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3,113,261

VOLTAGE DIVIDER OF THE INDUCTIVE TYPE

Filed May 11, 1962

3 Sheets-Sheet 1

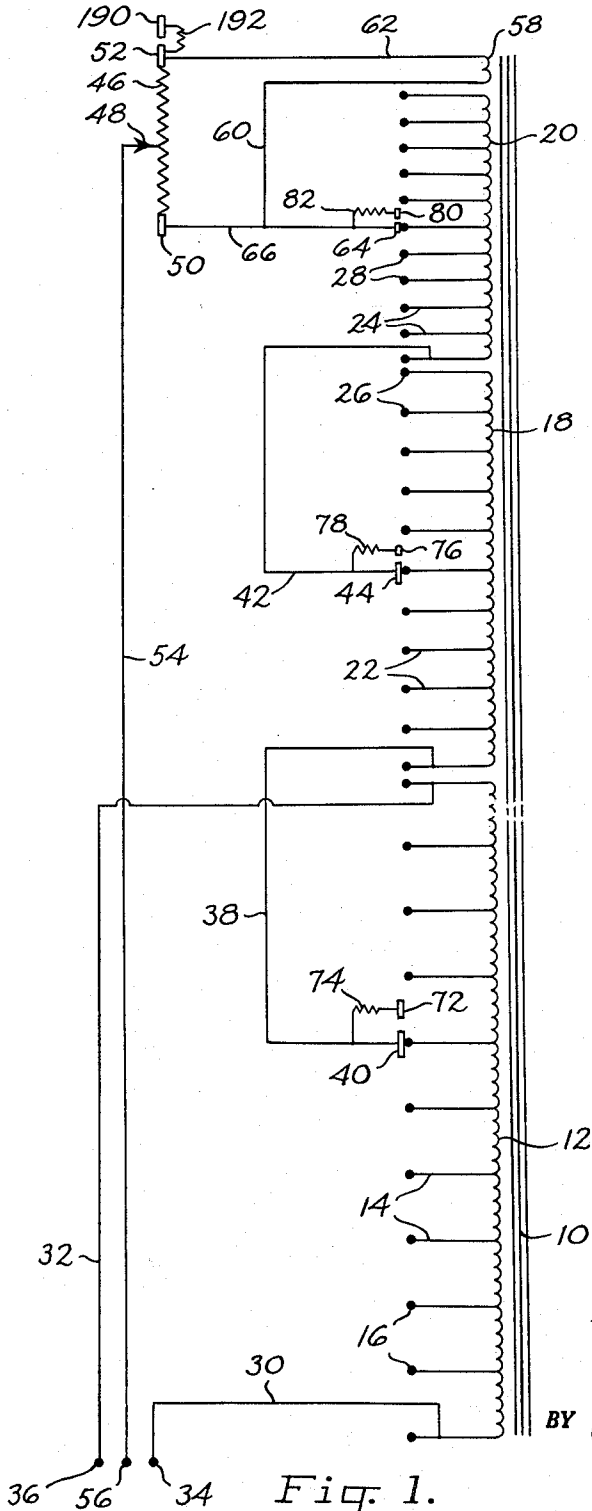


Fig. 1.

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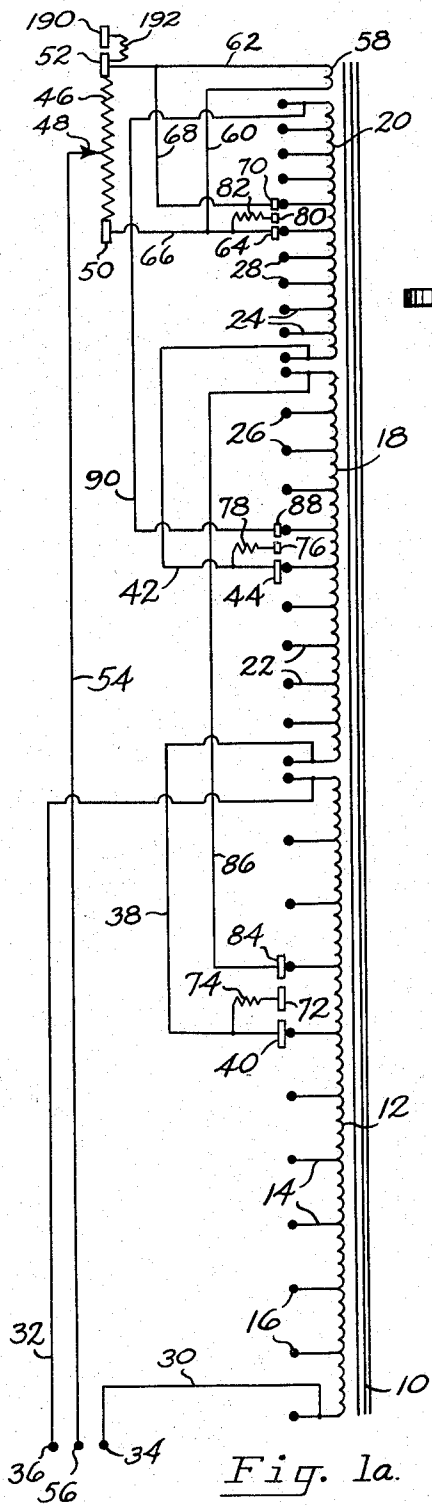
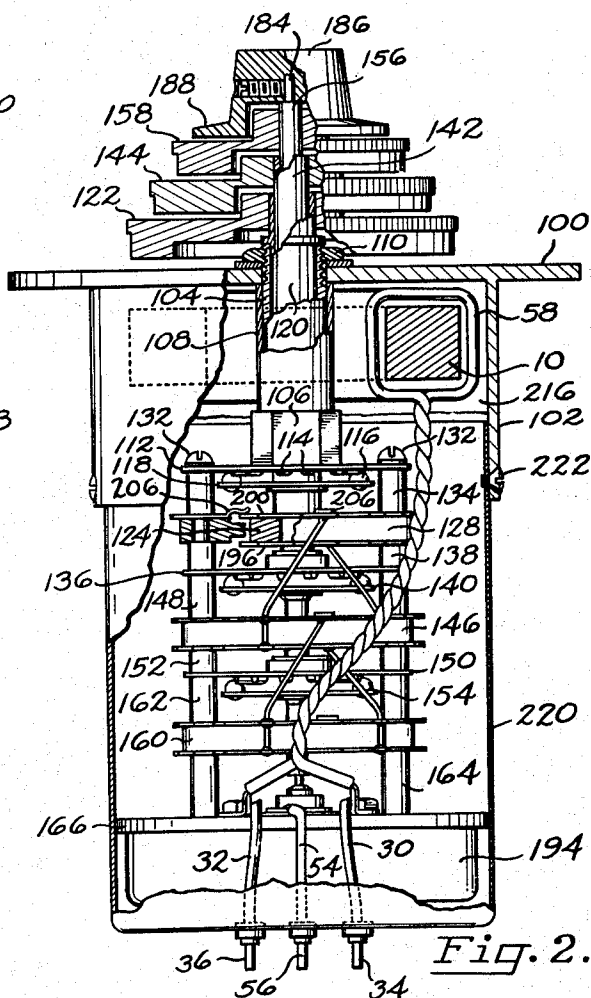
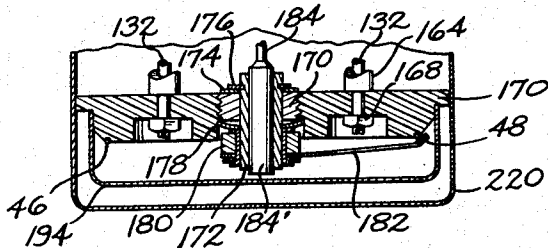
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Fig. 4.

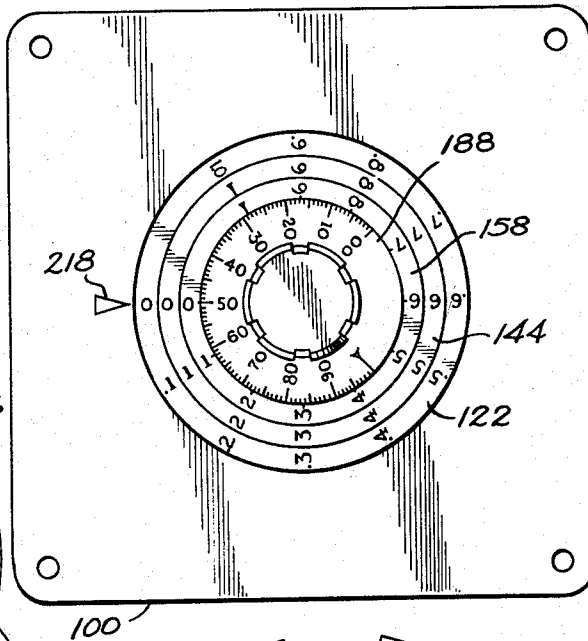
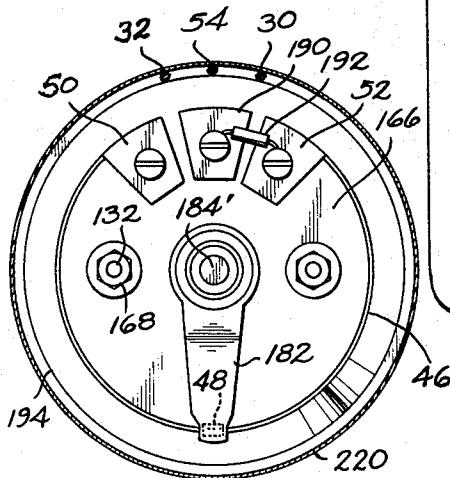


Fig. 5.

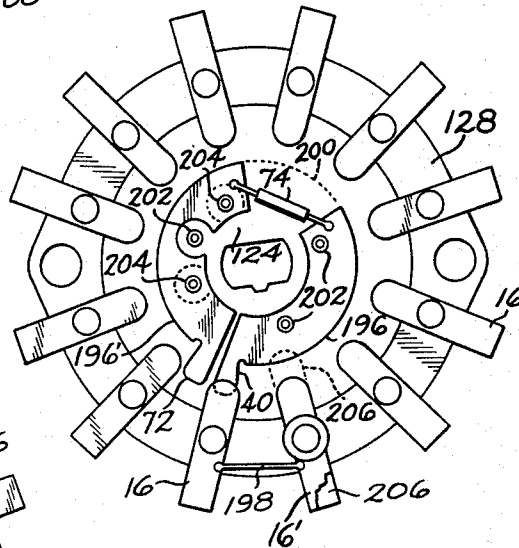


Fig. 6.

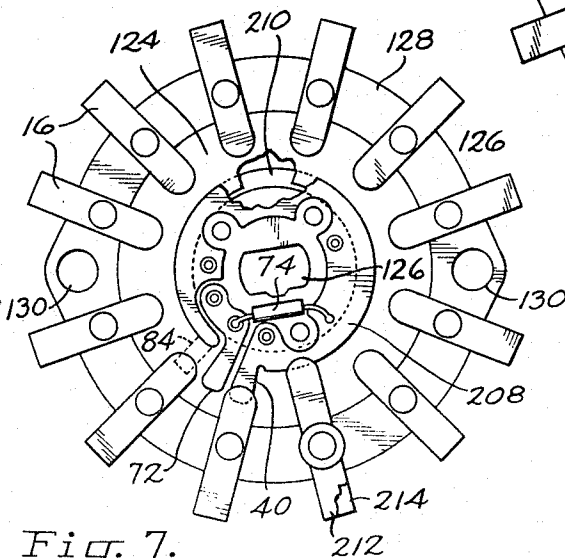


Fig. 7.

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3,113,261

VOLTAGE DIVIDER OF THE INDUCTIVE TYPE

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Continuation of application Ser. No. 751,247, July 23, 1958. This application May 11, 1962, Ser. No. 195,661
10 Claims. (Cl. 323—43.5)

This invention pertains to voltage dividers, and relates particularly to adjustable, calibrated voltage dividers of the inductive type. This invention represents an improvement over the mechanical and electrical arrangements disclosed in U.S. Patent No. 2,707,222.

This application is a continuation of application Serial Number 751,247, filed July 28, 1958 and now abandoned.

It is a principal object of the present invention to provide an inductive voltage divider of improved structural design and superior performance characteristics.

Another important object of this invention is the provision in an inductive voltage divider of novel means for reducing output impedance, enabling the device to be used at high currents with maximum accuracy.

A further important object of this invention is the provision of an inductive voltage divider which includes novel means for reducing switching transients to a minimum.

Still another important object of the present invention is the provision of an inductive voltage divider of compact construction, affording maximum ease and versatility of incorporation as a component of other instruments.

A further important object of this invention is the provision of an inductive voltage divider affording maximum facility of operation by means of a coaxial drive system.

A still further important object of the present invention is to provide a novel potentiometer construction for use in voltage dividers.

The foregoing and other objects and advantages of this invention will appear from the following detailed description, taken in connection with the accompanying drawings, in which:

FIG. 1 is a schematic diagram of an electric circuit illustrating a series arrangement of an inductive voltage divider embodying features of this invention.

FIG. 1a is a schematic diagram of an electric circuit illustrating a parallel arrangement of an inductive voltage divider embodying features of this invention;

FIG. 2 is a plan view, partly in section, of a structural assembly accommodating the electric circuits shown in FIGS. 1 and 1a and embodying features of the present invention;

FIG. 3 is a fragmentary sectional view of the lower portion of the assembly shown in FIG. 2;

FIG. 4 is a front view of the structural assembly, as viewed from the top in FIG. 2;

FIG. 5 is a rear end view, partly in section, of the structural assembly shown in FIG. 2;

FIG. 6 is a plan view of a wafer switch assembly embodying features of the present invention and forming a part of the structural assembly shown in FIG. 2; and

FIG. 7 is a fragmentary plan view of a modified form of wafer switch assembly adapted to form a part of the structural assembly shown in FIG. 2.

Referring to FIG. 1 of the drawings, there is shown for illustration the circuit diagram of a three decade inductive voltage divider, including the transformer core 10 upon which successive inductive windings are wound, thereby providing a common flux path linking all of the windings. A plurality of tap leads are connected to each of the inductive windings, every predetermined

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number of turns. Thus, the winding 12 is provided with the space tap leads 14 which, as explained more fully hereinafter, are connected to spaced switch contacts 16. In similar manner, the windings 18 and 20 are provided with spaced tap leads 22 and 24, respectively, connected to spaced switch contacts 26 and 28, respectively.

The terminal ends or, if desired, any intermediate spaced points on the first inductive winding 12, are connected through electrical conductors 30 and 32 to the terminal posts 34 and 36, respectively. One end, or, if preferred, any intermediate point on the second winding 18, is connected through conductor 38 to the brush 40 which is arranged for selective engagement with the switch contacts 16 to which are connected the tap leads of the first winding 12. In similar manner, one end or any intermediate point on the third winding 20 is connected through conductor 42 to the brush 44 arranged for selective engagement with the switch contacts 26 to which are connected the tap leads of the second trans-

former winding 18. In the embodiment illustrated there is provided a final stage interpolating voltage divider, in the form of a potentiometer resistance element 46 and the associated brush 48, the resistance element and brush being arranged for relative movement. The spaced ends of the resistance element are connected to terminals 50 and 52, and the brush is connected through conductor 54 to the terminal post 56.

A particularly important feature of the present invention involves the provision of an inductive winding 58 of very low resistance, wound on the core 10 and connected across the terminals 50, 52 of the resistance element to provide the voltage for the latter. This winding may be provided as a single winding or as a plurality of windings of equal turns connected in parallel to provide several current paths distributed to minimize leakage reactance. In the design illustrated this winding is provided in the form of a single turn. Since this winding is connected permanently across the resistance element, as by means of the conductors 60 and 62, full voltage is supplied to the potentiometer at all times, even during switching along the tapped sections of the windings. In addition, this permanent winding furnishes all of the current drawn by the potentiometer resistance, thus avoiding the disadvantage attending the drawing of current from the tapped windings through switch contacts. In this manner the potentiometer resistance may be very small, providing minimum voltage change at the potentiometer brush when current is drawn through the latter.

When the permanently connected winding 58 is employed, one end or any intermediate point thereon is connected, conveniently through conductor 60, to the brush 64 arranged for selective engagement with the switch contacts 28 to which are connected the tap leads of the third inductive winding. In the event this permanent winding is not employed, this brush 64 is connected through the conductor 66 to one terminal end 50 of the potentiometer resistance, and the opposite terminal 52 is connected through the conductor 68 to a second brush 70, spaced from the first brush 64 and arranged for selective engagement with the contacts 28, in the manner of the parallel arrangement shown in FIG. 1a and discussed hereinafter.

Another important feature of this invention resides in the provision of means for reducing switching transients to a minimum. To this end there is provided an auxiliary brush and an impedance element associated with each of the main brushes described hereinbefore. Thus, the auxiliary brush 72 is associated with the main brush 40, forming a pair of spaced brushes associated with the

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first inductive winding 12. The brushes forming this pair are so proportioned and arranged with respect to the spaced contacts 16, that one of them always engages a contact before the other disengages from another contact, during relative movement of the brushes and contacts of the switch. The auxiliary brush is connected through an impedance element, such as the resistor 74, to any desired point on the second winding 18. In the embodiment illustrated, this point of connection is conveniently chosen as the same point of connection of the conductor 38, and hence the resistor simply interconnects the spaced brushes 40, 72 of the pair.

In similar manner, the auxiliary brush 76 is associated with the main brush 44 on the switch of the second winding 18, and is connected through the resistor 78 to any desired point on the third winding 20. In like manner, the auxiliary brush 80 is associated with the main brush 64 on the switch of the third winding 20 and is connected through the resistor 82 to any desired point on the permanently connected winding 58. It will be understood that if this permanently connected winding is not employed, the resistor 82 will be arranged to connect the auxiliary brush 80 to either end of the potentiometer resistance 46, or any intermediate point thereon.

It is to be noted in the embodiment illustrated that each of the auxiliary brushes is positioned immediately adjacent its associated main brush, so that the pair is capable of engaging adjacent spaced contacts. It will be understood, of course, that the auxiliary brush may be spaced farther from its associated main brush, in order for the pair to engage spaced contacts which are not adjacent. It is important, in any event, that each pair of brushes be so arranged that one of them always engages a contact before the other brush disengages from another contact, and that one brush remain engaged with its contact until the other brush engages the next adjacent contact.

By use of the non-shorting pairs of brushes in the manner explained, shorting of any section of any winding is avoided, and corresponding excessive circulating currents are prevented. By use of the impedance elements in the manner described, circulating current developed during switching is limited to a point of relative insignificance, and the voltage at the terminal 56 is maintained in the vicinity of the voltages between which it is being switched. In this regard the value of the impedance should be high enough to limit the circulating current to a desired degree when the impedance is shunted across a winding, and yet low enough to minimize the voltage drop due to any current drawn through the terminal 56 when the impedance element is the only connection providing continuity between windings.

It is to be noted that the electric circuit described hereinbefore produces a series connected arrangement of succeeding inductive windings, and provides a voltage divider of high quality with a minimum of structural complication and cost. A shunt arrangement of successive windings offers the advantage of somewhat lower output impedance, and may be provided with a minimum of additional structural complication and cost. Referring to FIG. 1a, a shunt arrangement is provided by the addition of a second main brush associated with each first main brush, and connecting each second main brush to a spaced point on the next succeeding winding.

Thus, a second main brush 84 is arranged for association with the first main brush 40 on the switch of the first winding 12, and this second main brush is connected through conductor 86 to any point on the second winding 18 which is spaced from the point of connection of the conductor 38 leading to the first main brush 40. It will be understood, of course, that the number of turns of the second winding 18 between the points of connection of the conductors 38 and 86 must be equal to the number of turns on the first winding 12 between the tap contacts 16 engaged by the spaced main brushes 40 and 84.

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In similar manner, the second main brush 88 is associated with the first main brush 44 on the switch of the second winding 18, and this second main brush is connected through the conductor 90 to any desired point on the third winding 20 spaced from the point of connection of the conductor 42 leading to the associated first main brush 44.

The second main brush 70 associated with the first main brush 64 on the switch of the third winding 20, was previously described as functioning in cooperation with the first main brush to connect the opposite ends of the potentiometer resistance 46 selectively to any spaced pair of contacts 28, in the event the permanently connected winding 58 was not employed. For the purpose of the presently described shunt arrangement, this second main brush serves the same function when the permanently connected winding is not employed. However, when the permanently connected winding is employed, this second main brush is connected through the conductor 68 to any desired point on the permanently connected winding spaced from the point of connection of the conductor 60 leading to the first main brush 64.

Referring now particularly to FIG. 2 of the drawings, there is shown for illustration a preferred structural assembly adapted to accommodate either of the circuit arrangements described hereinbefore. The assembly includes a front panel 100 and a cylindrical hollow shell 102 secured thereto and projecting rearwardly therefrom. The panel and shell may be formed as an integral unit, as illustrated, or they may be provided as separate pieces secured together by screws or other means. The material of which the panel and shell are made may be aluminum or other suitable metal, or may be a synthetic thermoplastic or thermosetting resin. Alternatively the material may be characterized by having high magnetic permeability in order to shield the transformer against external magnetic fields.

The panel is provided with a central opening to receive freely therethrough the forward end of a hollow bushing 104, the rearward end of which is enlarged to form a head 106. A spacer sleeve 103 is mounted on the bushing between the head and the panel, and the forward end of the bushing is threaded to receive the securing nut 110 by which the bushing is anchored to the panel.

To the rearward end of the housing head is secured the transverse plate 112 which, in the embodiment illustrated, is a detent plate provided with a plurality of circumferentially spaced projections 114 forming therebetween spaced detent pockets adapted to receive one or more detent balls 116. The detent balls are held resiliently adjacent the detent plate by a resilient ball carrier plate 118 provided with an opening for each ball. The opening is smaller than the diameter of the ball, whereby to form a socket in which to confine the ball.

The ball carrier plate is secured to a hollow shaft 120, intermediate the ends of the latter. The shaft extends forward through the hollow bushing and mounts the circular dial 122 at its forward end. The shaft also extends rearward from the ball carrier plate for engagement with the central rotary section 124 of a wafer switch, preferably one of the types illustrated in FIGS. 6 and 7. As is well known, such connection generally is made by providing a non-circular end on the shaft for reception in the non-circular opening 126 in the rotary section. The rotary section is received freely within a central opening in the stator section 128 of the switch, and projecting collector rings overlap the sides of the stator to support the rotary section therein, as explained more fully hereinafter.

The stator is provided with a pair of laterally spaced openings 130 through which to receive the mounting screws 132, one end of which are supported by the detent plate 112. Spacer sleeves 134 are mounted on the screws to properly space the stator from the detent plate.

A second detent plate 136 is supported upon the

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screws, in rearwardly spaced relation to the stator 128, by means of spacer sleeves 138. Associated with the second detent plate is a resilient ball carrier plate 140, secured to a second hollow shaft 142 intermediate the ends of the latter. The shaft extends forward through the hollow shaft 120 and mounts a second dial 144 at its forward end. The shaft also extends rearward for connection to the rotary section of a second wafer switch, the stator 146 of which is mounted upon the screws and spaced from the detent plate 136 by means of the spacer sleeves 148.

Similarly, a third detent plate 150 is mounted upon the screws and spaced from the second stator 146 by means of the spacer sleeves 152. Associated with the third detent plate is a resilient ball carrier plate 154 secured to a third hollow shaft 156 which extends forward through the hollow shaft and mounts the third dial 158 at its forward end. The third hollow shaft also extends rearward for connection to the rotary section of a third wafer switch, the stator 160 of which is supported upon the screws and spaced from the detent plate 150 by means of the spacer sleeves 162.

Also mounted upon the screws and spaced rearwardly from the third stator by means of the spaced sleeves 164, is an electrically non-conductive plate 166. As best shown in FIG. 3, the rearward ends of the screws 132 extend through the plate and are threaded for the reception of nuts 168 by which the components of the entire assembly mounted on the screws are releasably secured together.

A central tapped opening is provided in the plate 166 for securing therein the threaded hollow bushing 170 of electrically conductive material. Mounted rotatably within the hollow bushing is a sleeve 172 of electrically non-conductive material. The sleeve is constrained against longitudinal movement by means of the washer 174 and keeper ring 176 positioned adjacent the forward end of the bushing, and by the electrically conductive collector ring 178 which is pressed onto the sleeve and slidably engages the rearward end of the bushing. The hub 180 of a radially extending electrical brush arm 182 is secured to the collector ring 178 intermediate the ends of the latter, and the rearward end of the collector ring is swaged over to secure the parts together.

Secured within the sleeve is the rearward end 184' of a shaft 184 which extends forward through the hollow shaft 156 and mounts the combination control knob 186 and dial 188 at its forward end.

Mounted on the electrically non-conductive plate 166 for sliding engagement of the brush element 48 of the arm 172 is the potentiometer resistance element 46, preferably in the form of a split turn of a single length of wire. The resistance range of the element is established by the spaced terminals 50 and 52 which are secured to the plate. As best shown in FIG. 5, an electrically conductive plate 190 is interposed between and spaced slightly from the terminals, the gaps being smaller than the contact width of the potentiometer brush 48 whereby the latter may bridge them during rotation. An impedance element, such as the resistance 192, preferably interconnects the plate 190 and any point on the potentiometer resistance, conveniently one of the terminals, such as terminal 52, as shown. If desired, a second resistance may interconnect the plate 190 and the other terminal 50. The impedance element performs a function analogous to the impedance elements 74, 78 and 82 previously described.

The potentiometer assembly preferably is provided with an enclosing dust cap 194 which is secured frictionally to the plate 166 by the provision of a shoulder section: in the latter, as best illustrated in FIG. 3.

Referring now particularly to FIG. 6 of the drawings, there is shown a wafer switch adapted for use in the structural assembly of FIG. 2 and especially suited for the series arrangement of inductive windings previously de-

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scribed. Each switch stator, for example the stator 128, is provided with a plurality of circumferentially spaced electrical contacts 16 mounted on one side of the stator, with their inner ends disposed for engagement by the brushes 40 and 72. These brushes extend radially from the collector ring segments 196 and 196', respectively, which are electrically isolated from each other and positioned on the same side of the rotary section 24 as the contacts 16. A circular collector ring 200 is positioned on the opposite side of the rotary section and is connected electrically to the segment 196, conveniently by means of the rivets 202 which secure these elements to the rotary section. The segment 196' is secured to the rotary section by rivets 204 which are isolated from the ring 200. A connector 206 is mounted on the stator with its inner end slidably engaging the collector ring 200. Mounting of the connector 206 is achieved conveniently by use of the rivet securing one of the contacts 16', it being understood that the contact and connector are isolated electrically from each other by appropriate insulation.

The collector ring segments 196 and 196' are interconnected by the resistor 74.

It is to be noted that the brushes 40 and 72 are so proportioned and arranged in the embodiment illustrated, that when the rotary section 124 is oriented by the associated detent assembly, with the ball 116 disposed in one of the detent sockets, the main brush 40 is in electrical engagement with one of the contacts 16 while the auxiliary brush 72 is disposed between, and out of electrical engagement with, adjacent contacts. Further, the arrangement is such that one of the brushes always engages a contact before the other brush disengages from its contact and remains engaged with its contact until the other brush engages the next adjacent contact.

It is to be noted further that the contacts 16 are spaced symmetrically about the stator for engagement by the brushes. Assuming that the contacts separated by the contact 16' are at the ends of a winding, the contact 16' may be connected electrically to one or the other of these end contacts, as by the conductor 198, to provide for continuous rotation of the brushes without breaking electrical continuity. Alternatively, all twelve contacts may be employed if the winding is provided with twelve tap leads. If the winding has fewer tap leads than the number illustrated, the excess contacts may be connected together electrically, as in the manner of the conductor 198, to maintain continuity.

Referring now to FIG. 7 of the drawings, there is shown a modified form of wafer switch adapted for use in the structural assembly of FIG. 2 and especially suited for use with the shunt arrangement of inductive windings described hereinbefore. In this embodiment the contacts 16 are arranged in pairs on opposite sides of the stator, the contacts of each pair being connected together electrically as by means of their common securing rivet.

The collector ring 208 carrying the brush 40 is split circumferentially, with the ends spaced apart sufficiently to provide room for the auxiliary brush 72 which is secured to the rotary section 124 and electrically insulated from the collector ring 208 and brush 40. The brushes 40 and 72 are so arranged that, when the rotary section is oriented by its associated detent assembly, with the detent ball 116 confined in a socket, the main brush 40 is in electrical engagement with one of the contacts 16 while the auxiliary brush 72 is disposed between, and out of electrical engagement with, adjacent contacts. The second main brush 84 projects from the collector ring 210 mounted on the opposite side of the rotary section for engaging the contacts 16 on that side of the switch. The electrically isolated connectors 212 and 214 are mounted on opposite sides of the stator, with their inner ends slidably engaging the collector rings 208 and 210, respectively.

The main brushes 40 and 84 are arranged to make sub-

stantially simultaneous engagement with any two circumferentially spaced contacts 16. All of the brushes are proportioned and arranged in such manner that, during rotation of the rotary section 124 in either direction, the auxiliary brush 72 always engages the next adjacent contact 16 before both or the later of the main brushes disengages from their respective contacts, and the auxiliary brush remains engaged until at least one of the main brushes engages the next adjacent contact.

When used with the wafer switch assembly of FIG. 7, the impedance element 74 conveniently interconnects the auxiliary brush 72 and the main brush 40 located on the same side of the rotary section 124, as illustrated.

Referring now to FIG. 2 of the drawings, the transformer assembly illustrated is provided in the form of a ring-shaped core 10, preferably of material characterized by having high magnetic permeability in order that the voltage ratio be equal to the turns ratio, with a minimum of error, thus achieving maximum accuracy of voltage ratio. About this core are helically wound a plurality of turns of wire to provide the inductive windings such as those illustrated in FIGS. 1 and 1a. Thus, the first winding 12 is formed by winding a length of wire helically about the core and connecting a tap lead 14 to the winding every predetermined number of turns. The second and third interpolating windings 18 and 20, respectively, are formed in similar manner by winding separate lengths of wire concentrically about the core and connecting tap leads 22 and 24, respectively, every predetermined number of turns. The tap leads on each winding are connected to the circumferentially spaced contacts on the stator of separate wafer switches for electrical association with the winding next succeeding, as previously explained. A single turn of heavy wire 58 is looped about the core and connected permanently at its ends to the spaced terminals 50 and 52 of the potentiometer resistance 46.

In the embodiment illustrated in FIG. 2, the ring-shaped transformer assembly conveniently is positioned within the hollow cylindrical shell 102, with the concentric shafts of the switch assembly extending through the central opening of the transformer assembly. A quantity of electrically non-conductive material 216, such as epoxy resin, is filled into the cavity of the shell to completely surround the transformer assembly and to anchor the same in place. In the case of epoxy resin, this material is poured into the cavity while in a liquid state, and then treated in well known manner to effect setting of the resin.

By means of the foregoing structural arrangement, the various positions of engagement of the brush 48 with the potentiometer resistance 46, and the various positions of interconnection of the inductive windings through the employment of the spaced brushes with the contacts associated with each wafer switch, may be read directly upon the concentric dials. Accordingly, these dials may be provided with graduated scales, such as are illustrated in FIG. 4, and an index mark 218 may be provided on the plate 100 for the dial assembly.

The switch assembly is enclosed by such means as the cylindrical container 220, the open end of which is received within the cylindrical shell and secured thereto by means of screws 222. The insulating plate 166 fits closely within the container and functions conveniently to support the rear end of the switch assembly and to provide an insulating spacer between the container and the switch assembly. In this regard it is important that a conducting path linking the core be avoided in order to prevent short circuiting the transformer turns. Thus, alternatively, the container may be omitted or may be made of electrically non-conductive material, or the plate 100 may be made of electrically non-conductive material, or the switch assembly merely supported from the plate 100 in spaced relation to the container.

Although the voltage divider of this invention may take various forms, including various numbers of in-

ductive windings, the following is illustrative of a typical assembly: The first winding 12 is formed by winding 1,000 turns of copper wire upon a ring-shaped core 10. The 1,000 turns are tapped every 100 turns. The second winding 18 is formed by winding 100 turns of copper wire over the first winding, and tapping at every 10 turns. The third winding 20 is formed by winding 10 turns of copper wire over the second winding and tapping at every turn. The low resistance permanently connected winding 58 is formed by a single turn of copper wire or strap, and the resistance element 46 of the potentiometer is formed by a single split turn of wire having a total resistance between the terminals 50 and 52, of about 1 ohm. Each of the resistance elements 74, 78 and 82 associated with the switch brushes has a resistance of about 1,000 ohms, and the resistance element 192 associated with the spaced terminals of the potentiometer resistance, has a resistance of about 10 ohms.

The operation of the device as described hereinbefore is as follows: Referring to FIG. 1, if a voltage input is applied between terminal posts 34 and 36 the voltage appearing between terminal posts 34 and 56 will be the output voltage. Assuming the illustrative values of the above described typical assembly, in which the numbers of turns on successive windings are related in ratios of 10 to 1, the voltages between successive spaced taps 14 on winding 12 will each be 0.1 of the input voltage; the voltages between successive spaced taps 22 on winding 18 will each be 0.01 of the input voltage; and the voltages between successive spaced taps 24 on winding 20 will each be 0.001 of the input voltage. The voltage applied to the interpolating voltage divider 46 by winding 58 will also be 0.001 of the input voltage.

Thus, with the settings illustrated in FIG. 1, the voltage between terminal post 34 and brush 40 will be 0.6 of the input voltage; the voltage between brushes 40 and 44 will be 0.05 of the input voltage; and the voltage between brushes 44 and 64 will be 0.005 of the input voltage. Assuming that brush 48 on winding 46 is set so that the resistance between terminal 50 and brush 48 is 0.45 of the total resistance between terminals 50 and 52, the voltage between terminal 50 and brush 48, and therefore also between brush 64 and terminal post 56, will be 0.00045 of the input voltage.

The output voltage between terminal posts 34 and 56 therefore will be 0.65545 of the input voltage, and this value will be indicated on the dial assembly at the index mark 218. Thus, for any setting of the various dials, the ratio of the output voltage to the input voltage will be indicated directly on the dial assembly.

In order to maintain high accuracy of voltage ratio when an output current is drawn between terminal posts 34 and 56, it is necessary that the output impedance of the divider be kept as low as possible. This is achieved in the present invention in part by minimizing the resistance of potentiometer winding 46. In order to provide an accurate voltage across this low resistance, it is necessary that its source of voltage have a very low impedance. Thus a separate winding 58 has been provided, and it is connected directly to the potentiometer. The use of this separate winding provides the two-fold advantage that it can be wound of heavier wire than the other windings and that its direct connection to the potentiometer avoids the interposition of switch resistances.

The operation thus far described relates to both the series and shunt arrangements.

As stated hereinbefore, the output impedance of the device is determined in part by the resistance of the interpolating potentiometer winding 46 and transformer winding 58. The output impedance is also affected by the resistance of windings 12, 18 and 20. This contribution to the output impedance is reduced in the shunt arrangement, as compared with the series arrangement.

The voltage ratio of the device may be changed by appropriate manipulation of the dial assembly. For ex-

ample, assume it is desired to change the voltage ratio from 0.65545, as illustrated hereinbefore, to 0.65645. This involves rotation of dial 158 to the next detent position of its associated switch, and it effects a change of 0.001 of the input voltage. It is clearly desirable that during this change the output voltage should not exhibit a transient change appreciably larger than 0.001 of the input voltage. Resistor 82 and brush 80 are provided in order to permit this magnitude of switching without incurring a transient voltage change of greater magnitude.

The following description of switching refers to the shunt arrangement illustrated in FIG. 1a, and the switching of the series arrangement is identical with the exception that brush 70 is omitted. As dial 158 is rotated, brush 80 will engage the contact 28 shown occupied by brush 70 before contact disengagement of brushes 64 and 70. Resistor 82 thus is connected across the adjacent contacts 28. The value of this resistor is chosen high enough that the voltage of the section of winding 20 across which it is connected is not disturbed, and that the input impedance of the voltage divider is not seriously lowered.

As the dial 158 is rotated further, brushes 64 and 70 next disengage from their contacts while contact 80 remains engaged. When contacts 64 and 70 disengage, the voltage at terminal 50 changes from 0.655 to 0.656 of the input voltage. Resistor 82 now appears in series with the output impedance of the divider, and accordingly its value is chosen low enough to minimize the effect of output loading on output voltage.

As the dial 158 is rotated further, brushes 64 and 70 engage the contacts 28 toward which they have been moving, before brush 80 disengages. As soon as either of the brushes 64 and 70 has engaged a contact, the resistor 82 is effectively shorted and its resistance removed from the output impedance of the divider. Finally, as the rotation of dial 158 to its detented position is completed, brush 80 disengages while brushes 64 and 70 remain engaged.

From the foregoing, it is apparent that the value of resistor 82 is chosen as a compromise between the extreme conditions in which either the transformer is short circuited or its output is open circuited. The value of resistor 82 may be varied over a considerable range, depending upon the relative importance of keeping the output impedance of the divider low versus keeping the input impedance of the divider high, during switching. It is apparent that the function of resistors 74 and 78 is similar.

The function of resistor 192 and conductive plate 190 is to permit continuous rotation of contact 48 across the end terminals of the potentiometer without incurring either a short circuit or an open circuit transient, in manner analogous to the function of the resistors 74, 78 and 82 and their associated brushes and contacts.

Various modifications and changes may be made in the types, numbers and arrangement of parts described hereinbefore. For example, the resistance elements 74, 78, 82 and 192 may be replaced with other forms of impedances, such as capacitive or inductive impedance elements. The potentiometer resistance may be replaced with various other types of interpolating voltage divider means, such as an inductive or capacitive voltage divider, an amplifier, or another complete voltage divider assembly such as the type described herein.

Additional main or auxiliary brushes may be provided on each switch in the manner previously explained for connecting additional points of a succeeding winding to other tap connections of a preceding winding. These additional brushes, as well as the brushes earlier described, may be supported upon separate switches forming a switch assembly for each winding, each assembly being operated by a separate shaft. The concentric shafts may be operated independently, as described, or end stops may be provided on the shafts or switch assemblies for sequential operation by the control knob 186.

The order of physical placement of the windings on the core as described hereinbefore may be varied, and sections of various windings may be intermixed, as desired. Additional windings may be employed, including a separate primary winding and additional tapped windings and switches for simultaneously providing various terminal voltages.

The ring shape for the core 10 is intended to include square or other non-circular configurations having a hollow center. Although the ring-shaped assembly and the rotary switch assemblies and associated concentric shafts, illustrated and described hereinbefore, are preferred for the compactness of design and ease of operation afforded thereby, other arrangements using rectilinear transformer assemblies and other switching components, may be employed.

It is to be understood that the divider of this invention may be employed as a calibrated current divider as well as a voltage divider, and that reference in the appended claims to voltage dividers is intended to include operation as a current divider.

In this case the input current is applied between terminal posts 34 and 56 and the output current is drawn between terminal posts 34 and 36. Since, in the current divider mode of operation, the input and output terminal posts, and hence the input and output impedances, are interchanged with respect to the voltage divider mode of operation, the resistors 74, 78, 82 and 192 now serve to prevent open circuiting the input or short circuiting the output of the divider.

It will be understood further that the concept of voltage division and interpolation is intended herein to include those cases in which interpolation is made of voltages between spaced points and also in which extrapolation is made of voltages beyond the spaced points. For example, in the series arrangement of windings described hereinbefore, extrapolation of the voltage at the terminal 56 beyond the voltage at the terminal 36 is achieved when the brush 40 engages the uppermost tap contact 16. Further extrapolation is available by connecting the conductor 32 to the winding 12 inward of the upper end of the latter. As another example, extrapolation beyond the voltage between adjacent taps on the winding 20 is available by providing the winding 58 with more turns than the turns between the adjacent taps on the winding 20, or by substituting for the interpolating potentiometer 46 a voltage divider which inherently provides to the terminal 56 an output voltage which is greater than the input voltage supplied by the winding 58. This may be achieved, for example, by replacing the potentiometer with another complete voltage divider assembly.

The foregoing and other changes may be made, as desired, without departing from the spirit of this invention and the scope of the appended claims.

Having now described my invention and the manner in which the same may be used, what I claim as new and desire to secure by Letters Patent is:

1. A voltage divider comprising a core, a plurality of successive inductive windings associated with the core, each winding succeeding the first having a free end, a plurality of spaced tap leads on each winding, and conductor means connecting a single fixed point on each succeeding tapped winding spaced from the free end thereof selectively to a tap lead on the next preceding tapped winding for interconnecting at least portions of the windings in series.

2. A voltage divider comprising a core, an inductive winding associated with the core, a plurality of spaced tap leads on the winding, a pair of brush means arranged for relative movement with respect to the tap leads and spaced in such manner that one of them engages a tap lead before the other disengages from another tap lead, interpolating voltage divider means, conductor means interconnecting the interpolating voltage divider means and one of the brush means for interconnecting the voltage

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divider means and at least a portion of the winding in series, and impedance means inconnecting and interpolating voltage divider means and the other of the pair of brush means, whereby series continuity is maintained through the impedance means during transfer of the said one brush between tap leads.

3. The device of claim 2 including third brush means arranged to engage one tap lead when the conductor-connected brush means of the pair engages another tap lead, the third brush means being connected to a spaced point on the interpolating voltage divider means for interconnecting the voltage divider means and a portion of the winding in parallel.

4. A voltage divider comprising a core, a plurality of successive inductive windings associated with the core, a plurality of spaced tap leads on each winding, a pair of brush means arranged for relative movement with respect to the tap leads on each tapped winding and spaced in such manner that one of them engages a tap lead before the other disengages from another tap lead, conductor means interconnecting a fixed point on each succeeding tapped winding and one of the brush means associated with the next preceding tapped winding, impedance means connecting a fixed point on each succeeding tapped winding and the other brush means of the pair associated with the next preceding tapped winding, interpolating voltage divider means, a supply voltage winding on the core permanently connected to the interpolating voltage divider means, conductor means interconnecting a fixed point on the supply voltage winding and one of the brush means of the pair associated with the last succeeding tapped winding, and impedance means interconnecting a fixed point on the supply voltage winding and the other brush means of the pair associated with the last succeeding tapped winding.

5. The device of claim 4 including a third brush means associated with each pair of brush means and arranged to engage one tap lead when the conductor-connected brush means of the pair engages another tap lead, each third brush means being connected to a spaced point on the winding to which the associated pair of brush means is connected for interconnecting at least portions of the windings in parallel.

6. A voltage divider comprising a core, an inductive winding associated with the core, a plurality of spaced tap leads on the winding, interpolating voltage divider means, a second inductive winding associated with the core and permanently connected to the interpolating voltage divider means for supplying the voltage to be interpolated, and conductor means connecting at least one point on the second winding selectively to a respective tap lead on the tapped winding.

7. A voltage divider comprising a core, an inductive winding associated with the core, a plurality of spaced tap leads on the winding, a pair of brush means arranged for relative movement with respect to the tap leads and

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spaced in such manner that one of them engages a tap lead before the other disengages from another tap lead, interpolating voltage divider means, a second inductive winding associated with the core and permanently connected to the interpolating voltage divider means for supplying the voltage to be interpolated, conductor means interconnecting a fixed point on the second winding and one of the brush means for interconnecting at least portions of the windings in series, and impedance means interconnecting the second winding and the other of the pair of brush means.

8. The device of claim 7 including third brush means arranged to engage one tap lead when the conductor-connected brush means of the pair engages another tap lead, the third brush means being connected to a spaced point on the second winding for interconnecting at least portions of the windings in parallel.

9. A voltage divider comprising a ring-shaped core, an inductive winding on the core and having a plurality of spaced tap leads, a switch associated with the winding and having a fixed section and a movable section coaxial with the core, one section of the switch having a plurality of spaced contacts, the other section of the switch having a first brush means arranged for selective engagement with the associated contacts, the tap leads of the winding being connected to the spaced contacts of the switch, interpolating divider means connected to the first brush means, a second brush means on said other switch section forming with the first brush means a pair of spaced brush means with one of the pair always engaging a contact before the other of the pair disengages from another contact, impedance means interconnecting the second brush means and the interpolating voltage divider means, movable control means for the interpolating voltage divider means and arranged coaxial with the core, and drive means coaxial with the core and operatively connected to the movable section of the switch and control means.

10. The device of claim 9 including a third brush means associated with the pair of brush means and arranged to engage a different contact when the first named brush means of the pair of brush means engages another contact, the third brush means being connected to the interpolating voltage divider means at a point spaced from the connection of the first named brush means for interconnecting the voltage divider means and a portion of the winding in parallel.

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