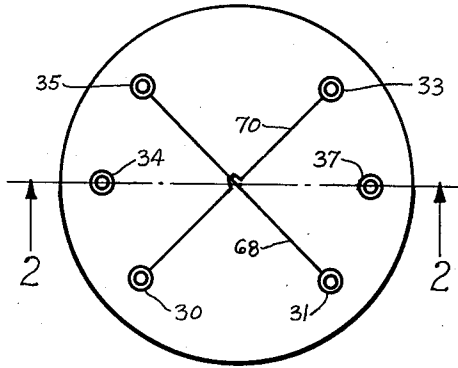


Fig. 1

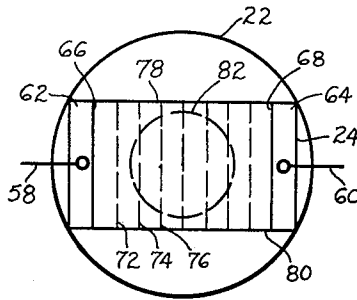


Fig. 3

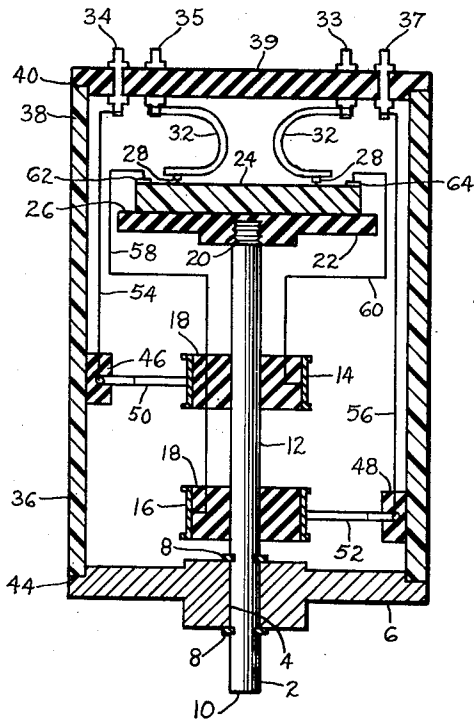


Fig. 2

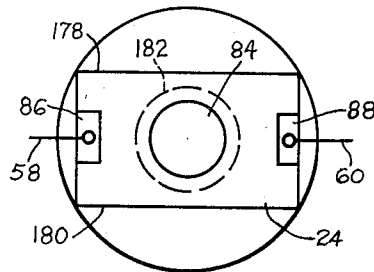


Fig. 4

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SINE-COSINE GENERATOR

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This invention relates in general to the generation of functions that are proportional to the sine-cosine curves.

Electrical resistor units that generate a voltage in the form of a sine-cosine curve consist of a wire-wound card mounted rigidly to one end of a rotatable shaft so that the flat portion of said card is perpendicular to the longitudinal axis of said shaft. The stationary electrical brushes, separated at an angle of 90° and spaced equally from the center of rotation, make contact with the electrical conducting wires of the wire-wound card. Since the voltage drop per unit length of said wire is constant, a relatively uniform electric field is generated in a direction that is transverse to the wires. The stationary electrical brushes receive voltage from the electrical conductors as the wires of said wire-wound card are rotated by the rotation of the shaft. The brush voltages have the value $A \sin \theta$, $A \cos \theta$, where A is the amplitude and θ is the angular displacement of said wire-wound card relative to said electrical pick-up brushes.

The wire-wound sine-cosine generating electrical resistors have numerous latent disadvantages. The cost of the precision wire-wound card is relatively high and the output voltage as received at the electrical pick-up brush is not smooth and uniform, but is delivered as a step function. This stepping or jumping of the sine-cosine voltage function is the result of the electrical pick-up brush being advanced to and making electrical contact with a new conductor having a potential that varies greatly from the potential of the conductors on each side. Therefore, the change of voltage is in the form of a step function or jump rather than a smooth continuous change.

Another disadvantage of said wire-wound unit is that the degree of resolution is controlled by the coarseness of the electrical conducting wires. The wire-wound unit has almost no resolution at the 90° position where the electrical brushes move parallel to the electrical conducting wires.

Another limitation of the wire-wound unit is that it is limited in total resistance by the conventional wire sizes and types. The upper limit of resistance is reached when the electrical conducting wire must be so fine as to be difficult to draw or extremely vulnerable to wear. A difficulty encountered when using the wire-wound unit is that the inductance of the wire-wound card might offer some difficulty when applied to alternating current applications. Another difficulty encountered when using the wire-wound unit is that the diameter of the electrical conducting resistance wire is reduced during use, thus resulting in an increase in the total resistance of the wire-wound unit.

Another disadvantage of the wire-wound unit is that, due to wear, the noise level will increase. Often adjacent coils of the resistance wire will short due to a mechanical failure of insulation or accumulation of deposits of electrical conducting material between adjacent coils of wire.

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Another disadvantage of said wire-wound unit is that said electrical conducting wire may separate as a result of wear.

The present invention contemplates the use of an electrical conducting plastic card and the use of electric brushes that trace a circular path on the plastic card to generate a sine-cosine voltage wave.

The brushes are separated by an arc of 90° and are adjusted so that the points of contact between said brushes and said plastic card are of equal distance from the center of rotation of said plastic card. One brush generates the sine function while the other brush generates the cosine function.

The plastic card, when connected to a source of voltage, contains an infinite number of parallel equi-potential lines, each line varying from those on either side by an infinitesimal degree of potential.

It is an object of this invention to provide a sine-cosine generator using a plastic card of relatively high specific resistivity as a conductor.

It is another object of the invention to provide a current carrying card that is completely void of current carrying wire conduits.

It is another object of the invention to generate a relatively smooth continuous sine-cosine function that is free of abrupt step changes.

It is another object of the invention to provide a device that has good resolution at all positions.

It is another object of the invention to provide a sine-cosine generator that is free of inductance effects when used in conjunction with alternating current.

Another object of the invention is to provide a current conducting card that is not limited to a narrow range of resistance values.

Another object of the invention is to provide a sine-cosine generator that will not alter in resistance value with use.

Another object of the invention is to provide a sine-cosine generator that will not be subject to sudden failure attributable to wear.

Another object of the invention is to provide a device that is relatively free of microphonics and noise.

Another object of the invention is to provide a device possessing excellent long life characteristics.

Other objects and many of the attendant advantages of this invention will be readily appreciated as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawings wherein:

Figure 1 is a top view of the sine-cosine generator showing the external connection of the device,

Figure 2 is a vertical cross-sectional view of the generator along line 2—2 of Figure 1,

Figure 3 is a top plan view of one type of plastic card made of material already in use prior to the concept of the present invention and

Figure 4 is a top plan view of the plastic card employed in the present invention.

Referring now to the form of the invention disclosed in Figures 1, 2 and 4, the sine-cosine generator there shown is enclosed in a standard conventional type housing. Shaft 2 is rotatably mounted in guide bearing 4 of face plate 6 and said shaft 2 is retained in a fixed longitudinal position by retaining clips 8. End 10 of said shaft 2 is rigidly connected to a rotary prime mover means that is not shown. Electrically conducting slip rings 14 and 16 completely encircle said shaft 2 at location 12 of said shaft 2. Bushings 18 are made of electrical insulating material and electrically isolates said electrically conducting slip rings 14 and 16, that are mounted on the outer circumference of said bushings 18, from said shaft 2. Said insulating

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bushings 18 are rigidly attached to said shaft 2 thus preventing relative motion or angular rotation between shaft 2 and slip rings 14 and 16. Disk 22 possesses electrical insulation properties and is rigidly mounted by suitable means, to end 20 of rod 2 so that there is no relative movement of said disk 22 with respect to said rod 2. Said rod pierces and enters disk 22 but does not penetrate disk 22. Electrically conducting plastic card 24 is fastened securely to surface 26 of disk 22.

The plastic card 24 is an organic plastic and depends primarily on high polymeric carbon-carbon chains and networks for their plastic structure. The conducting card 24 is composed of an electrically conducting material commingled with a thermosetting, thermoplastic or elastomeric material that is moulded to the desired dimensions and shape. The density of the electrically conducting material, with respect to the card, determines the total resistance of the card. An example of the type of plastic found satisfactory for making a card used in the present invention was manufactured by The Markite Company and is designated as #G-169.

Electrical conducting brushes 28 make electrical contact with plastic card 24. The electrical conducting brushes 28 are electrically and mechanically attached to terminal posts 30, 31, 33, and 35 through brush pressure spring 32.

Input terminals 34 and 37, and said terminals 30, 31, 33, and 35 are securely and rigidly attached to terminal plate 39, said terminal plate 39 being composed of Bakelite or any other material bearing excellent insulation properties. End 38 of hollow cylinder 36 is received in annular groove 40 of said terminal plate 39 and said cylinder 36 is securely fastened to said terminal plate 35 by convenient means. End 44 of the hollow cylinder 36 is connected to the face plate 6 in the same manner and by the same means as end 38 of hollow cylinder 36 is attached to terminal plate 35.

Terminal blocks 46 and 48, made of insulating materials, are securely attached to the inner wall of said hollow cylinder 36 at a convenient position as shown in Figure 1. Electrical contact brushes 50 and 52 are anchored to terminal blocks 46 and 48 respectively. Brush 50 makes electrical contact with slip ring 14 and brush 52 makes electrical contact with slip ring 16. The voltage input terminal 34 is electrically connected to slip ring brush 50 by conductor 54. Conductor 56 connects input terminal 37 to slip ring brush 52. Electrical conduits 58 and 60 connect slip rings 16 and 14 respectively to the electrical conductive contact material 62 and 64 that possesses very low electrical resistance. The conductive paint strips 62 and 64 are located on and make electrical contact with the surface of the plastic card 24.

Where a single contact pick up for each function is used, the centering of the pivot for the electrical brush 28 must be very accurate; otherwise there will be an error equal to one half the difference between the magnitude of the maximum voltage outputs that occurs at angular displacements of 180 degrees. This error is removed when a double contact pick up for each function is utilized.

As shown in Figure 1, output terminals 31 and 35 are electrically interconnected by conducting wire 68. Electrical conducting wire 70 interconnects output terminals 30 and 33. One set of output terminals will deliver the sine function and the other set of output terminals will deliver the cosine function.

Referring to Figure 3, the plastic card 24 generally in use is approximately $1\frac{1}{2}$ inches long, $1\frac{1}{16}$ inches wide and 0.050 inch thick. The conductive paint electrodes 62 and 64 extend across the width of the card 24, at each end, and is approximately 0.250 inch in width. Ends 66 and 68 of the conductive paint electrodes 62 and 64 provide two straight parallel equipotential lines.

The current flow in card 24 is between the conductive paint electrodes 62 and 64, and therefore, all equipotential lines will be at right angles to the flow of current.

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Dotted lines 72, 74 and 76 represent the location of a few of the infinite number of equipotential lines that are present on card 24 when there is a potential differential between the conductive electrodes 62 and 64.

Assume that a continuous generation of the sine and cosine functions, having a frequency of 60 cycles per minute, is required. In operation, a prime mover with a rotational speed of 60 cycles per minute is coupled to end 10 of said shaft 2. There is no relative motion between the plastic card 24 and shaft 2, therefore, the plastic card will rotate at a speed of 60 cycles per minute. A voltage is then placed across plastic card 24 by applying a potential to the input terminals 34 and 37. The electrical brush contacts 28 attached to output terminals 30, 33 and 31, 35 track the circular path 82. As the electrical brush contacts travel from one equipotential line to the next equipotential line, a new increment of voltage is transmitted to the output terminals 30, 33 and 31, 35. The brushes attached to output terminals 30, 33 are displaced from the respective brushes that are connected to output terminals 31, 35 by an arc of 90° . Therefore one set of output terminals will generate the sine function and the other set of output terminals will generate the cosine function.

A card of the type generally described above but punched out or perforated to make it more useful as a sine-cosine potentiometer can be moulded to the desired dimensions and configuration and can be adapted to A. C. circuits as well as D. C. circuits. Inductance effects of the plastic card, when used in conjunction with A. C. applications, is negligible.

This invention relates to such a form of card construction as shown in Figure 4. A circular cutout 84 in said plastic card 24 with a diameter of $\frac{7}{8}$ of an inch will increase the resistance of the said plastic card 24 by approximately 100% without great deterioration of function. A cutout with a diameter of $1\frac{1}{16}$ of an inch increases the resistance of the plastic card approximately 200%; however, the deviation of function is about 10%. By reducing the conductive electrodes 62 and 64 from the width of the full card (approximately $1\frac{1}{16}$ of an inch) to about $\frac{5}{16}$ of an inch (86 and 88) and equally spaced from sides 178 and 180 an accuracy of about 2% is obtained. The conductive electrodes 86 and 88 were reduced in length so that the adjacent equipotential lines within each quadrant will be parallel to each other.

Referring to Fig. 4, if the conductive paint electrodes 86 and 88 continued across the card 24 from one end 178 to the other end 180, the adjacent equipotential lines within each quadrant would not be parallel to each other. This condition would exist because the void 84 decreases the area of conducting material, thus creating various path lengths for the flow of current. The path of the current flow from a point midway between the two edges 178 and 180 would be greater than the path of current flow from a point near one of the edges 178 or 180.

By decreasing the length of the conductive paint electrodes as illustrated in Fig. 4, the various current paths are equal, thus resulting in parallel equipotential lines within each quadrant.

Obviously many modifications and variations of the present invention are possible in the light of the above teachings. It is therefore to be understood that within the scope of the appended claims the invention may be practiced otherwise than as specifically described.

What is claimed is:

1. A potentiometer element across which a uniform electrical field may be established by applying a source of potential across a pair of contact elements comprising a smooth-surfaced resistance member composed of electrically homogeneous and resistive material formed with a centrally located hole, and a pair of conductive contact elements disposed on said smooth surface and electrically connected to said resistive material, each said conducting element spaced from and lying on a different side of said

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hole opposite the other said conducting element, the size of said contact elements being adapted to compensate for the distortion produced by said hole in the equipotential lines of said uniform electric field.

2. A potentiometer element across which a uniform electrical field may be established by applying a source of potential across a pair of contact elements comprising a smooth-surfaced resistance member composed of plastic material containing conductive material commingled therewith to form an electrically homogeneous material, said member formed with a centrally located hole, and a pair of conductive contact elements disposed on said smooth surface and electrically connected to said resistive material, each said conducting element spaced from and lying on a different side of said hole opposite the other said conducting element, the size of said contact elements being adapted to compensate for the distortion produced by said hole in the equipotential lines of said uniform electric field.

3. A potentiometer element across which a uniform electrical field may be established by applying a source of potential across a pair of contact strips comprising a flat rectangular card composed of electrically homogeneous and resistive material formed with a centrally located hole, and a pair of conductive contact strips disposed on one side of said card and electrically connected to said resistive material each said strip spaced from and lying on a different side of said hole opposite the other said strip, the size of said strips being such as to substantially compensate for the distortion produced by said hole in the equipotential lines of said uniform electric field.

4. A potentiometer element across which a uniform electrical field may be established by applying a source of potential across a pair of contact strips comprising a flat rectangular card composed of electrically homogeneous and resistive material formed with a centrally located hole, and a pair of conductive contact strips disposed on one surface of said card extending along opposite edges thereof and electrically connected to said re-

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sistive material, the size of said strips being such as to substantially compensate for the distortion produced by said hole in the equipotential lines of said uniform electric field.

5. A sine-cosine wave generator of the type in which the voltage-deriving members rotate in a circular path relative to a uniform electrical field comprising, in combination: a smooth-surfaced resistance member composed of electrically homogeneous and resistive material formed with a centrally located hole therein; a set of voltage-deriving members adapted for rotation in contact with said smooth-surface; and a pair of conductive contact elements electrically connected to said resistance member and disposed on said smooth surface on opposite sides of and spaced from said hole, the size of said contact elements being such as to compensate for the distortion in said uniform electrical field caused by forming said resistance member with said centrally located hole so that said voltage-deriving members derive substantially sine- and cosine-shaped waves as they would while rotating through said uniform field.

6. A device as set forth in claim 5, wherein said homogeneous resistive material is composed of conductive material commingled with plastic material.

7. A device as set forth in claim 5, wherein said contact elements comprise longitudinal strips.

8. A device as set forth in claim 5, wherein said resistive element comprises a substantially flat rectangular card, and said contact elements comprise longitudinal strips extending along opposite edges of said card.

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