

April 4, 1967

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CONTACTLESS ELECTRICAL TRANSDUCER HAVING MOVING PARTS

Filed May 4, 1964

3 Sheets-Sheet 2

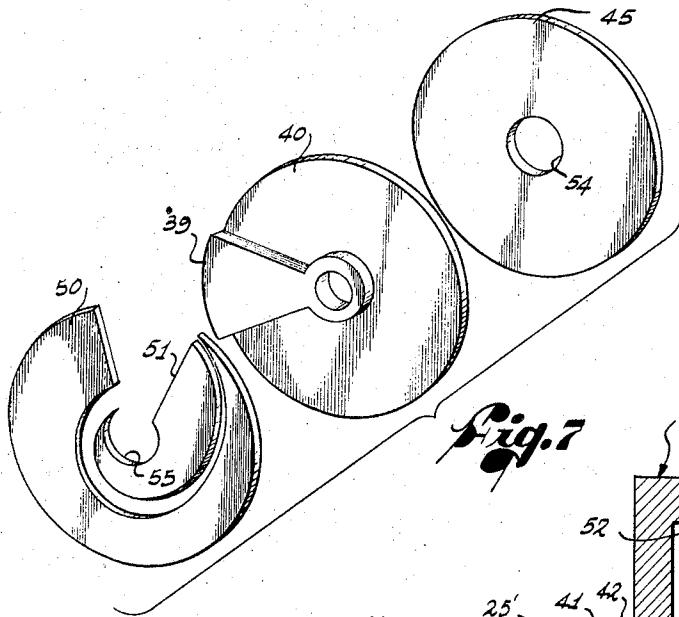


Fig. 7

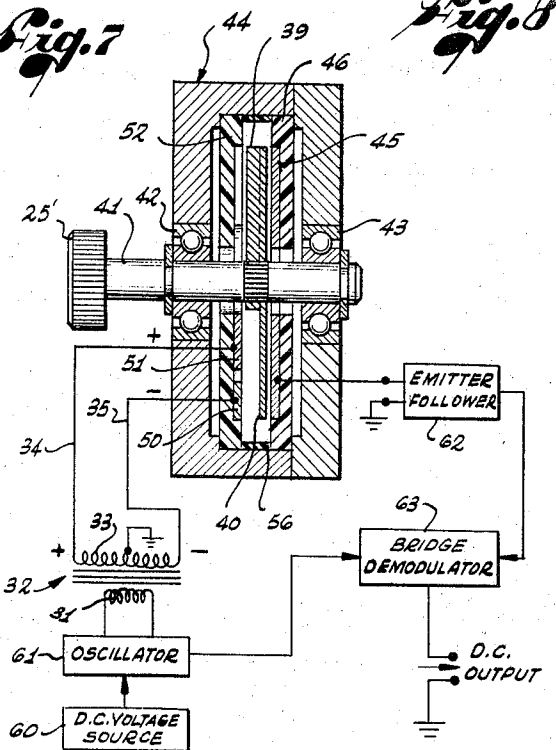


Fig. 8

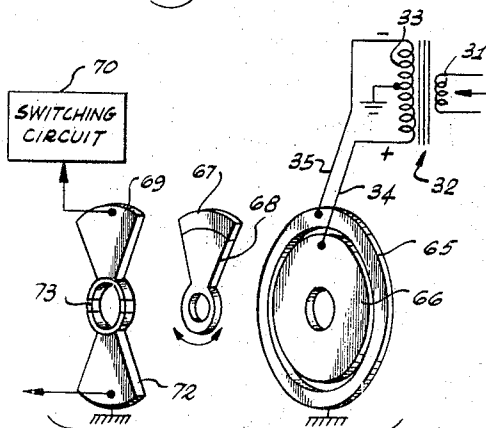


Fig. 9

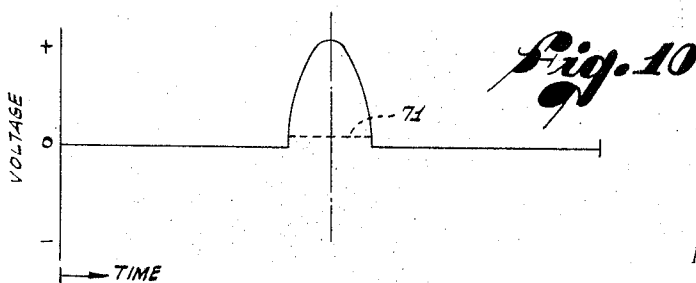


Fig. 10

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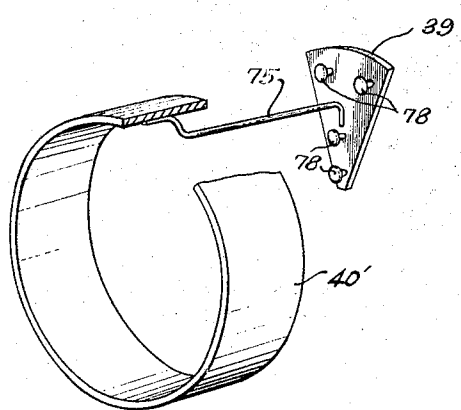
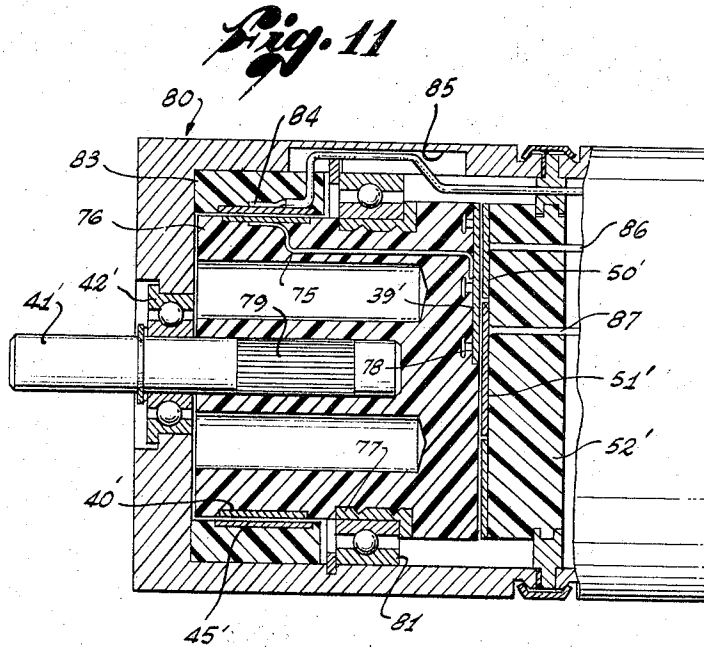
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3 Sheets-Sheet 3



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CONTACTLESS ELECTRICAL TRANSDUCER HAVING MOVING PARTS

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14 Claims. (Cl. 323—93)

This invention relates to electrical circuit devices having moving parts, and more particularly to unique electromechanical circuit means which does not employ any contacts.

Typical electromechanical circuit devices heretofore known have one or more sets of electrical contacts, at least one contact of which is movable. Whether it is a simple switch in a line, a commutating switch, or a transducer for developing output signals which are functionally related to signals related thereto (e.g., linear and rotary potentiometers), it functions through make-and-break operations of contact elements. Regardless of how such contacts might be made and arranged to make and break engagement with one another, it is well known that their physical and electrical characteristics change each time they are brought together and separated.

For any such device, in due course, the contact or wear surfaces become so deformed, and the electrical characteristics become so degraded, that their further use cannot be tolerated. The problem is particularly acute in highly critical applications, e.g., wherein selective positioning of a rotary device, such as the control shaft of a potentiometer, is utilized for remote control of mechanical and/or electronic devices.

Typical of such remote control rotary devices is a potentiometer for use in electrically controlling the speed of operation of another rotary device in accordance with the angular position of the potentiometer shaft, and hence the magnitude of the output voltage from the potentiometer. However, a potentiometer is not a device having infinite resolution, because it is limited in that the smallest voltage change that can be attained with it is a direct function of the number of turns of wire over which the movable contact or wiping contact passes. Thus, if the wire-wound potentiometer resistor is made with one thousand turns of wire, the potentiometer has a resolution of .001 of the total voltage, or a resolution of 0.1 volt for the situation where the applied voltage is 100 volts.

In addition to the foregoing disadvantage of potentiometers, the turns of wire over which the sliding contact passes become worn due to friction between the rubbing surfaces. This in turn leads to a change in the shape of the turns affected, and hence into a change in their electrical characteristics. Also, due to the manner of operating a potentiometer, each turn becomes worn to a different extent than every other turn, which means that in order to provide the same output voltage at different times, the sliding contact must be placed at different positions along the potentiometer resistor.

Such results are anathema to extremely fine control of output voltages, where it is essential that output conditions be the same for the same position of the potentiometer shaft. Highly precise control is, of course, not possible with devices which have parts in frictional engagement. The best that can be done is to provide parts with specially treated materials, or which are made of exotic metals, special alloys, and the like. However, these precautions are at best of only limited effectiveness, in that although a longer period of reasonably uniform operations is obtained with them, they cannot avoid ultimate wear, deterioration, and degraded performance. Where high degree of reliability is required, even the

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best made potentiometers must be replaced after an undesirably short period of use.

It is an object of my invention to provide a unique electromechanical circuit means which avoids the above and other disadvantages of the prior art.

It is another object of my invention to provide an electromechanical circuit means in which frictionally engaging contacts are eliminated.

A further object of my invention is to provide a unique electromechanical circuit device capable of functioning as a potentiometer, but which is characterized by substantially infinite resolution and operating life.

A still further object of my invention is to provide electromechanical circuit means suitable for use as a switch, transducer, function generator, or the like, which comprises a minimum number of component parts of simple design and rugged construction, capable of reliable operation with uniform characteristics over a substantially infinite life.

The above and other objects and advantages of this invention will become apparent from the following description, taken in conjunction with the accompanying drawings of illustrative embodiments thereof, in which:

FIGURE 1 is an exploded view of the basic parts of my invention, in which one plate element is adapted for movement in one plane;

FIGURE 2 is a side elevation view of the movable and fixed plates of FIGURE 1 in assembled relation and showing schematically connections to the fixed plates through which input voltages are applied and from which output signals are supplied which vary linearly with movement of the movable plate;

FIGURE 3 is a top plan view taken along the line 3—3 of FIGURE 2, to aid in explaining the positions of the parts in FIGURE 2 corresponding to a zero output voltage;

FIGURE 4 is a side elevation view, similar to FIGURE 2, of the parts in position wherein the output voltage is a voltage of one polarity;

FIGURE 5 is a top plan view, similar to FIGURE 3, showing another form of the fixed input plates from which to develop an output voltage that varies linearly with movement of the movable plate;

FIGURE 6 is a top plan view, similar to FIGURE 3, showing the input plates having non-linear shape, so that an output voltage is developed which varies non-linearly with changes in the position of the movable plate;

FIGURE 7 is an exploded view of the basic parts of a rotary version of the device illustrated in FIGURE 2;

FIGURE 8 is a longitudinal sectional view of a rotary potentiometer formed with the parts of FIGURE 7;

FIGURE 9 is an exploded view of parts for a rotary switch device of my invention;

FIGURE 10 is a graph for use in explaining the operation of the switch mechanism of FIGURE 9;

FIGURE 11 is a longitudinal sectional view of another form of rotary device of my invention; and

FIGURE 12 is a fragmentary view in perspective of the rotary element of the device of FIGURE 11.

Referring to FIGURES 1—3, a pair of stationary metal plates 15, 16 are supported on respective substrates 17, 18 of suitable non-conductive material, e.g., plastic or the like, and are placed side by side in the same plane. Held parallel to the plates 15, 16 and spaced therefrom is a large rectangular metal plate 19, also shown mounted on a substrate 20. As best understood with reference to FIGURE 1, the plate 19 is sufficiently large that it overlies or spans both plates 15, 16 and the space between them.

Sandwiched between the plate 19 and the plates 15, 16, and movable parallel thereto, is a metal plate 21.

As best seen with reference to FIGURE 2, the plate 21 is of such size and is arranged so that there is a small air gap between its lower surface and the plane of the upper surfaces of the plates 15, 16, and there is a similarly small air gap separating the confronting surfaces of the plates 19 and 21.

In accordance with my invention, the plate 21 is arranged to be moved to any desired position between the remote ends of the plates 15, 16, i.e., so that in the extreme left-hand position it overlays only the plate 15, and in the extreme right-hand position it overlays only the plate 16 (as, e.g., in FIGURE 4). One means for effecting movement of the plate 21 is illustrated in FIGURE 1, and comprises an elongated rigid bar 23 of suitable non-conductive material, e.g., rigid plastic or the like, to which the plate 21, as indicated by the mechanical connection, is rigidly connected. Rotatable beneath the bar 23 is a cylindrical roller 24 which is carried on the shaft of a control knob 25. The roller 24, for example, may be a hard rubber element which frictionally engages an elongated strip 26 of a similar material secured to the lower surface of the bar 23. Such an arrangement is similar to that of a rack and pinion device, but is characterized in that the plate 21 can be placed in any of an infinite number of positions and without the drawbacks of "play," backlash, and possible stepwise movement which could occur with a conventional rack and pinion having gear teeth.

Referring again to FIGURE 2, an A.C. voltage source 30 is connected to the primary winding 31 of the transformer 32 which has a center-tapped secondary winding 33. The ends of the secondary 33 are connected, as at 34, 35, to the respective plates 15, 16, which are input plates. An output lead 36 is connected to the upper plate 19.

With the above-described circuit arrangement, the plates 15, 16 at any instant have opposite charges of equal magnitude. For purposes of explanation, the lead 34 (and hence the plate 15) is shown as positive, and the lead 35 (and hence the plate 16) is shown as negative.

With the plate 21 overlaying portions of both the plates 15, 16 as shown in FIGURE 2, it will be noted that the plate 21 is charged from both plates 15, 16. When the plate 21 has equal portions thereof overlaying the plates 15, 16 (see FIGURE 3), the charges on the plates 15, 16 are equal and opposite, and the net charge on the plate 21 is zero. On the other hand, when the plate 21 overlays only one of the plates 15, 16 (for example, the plate 16 as shown in FIGURE 4), the entire charge on the plate 21 comes from the negative plate 16, and in this case is a positive charge. The output plate 19 thus acquires a negative charge equal to that of the positive charge on the plate 21. It is apparent that the upper plate 19 assumes a positive charge when the movable plate 21 is positioned at the extreme left-hand side so as to cover only the positive plate 15.

It will be apparent that in any position of the plate 21 other than its center position, the output plate 19 is charged in accordance with the difference in areas of the plates 15, 16 covered by the plate 21. Thus, if the portion of the plate 21 overlaying the plate 15 is only one-third of the portion of the movable plate overlaying the other plate 16, the result is a net positive charge on the plate 21 of one-half that corresponding to the area of the plate which overlays the plate 16. The charge on the output plate 19, is a corresponding negative charge.

With the foregoing operations in mind, it will be appreciated that my invention provides a unique means for providing an output voltage that varies linearly with the position of the movable plate 21 as it is moved between its center position and either of its extreme positions. Furthermore, the output voltage changes from zero to a maximum positive output for one direction of movement of the plate 21 from its center position, and from zero to a maximum negative output for movement

of the plate 21 in the opposite direction from its center position. Of greatest importance is the fact that although the electrical operations are carried out through the use of a movable element, no conductive elements are in contact with each other at any time. For any given position of the shaft of the control knob 25, the output voltage is always the same.

FIGURE 5 illustrates another form for the input plates for obtaining a linear charge in the output voltage with changes in the position of the movable plate 21. As shown, plates 15', 16' are triangular shaped elements, and are so positioned that the gap between them corresponds to the diagonal of the rectangle formed thereby. As will be observed, this arrangement provides for smaller voltage changes for a given movement of the movable plate 21 than is obtainable with the arrangement of FIGURES 1-4.

FIGURE 6 illustrates an example of a form for the input plates with which to obtain output voltages that vary non-linearly with movements of the movable plate 21. As shown, the plates 37, 38 have their confronting edges shaped to form a curved gap between them, shown as a sine wave in this example. With this arrangement, during movement of the movable plate 21 between its center position toward either end of the plates 37, 38, the charge on the movable plate 21 increases from zero to a maximum in one direction, and then decreases.

As will be apparent, my invention embraces any suitable shape for the input plates for obtaining an output voltage that varies as any desired function of the position of the movable plate 21, and hence of the operation of the prime mover for the movable plate 21. Further, my invention embraces any suitable shape for the movable and output plates. Any or all of the various plates may be made without an axis or line of symmetry, and arranged to provide either linear or non-linear results.

FIGURES 7 and 8 illustrate an embodiment of my invention wherein the movable plate is arranged to rotate with the control shaft. Referring to FIGURE 7 along with FIGURE 8, the movable plate 39 is a wedge-shaped element that is integral with and projecting from one surface of a relatively thin disc 40. Such a unit may be formed, for example, by milling the plate 39 out of one face of a metal disc of the combined thicknesses of the plate 39 and the disc 40. As shown in FIGURE 8, this unit is secured to a shaft 41 which is rotatably mounted in bearings 42, 43 in the end walls of a housing 44.

Separated from the disc 40 by a small air gap is a metal disc 45 which is embedded in one face of a non-conductive substrate disc 46. Immediately adjacent the plate 40, and separated therefrom by a small air gap, is a pair of curved plates 50, 51 of equal thickness, arranged in coplanar fashion with one plate 50 circumscribing the other plate 51. As shown in FIGURE 8, the plates 50, 51 are embedded in one surface of a non-conductive substrate disc 52. Also as shown in FIGURE 8, the opening 54 in the disc 45 and the opening 55 in the center of the curved plate 51 are of larger diameter than the shaft 41. The confronting surfaces of the non-conductive discs 46, 52 are separated by a spacer ring 56, and the remote surfaces of the non-conductive discs 46, 52 are captured between opposed walls within the housing 44, and thereby held stationary.

The plates 50, 51 form the input plates corresponding to the input plates 15, 16 of the embodiment illustrated in FIGURES 1-4, and the disc 45 forms the output plate corresponding to the output plate 19 previously described. As will be apparent, the curved plates 50, 51 are shaped so that the surface areas thereof confronted by plate 39 vary throughout a revolution of the plate 39.

Any charge on the plate 39, of course, spreads instantly through the disc 40. Since the disc 40 has a much greater surface area than the plate 39, it is more effective (than the plate 39 by itself) in charging the output plate

45. The disc 40, in effect, is a transfer plate for the charge on the plate 39.

Again referring to FIGURE 7, and to the curved plates 50, 51, it will be noted that the larger end of the outer plate 50 and the smaller end of the inner plate 51 are located along one radial line, and the smaller end of the outer plate 50 and the larger end of the inner plate 51 are located along another radial line, the angle between such radial lines being substantially the angle of the wedge-shaped plate 39. Still further, it will be noted that the plates are shaped so that the air gap is widest at its inner end and decreases progressively to a minimum at its outer end. This gap is tailored so that the area of the gap spanned by the wedge-shaped plate 39 is always substantially the same.

Referring again to FIGURE 8, the device of my invention is shown arranged to develop a D.C. output voltage that is linearly related to the position of the control shaft 41. In this connection, a D.C. voltage source 60 is connected to an oscillator 61 which develops an output voltage of a frequency corresponding to the magnitude of the voltage of the source 60. The alternating voltage from the oscillator 61 is supplied to the transformer 32 to cause the input plates 50, 51 to receive equal and opposite charges. The charge on the output plate 45 is applied to an isolating emitter follower 62. The emitter follower 62 is coupled to a bridged phase-sensitive, demodulator 63, which is also referenced to the output of the oscillator 61. The output of the demodulator is a D.C. voltage, the magnitude and polarity of which depend, of course, on the position of the movable plate 39, and hence the position of the control shaft 41 and the control knob 25' thereof. Accordingly, any given D.C. output voltage can be established by simply turning the control knob 25' to the position for which such an output voltage is needed, which position can be determined by means of a suitable pointer or other indicator operable by the control knob 25'.

As will be apparent, my rotary transducer device, like my translatable device previously described, has the advantages of being devoid of contacts and noise, having infinite resolution and reliable operation and requiring no maintenance.

FIGURE 9 illustrates a device of my invention which operates as a switch. In this case, the input plates are comprised of an outer metal ring 65 surrounding and concentric with an inner metal ring or disc 66. The movable metal plate in this case is an arcuate segment 67 which has the same radius of curvature and radial dimension as the outer ring 65. The movable plate 67 is shown to be carried on an integral non-conductive wedge-shaped element 68. Thus, the metal plate 67 is adapted to confront only the outer ring 65, and never is in confronting relation with any portion of the inner ring 66.

An output plate for the switch of FIGURE 9 is a wedge-shaped metal plate 69. As is apparent, the output plate 69 is charged only during the interval that the movable plate 67 is in confronting relation with the output plate 69. Referring to FIGURE 10 along with FIGURE 9, the charge voltage on the output plate 69 is zero until the movable plate 67 begins to move between the output plate 69 and the outer ring 65, builds up to a maximum at the position point where the confronting surface areas of the plates 67, 69 are at a maximum, and decreases again to zero when the movable plate 67 moves past the fixed output plate 69. The output plate 69 is shown connected to a switch circuit 70 which, for example, is adapted to be triggered into operation during the interval that the charge voltage on the output plate 69 is above a predetermined level, indicated at 71 in FIGURE 10.

Again referring to FIGURE 9, an additional output plate 72 is shown spaced from the output plate 69, and, of course, insulated therefrom as by non-conductive spacers 73 between segmented hubs of the output plates 69, 72. In this manner, the charge voltage on the output

plate 72 is made to appear in precisely the same manner as that of the output plate 69 (although at a different time), whereby the same device is utilized for switching or commutating between the two different output circuits.

It will be apparent from the foregoing that the arrangement of the switch mechanism of FIGURE 9 can be expanded to include a plurality of output plates coupled to respective circuits. Other suitable operations may be performed, such as for example, connecting a single output circuit to each of a plurality of output plates, whereby the output circuit is turned on and off a plurality of times during each revolution of the movable plate 67.

FIGURES 11 and 12 illustrate another form of a rotary device of my invention. In this case, the wedge-shaped movable plate 39' is a separate element, and the transfer plate 40 of FIGURE 7 is replaced by a cylinder 40' to which the movable plate 39' is conductively connected, as by the wire 75 shown, and the output plate 45 of FIGURE 7 is replaced by a cylinder 45' which surrounds the cylinder 40'.

The plate 39', the cylinder 40' to which it is connected, and the wire 75 are made to rotate as a unit. As shown in FIGURE 11, these elements are supported in fixed spaced relation by a non-conductive element 76 of potting material, in the center of which the shaft 41' extends. Also, the element 76 supports a bearing support ring 77 in its lateral surface intermediate the transfer ring 40' and the plate 39'. This unitary structure may be formed, for example, by supporting elements 39', 40', 75, 41', and 77 in fixed spaced relation in a suitable mold, then filling the mold with the potting compound in a liquid state, so that upon hardening, the various elements are permanently held in the positions shown. In this regard, the plate 39' is provided with integral buttons 78, and the internal portion of the shaft 41' is knurled as at 79, around and into which the potting material flow, whereby these elements cannot subsequently be moved relative to each other.

As shown, the unitary structure above described is rotatably supported in the housing 80, by the bearing 42' adjacent the outer end of the shaft 41' and a bearing 81 placed around the bearing support ring 77.

The output cylinder 45' is shown embedded in the inner wall of a cylinder 83 of non-conductive material. A wire connection 84 to the outer surface of the output cylinder 45' is embedded at one end in the non-conductive cylinder 83, and is led through a slot in the inner wall of the housing 80 and into the opposite end of the housing, together with leads 86, 87 which extend through the substrate 52' from the input plates 50', 51'. Such an arrangement permits all the electronic components to be located in one end of the housing 80, thereby providing a small, compact package for the entire mechanical and electronic assemblies.

As is apparent, with the plates 50', 51' shaped the same as the plates 50, 51 of FIGURE 8, the electromechanical device illustrated in FIGURE 11 operates in the same manner as that illustrated in FIGURE 8. However, due to the fact that the transfer and output cylinders 40', 45' have their confronting surface areas located at right angles to the radial faces of the plates 39', 50', 51', I am able to better prevent possible stray capacitance effects which might exist between the elements of the structure of FIGURE 8. The structure of FIGURE 11 is better suited for applications in which even the slightest amount of stray capacitance cannot be tolerated.

It will be apparent from the foregoing that the various embodiments of my invention shown and described herein are illustrative only, and that various modifications can be made therein without departing from the spirit and scope of my invention, which is not intended to be limited, except by the appended claims.

I claim:

1. In combination:

a pair of juxtaposed stationary plates having confront-

ing edges, said edges being separated by a gap defined by the contours of said edges, said plates having input leads through which to charge said plates so as to have charge potentials of opposite polarity;

a movable plate parallel to said pair of plates and adapted for movement parallel thereto so as to span said gap and have portions confronting both plates of said pair, said movable plate when spanning said gap being charged an amount corresponding to the difference between the portions thereof confronting both plates of said pair, said movable plate also being movable to confront either one of the plates of said pair and charged an amount corresponding to the charge on such one plate;

a further stationary plate to be charged from said movable plate but which is not capacitively coupled thereto, said movable plate having a plate section in fixed spaced relation and electrically connected therewith which is movable parallel to and capacitively coupled to said further plate, said further plate being adapted to be charged from said plate section, the capacitance between said plate section and said further plate being constant throughout movement of said movable plate, said further plate having an output lead;

and means for effecting movement of said movable plate and plate section in unison.

2. A device as defined in claim 1, wherein said movable plate is supported so that the surface thereof confronting said pair of plates undergoes angular movement, and wherein the plates of said pair and said movable plate are flat elements.

3. A device as defined in claim 2, wherein said further plate is a flat plate parallel to said movable plate, and said plate section is part of said movable plate.

4. A device as defined in claim 2, wherein said further plate and said plate section are concentric cylinders, said plate section being the inner cylinders; an electrical connection between said plate section and said movable plates; and means supporting the plate section, the electrical connection and the movable plate for unitary rotation.

5. A device as defined in claim 2 including a transformer having a center-tapped secondary winding connected at its ends to the respective plates of said pair, and a primary winding for connection to an A.-C. voltage source.

6. A device as defined in claim 2, wherein the plates of said pair are rectangular plates having coplanar surfaces confronting said movable plate, said movable plate is a rectangular plate of substantially the dimensions of one of said pair of plates, and said further plate is a rectangular plate having a surface confronting said pair of plates that is substantially equal to the combined surface areas of the coplanar surfaces of said pair of plates, said further plate, said movable plate and said pair of plates being parallel to each other, and said movable plate being movable to extreme positions wherein it confronts only one or the other of the plates of said pair.

7. A device as defined in claim 2, wherein the plates of said pair are coplanar plates on the axis of movement of said movable plate, said plates being shaped to form a flat disk, the confronting edges of said coplanar plates defining a spiral gap, and said movable plate being a triangular element.

8. A device as defined in claim 7, wherein said gap is widest nearest the axis of said disk and decreases gradually to a minimum at the periphery thereof.

9. A device as defined in claim 2, wherein the plates of said pair are formed of concentric flat rings, and said movable plate is a flat element which confronts only one of the plates of said pair.

10. A device as defined in claim 7, wherein said further plate is a triangular element; at least one additional plate of the shape of said further plate and coplanar therewith, said additional plate being angularly spaced from said

further plate and insulated therefrom, whereby each of said further and additional plates receive charges during a revolution of said movable plate.

11. In combination:

a pair of conductive stationary plates having confronting edges separated by a gap defined by the contours of said edges;

means including input leads connected to said plates by which to charge said plates to potentials of opposite polarity;

a movable conductive plate adapted to be moved along said stationary plates to be capacitively coupled to either of said plates, said movable plate being movable across said gap, said movable plate when spanning said gap being charged to a potential corresponding to the differences between the portions thereof confronting the respective stationary plates;

a further stationary conductive plate which is not capacitively coupled to said movable plate;

an output lead connected to said further stationary plate;

a second movable conductive plate movable along said further stationary plate and capacitively coupled thereto, the spacing and capacitive coupling between said further stationary plate and second movable plate being constant in all positions of said second movable plate;

a direct electrical connection between said movable plates;

and means for moving said movable plates in unison.

12. The combination of claim 11, wherein the plates of said pair having flat coplanar surfaces, said first movable plate having a flat surface confronting and parallel to the flat surfaces of the plates of said pair, and said second movable plate and said further stationary plate having confronting parallel surfaces disposed at right angles to the confronting surfaces of said first movable plate and the plates of said pair.

13. The combination of claim 12, wherein said second movable plate and said further stationary plate are concentric cylinders, the ends of said cylinders lying in planes parallel to the confronting surfaces of said first movable plate and the plates of said pair.

14. The combination of claim 13, including a cylindrical body of non-conductive material, the inner cylinder being supported on the lateral surface of said body, said first movable plate being supported on one end of said body;

a shaft element on the axis of said body, said shaft element at one end being embedded in the end of said body opposite said first movable plate;

a housing surrounding said body;

means supporting said body and said shaft for rotation in said housing;

the outer cylinder being supported in said housing;

a non-conductive substrate supporting the plates of said pair, said substrate being supported in said housing; and said input leads and said output lead connected to the plates of said pair and to said outer cylinder extending to the exterior of said housing.

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