

April 5, 1966

E. P. GERTSCH ETAL

3,244,966

MULTI-UNIT VARIABLE TRANSFORMER DEVICE

Original Filed Sept. 28, 1959

3 Sheets-Sheet 1

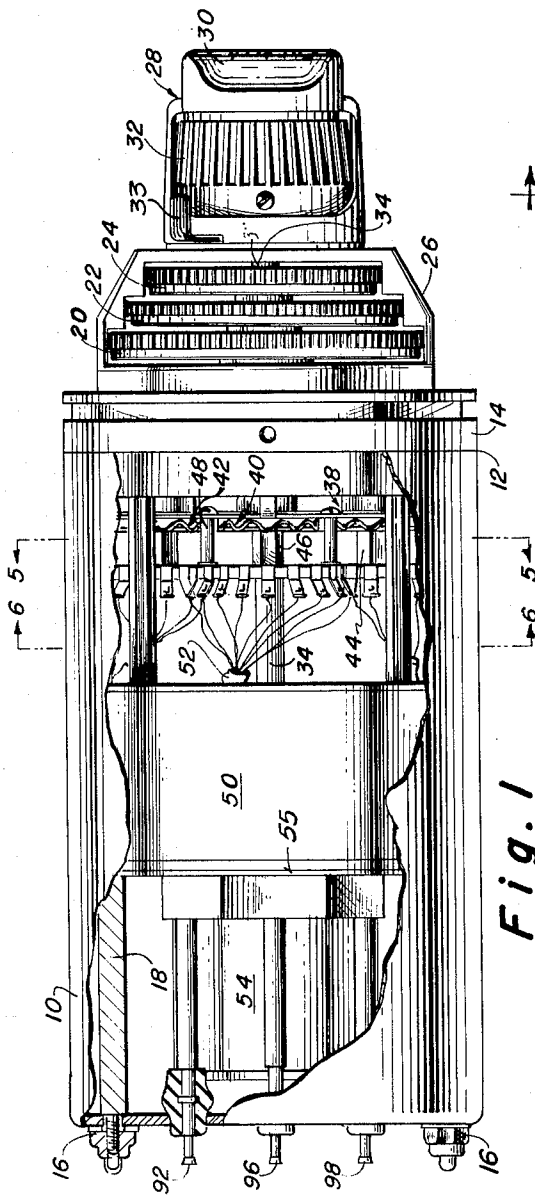


Fig. 1

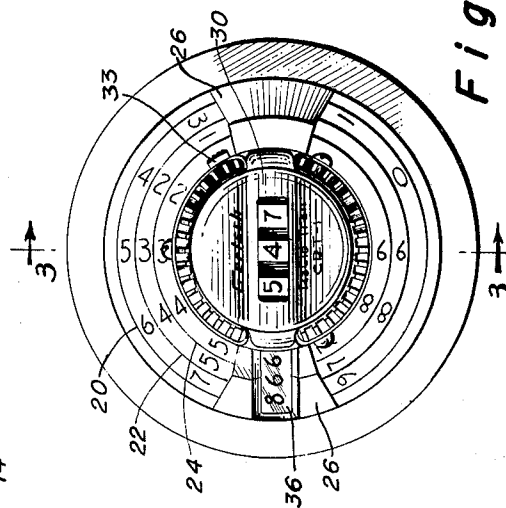


Fig. 2

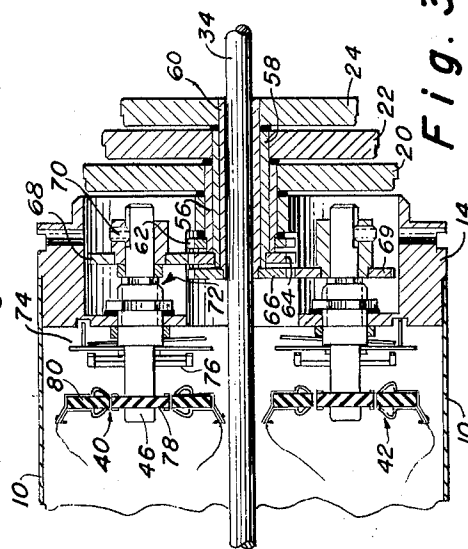


Fig. 3

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April 5, 1966

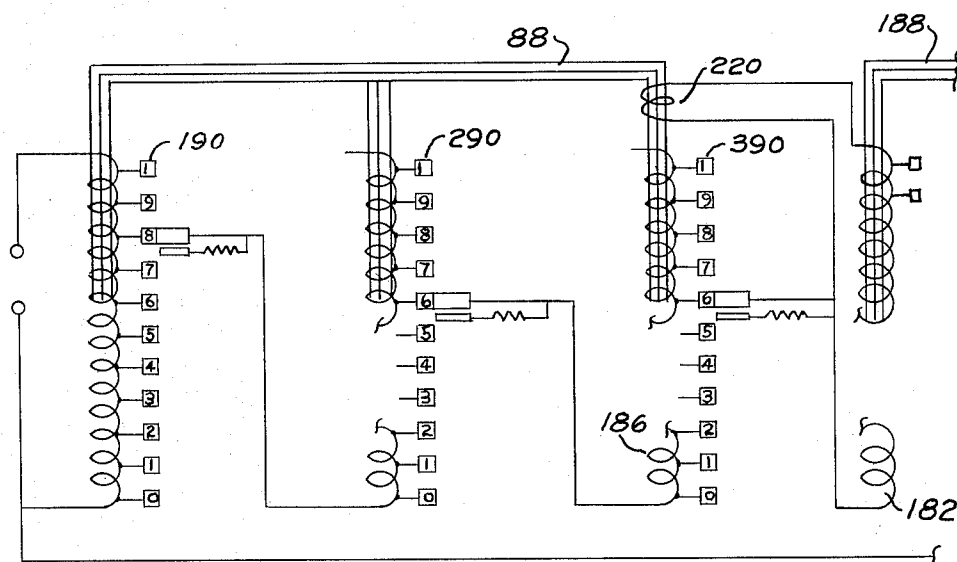
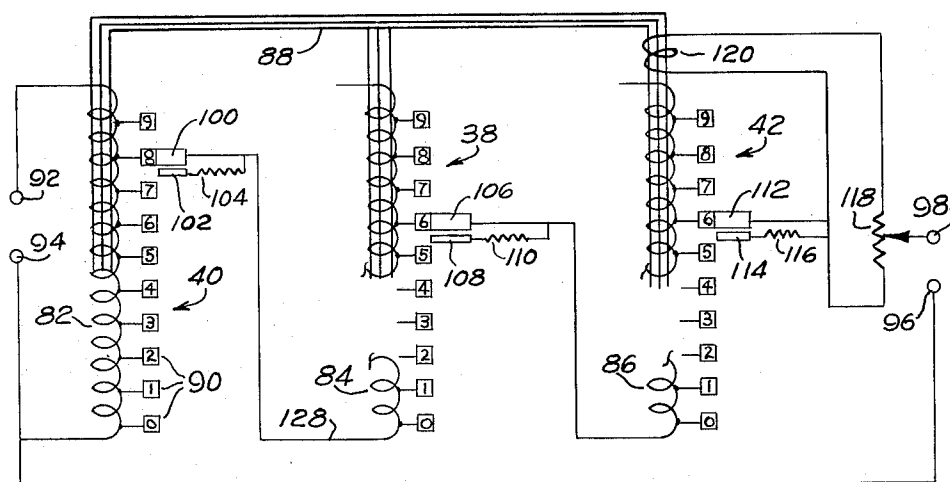
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3 Sheets-Sheet 3

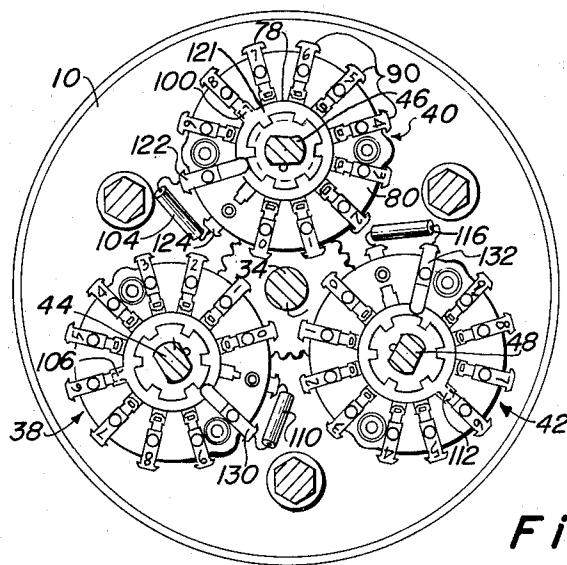


Fig. 5

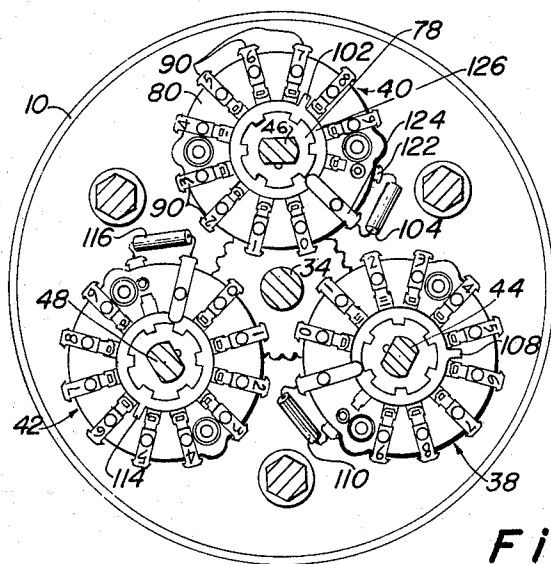


Fig. 6

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3,244,966

MULTI-UNIT VARIABLE TRANSFORMER DEVICE

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Continuation of application Ser. No. 842,770, Sept. 28, 1959. This application Oct. 4, 1962, Ser. No. 228,467
9 Claims. (Cl. 323—43.5)

This is a continuation of our prior application, filed September 28, 1959, Serial No. 842,770, now abandoned.

This invention pertains generally to variable electrical devices having a plurality of electrically variable units therein, and more particularly to such a device wherein each of the variable units includes an impedance element or the like having a plurality of taps thereon and an electrical switch connected thereto to provide means for connecting selectable taps to an output circuit.

While the present invention is applicable generally to any electrical device wherein a plurality of variable and manually adjustable rotary elements cooperate to produce a desired output, the description herein is limited to a preferred form of an exemplary device to which the present invention is particularly applicable, viz., a variable inductance device comprising a transformer the output-to-input voltage ratio of which is both conveniently adjustable and very accurately controlled. Transformers in which the voltage ratio can be selected in a very precise manner from a number of different values are, of course, well known in the art. They are used, for example, where equipment must be connected at different times to alternating current supplies each having different voltage values. However, in many cases, the actual voltage value is not a matter of great interest, since the equipment will generally have a certain tolerance for input voltages differing from the normal value. The present invention is not concerned with transformers of this type, nor with power transformers generally. On the contrary, transformers of the type with which the present invention is concerned are intended exclusively for very precise measuring, computing and control functions. In such cases, the transformation ratio of the transformers must be known with a precision at least equal to the accuracy of the voltages being applied. While it is possible to wind a transformer for a particular application so as to have substantially exact precision in the turns ratio, and hence in the voltage ratio, for many purposes it is desirable to be able to select this transformation ratio in accordance with a particular purpose or problem. For greatest utility, also, it is generally desirable for one to be able to adjust the transformer ratio by means of switches or the like without introducing significant error in the output ratio.

Inasmuch as it is a main object of the invention to provide transformers having transformation ratios of high accuracy, it follows that sufficient resolution must be provided to fully utilize this accuracy. Means are subsequently described for obtaining fractional-turn resolution, and for avoiding the effects of loading, or voltage drops due to the flow of current in the windings themselves.

The prior art affords many examples of devices of this general type wherein it has been attempted to achieve a desired precision within reasonable equipment size. These prior art devices have usually achieved the desired precision by sacrificing valuable equipment space in the installation, or have failed to achieve any great degree of operational precision as a result of having reduced the size of the equipment in order to meet space requirements.

Another object of the present invention is to provide a

plural stage, voltage-dividing precision electrical transformer of small physical size affording readily accessible means for adjusting the voltage-division ratio thereof and for providing a direct-reading indication of such ratio.

An additional object of the present invention is to provide a multi-stage, precision potential-dividing transformer having a plurality of taps connected to the inductance of each stage thereof, and movable brushes or the like adapted to selectively contact the taps of each stage, wherein the transient energy surges normally encountered in changing the brushes from one tap to another are effectively eliminated.

In accordance with the present invention, the above and other objects are achieved by means of a multi-unit, compartmentalized ratio transformer including a housing having a central axis, a plurality of coaxial rotary shafts mounted in nested relation on said central axis, and a plurality of knobs each attached to a respective one of said coaxial shafts and each having a diameter significantly different from the others. At the end of each of the shafts remote from the knob thereon there is affixed a spur gear or the like which meshes with a respective mating gear carried by an auxiliary shaft radially displaced from the central axis. Each of the auxiliary shafts carries the rotary element of a respective electrical switch, the switches being correspondingly radially spaced from the central axis of the housing and in substantial alignment lengthwise of the axis, thereby providing a great reduction in the overall length of the device in comparison to the devices of the prior art which employ a plurality of switches spaced along the length of the central axis.

A plurality of tapped inductances are wound around a common core, or cores in magnetically-coupled relation, and serve as the inductive voltage-dividing components of the respective stages of the device. The several taps on each winding are connected to respective stationary contacts on each of the several switches, and a movable contact of each switch except the switch associated with the final or output stage of the device is connected to one end of the next succeeding winding. An input circuit is connected across the first or input winding, and a movable contact of the switch associated with the output stage is connected to one side of the resistance element of an output vernier potentiometer, the movable tap of which is connected to the output circuit. The remaining side of the output circuit is connected to one side of the input circuit, and the resistance element of the potentiometer is connected across an auxiliary winding of relatively few turns wound about the afore-mentioned common core. In applications where more resolution is required than can be afforded by an interpolating potentiometer, the auxiliary winding may be used to excite a second multi-winding core. Inasmuch as the impedance ratio of the second core winding to the auxiliary winding is extremely high, no measurable loading effects will occur. The cascading of transformers in this manner provides limitless resolution capabilities.

In order to effectively suppress transients in the operation of the several movable contacts or brushes of the switches, an auxiliary movable contact is provided in each switch, rotationally spaced from the main movable contact of each switch by an amount corresponding to about one half of the distance between the stationary contacts. The auxiliary brushes are connected to the respective relatively wider main brushes by means of a suitable resistor, and as the ganged pair of movable contacts in each switch is rotated in one direction, the auxiliary contact "makes" with the next stationary contact before the main moving contact "breaks" from the previous fixed contact. At this intermediate point the resistor is momentarily across one section of the transformer, and dissipates power from

the transformer. As the switch rotation is continued, the main moving contact "breaks" with the previous stationary contact and "makes" with the next stationary contact before the auxiliary contact "breaks" with this contact. Further rotation causes the auxiliary moving contact to "break" from the stationary contact and to assume a final "reading" position in between two stationary contacts.

Rotation in the other direction causes the auxiliary moving contact to "make" with one stationary contact before the main moving contact "breaks" with this contact. Further rotation causes the main moving contact to "make" momentarily with the next stationary contact before the auxiliary moving contact "breaks" with the previous stationary contact. This likewise places the resistor momentarily across the section of transformer between the stationary contacts, thereby again permitting the resistor to dissipate power from the transformer. Continued rotation causes the auxiliary moving contact to break with its stationary contact and to assume a "reading" position between the two stationary contacts. Thus the transient-dissipating resistor is only in circuit during switching operations, and has no effect in the static or set condition of use of the instrument.

The elongate housing of the device of the present invention is effectively divided into compartments or segments along the length of the central axis, with the substantially aligned switches being included in one compartment, the several windings on the common core lying in another compartment and the output vernier potentiometer, which will preferably be a helical resistance element with a rotary sliding contactor, lying in another segment. The several knobs on the coaxial shafts lie just outside one end of the housing, with the knob of the greatest diameter being positioned closest to the housing and the remaining knobs being arranged in order of decreasing diameter.

With the above considerations and objects in mind, the invention itself will now be described in connection with a preferred embodiment thereof given by way of example and not of limitation, and with reference to the accompanying drawings, in which:

FIG. 1 is a plan view of the apparatus of the present invention, with portions thereof being broken away.

FIG. 2 is an end view of the device shown in FIG. 1.

FIG. 3 is a sectional view of a portion of the device shown in the previous figures, taken on line 3—3 in FIG. 2.

FIG. 4 is a schematic wiring diagram of one form of the electrical circuitry of the apparatus of the present invention.

FIG. 5 is a sectional view taken on line 5—5 in FIG. 1, and showing one face of the rotary switches of the apparatus of the present invention.

FIG. 6 is a sectional view taken on line 6—6 in FIG. 1, and showing the reverse face of the switches shown in FIG. 4.

FIG. 7 is a schematic wiring diagram similar to FIG. 4 but illustrating other possible circuit arrangements.

Referring now particularly to FIG. 1, an elongate cylindrical housing 10 is shown in position over the apparatus of the present invention, with the open end 12 of the housing in abutting relation with a shoulder on the end cap 14. A plurality of elements, both internal and external of the housing 10, are supported by the end cap 14, as will be described, and the housing 10 is held in place by means of a plurality of nuts 16 which are threaded onto respective supporting rods, one of which is shown at 18.

To the right of end cap 14 are a plurality of rotary knobs 20, 22 and 24 which are mounted on coaxial shafts in a manner to be described in connection with FIG. 3. As may be seen, the knobs 20, 22 and 24 are arranged in order of decreasing diameter with increasing distance from the end cap 14. A suitable guard 26 is positioned over the three knobs, being connected to both the end

cap 14 and to a housing 28 for a counter or register 30 which serves to indicate the number of turns through which a rotary knob 32 (and the shaft 34 connected thereto) has passed with respect to some fiducial position. A lock lever 33 may be provided for the counter shaft 34. As may be seen in FIG. 2, this counter 30 may provide an indication of the number of turns of shaft 34 away from the fiducial position from one to nine hundred and ninety nine. Accordingly, knobs 20, 22 and 24 may bear numerals from zero to nine to indicate the relative positioning thereof with respect to a fiducial rotary position. However, as described below, there may optionally be provided eleven taps per winding, and corresponding dial markings, to permit ratio settings greater than unity; for example, as high as 1.111.

The guard 26 has an aperture 36 therein to permit viewing of the indicia on the three knobs 20, 22 and 24, with the three digits of the knobs appearing through aperture 36 combining with the three digits of the counter 30 to form a six-digit reading corresponding to the setting of all the knobs, and, as a result, of all the adjustable rotary elements of the apparatus of the present invention, as will be better understood in connection with the description that follows. For some uses, the ten turn potentiometer shown can be replaced with a one turn potentiometer; in this case, a dial calibrated from zero to one hundred is used in place of counter 30, providing 5-place resolution.

Referring again to FIG. 1, end cap 14 extends into the housing 10 a short distance and terminates in a face which provides a support surface for three switch assemblies 38, 40 and 42. As shown in the drawing, these three switches are substantially aligned axially of the housing 10 and the shaft 34, and they are radially displaced from central shaft 34 (as may better be seen in FIGS. 5 and 6). Rotary shafts 44, 46 and 48 are connected to the rotary elements of the three respective switches 38, 40 and 42, and these shafts are also respectively connected by suitable gearing to the shafts of the three knobs 20, 22 and 24, as will be further explained.

A potted, toroidal transformer is indicated at 50, the taps on the several windings of which are connected to respective ones of the stationary contacts on the several switches 38, 40 and 42 by means of the conductors indicated generally at 52. The center of toroidal transformer 50 is hollow to permit passage therethrough of the central shaft 34 into a potentiometer the casing of which is shown at 54, and which is attached by suitable means to the plate 55. This plate 55 is secured to transformer 50, and serves to divide the housing into two compartments. One of these compartments includes the potentiometer 54, while the other includes the several switches and the transformer 50. Actually, the transformer 50 serves to divide the latter compartment into two smaller compartments, containing, respectively, the transformer itself and the switches. It will be understood that in the preferred form the transformer 50 comprises a single annular ferromagnetic core, with a plurality of toroidal windings thereon.

The manner in which the three knobs 20, 22 and 24 are attached to the three switches may be seen in FIG. 3. As previously stated, FIG. 3 is a sectional view of the apparatus taken on line 3—3 in FIG. 2, but with housing 28, knob 32 and all of the elements to the left (in FIG. 1) of the switches removed. Thus, shaft 34 passes centrally through all of the apparatus shown in FIG. 3, and a plurality of nested coaxial shafts 56, 58 and 60 are mounted thereon. Knob 20 is affixed to shaft 56, knob 22 is affixed to shaft 58, and knob 24 is affixed to shaft 60. The inner ends of the shafts 56, 58 and 60 (the ends remote from the respective knobs thereon) carrying respective spur gears 62, 64 and 66. Each of these gears engages with a respective mating gear, only two of which are shown; viz., spur gears 68 and 69 which mesh with gears 62 and 64. The description that follows in connection with spur gear 68, and its mounting and connection with the switch assembly 40, is exemplary of the manner of

mounting and connection for the remaining gears and their respective switch assemblies 38 and 42.

Spur gear 68 is mounted on shaft 46, and is secured for rotation therewith by means of a screw 70 or the like which passes through an aperture in the gear hub to engage the shaft. Shaft 46 is mounted for rotation with respect to the end cap 14 by means of a bearing indicated generally at 72, where the shaft passes through the inner face of the end cap. Shaft 46 then passes through a detent assembly 74 which includes a rotary element 76 having a plurality of detents therein and mounted on shaft 46. A rotationally stationary ball or the like (not shown) is spring mounted with respect to the bearing assembly 72 for limited motion relative thereto in a direction axial of the shaft 46. As shaft 46 is rotated, the ball is forced out of a seat in one of the detents in the detent plate 76, and then, upon further rotation, seats again in the next adjacent detent under the action of the spring mount. This detent assembly serves to position the rotary elements of the switch assembly in defined and discrete positions, as is well known in the art.

The inner end of shaft 46 carries the rotary element 78 of switch 40, which rotary element is concentric with the annular stationary element 80 of the switch. In FIG. 3 the wiring to the several terminals on the switch assemblies has been removed, and the manner in which the wiring is connected, as well as the arrangement of the several stationary and movable contacts on the switches, will better be understood in connection with the description of subsequent figures of the drawings.

The preferred form of the electrical device of the present invention as shown and described herein is an inductive voltage divider, as previously stated. The electrical circuitry of this preferred form of the device is shown in FIG. 4. The three windings 82, 84 and 86 are wound about a common magnetic core indicated schematically at 88. Actually, this core 88 is in the form of an annulus within the housing 50 shown in FIG. 1, and the three windings are toroidal in configuration.

Each of the windings 82, 84 and 86 is tapped at a plurality of points thereon to provide connections to a corresponding number of stationary contacts on the switching assembly associated therewith. For example, the switch assembly 40 has a plurality of stationary contacts, a few of which are indicated at 90 in FIG. 4, and each of these stationary contacts is connected to a respective tapping point on the winding 82. As will be appreciated by those skilled in the art, the spacing (or, more accurately, the number of turns) between each adjacent pair of these stationary contacts is preferably equal, and the number of turns between adjacent taps on winding 82 will also preferably bear a predetermined relationship with the number of turns between adjacent taps on windings 84 and 86. In order to conform to the decimal number system, and to provide ratios up to 0.999+, there will be ten taps (including one at one of the end points) on each winding, providing nine segments thereon. The number of turns between taps on winding 84 will preferably be ten times the number between adjacent taps on winding 86. Similarly, the number of turns between adjacent taps on winding 82 will be ten times the number of turns between adjacent taps on winding 84, and one hundred times the number of turns between adjacent taps on winding 86. If the number of turns (i.e., the number of turns of wire around the core 88) between adjacent taps on winding 86 is unity, then the number of turns between adjacent taps on windings 84 and 82 are ten and one hundred, respectively. Thus, the total number of turns on windings 82, 84 and 86 are one thousand, one hundred, and ten, respectively. However, in FIG. 4, the use of ten fixed contacts providing nine winding segments leaves one segment idle insofar as the sliding contact is concerned. It will be understood that these specific figures are merely representative of a preferred form of the apparatus of the present invention, and other values may be employed with

satisfactory results. Further, it is not necessary that the relationship between the several windings (and the corresponding marking on the several knobs shown in FIG. 2) bear a direct relationship in the decimal system, such system being described herein only as a preferred and convenient form.

A pair of input terminals 92 and 94 are connected to respective ends of winding 82, and terminal 94 is also connected to one output terminal 96. The remaining output terminal 98 is adapted to be adjustably connected through and by means of the several variable elements of the apparatus of the present invention to a selectable point on the first stage winding 82, which winding has the entire input voltage impressed across it. The voltage at output terminal 98 is smoothly adjustable over the entire range of this input voltage by virtue of the several adjustable elements of the circuit, as will now be described.

Switch assembly 40 includes a movable contact 100 which serves as the main tap or movable contact for contacting the several taps of the winding 82. Contact 100 is mounted for movement with respect to the several stationary contacts 90 of switch assembly 40 in such manner that the contact 100 "breaks" and then "makes" contact with successive adjacent ones of the stationary contacts. The assembly including the detent plate 76 (FIG. 3) urges the rotary portion of switch 40 into definite positions defined by the registry of movable contact 100 with any one of the several stationary contacts 90, and thus the contact 100 is prevented from stopping at a point at which it fails to make connection with one of the stationary contacts.

An auxiliary contact 102 is also mounted on the rotary portion of switch assembly 40, for rotary movement with contact 100. Auxiliary contact 102 is electrically connected to contact 100 by means of a resistor 104 of suitable size for the purpose of eliminating transients in the making of the circuit connections between movable contact 100 and the several stationary contacts of the switch. As will better be understood in connection with the description of FIGS. 5 and 6 below, auxiliary contact 102 is mechanically mounted on the movable element of switch assembly 40 in such manner with respect to main contact 100 as to be spaced therefrom a distance substantially equal to one half of the spacing between the adjacent stationary contacts 90. In this manner, when contact 100 is in exact registry with one of the contacts or taps 90, auxiliary contact 102 is in circuit with none of such contacts, but is positioned between an adjacent pair as indicated in FIG. 4. When contact 100 is in transit between and adjacent pair of the contacts 90, the auxiliary contact 102 is then making connection with either the next subsequent stationary contact to be contacted by the movable contact 100, or the stationary contact that this movable contact is just leaving.

Movable contact or brush 100 is connected to one end of the winding 84, the taps of which are connected to a plurality of stationary contacts of the switch assembly 38 in a manner substantially identical to that of switch 40. Movable brush 106 of switch 38 is connected to one end of winding 86, and the auxiliary contact 108 is connected to main contact 106 through a resistor 110. Similarly, the movable brush or contact 112 of switch 42 is connected to the auxiliary contact 114 thereon by means of a resistor 116. Movable contact 112 is also connected to one end of the resistance element 118 of the helical (or single turn) potentiometer indicated at 54 in FIG. 1. This resistance element 118 is connected in shunt with an auxiliary winding 120 wound on the common annular core 88, which connection between the auxiliary winding and the potentiometer develops voltage across the latter. When reference is made to a potentiometer herein, it will be understood by those familiar with the art that the term is intended to include equivalents, such as a set of fixed resistors connected in series, with a suitable switch to connect between them in turn.

The auxiliary winding is normally made of heavy gauge wire to minimize the loading effects of the resistance element.

The structure of the several switches 38, 40 and 42 is shown in FIGS. 5 and 6, showing the opposite faces of the three switches. Referring first to FIG. 5, the rotary element 78 of switch 40 is shown mounted on rotary shaft 46. Rotary element 78 is in the form of a disc or the like, and carries a conductive ring 121 on the near face thereof, said ring including a protruding finger or the like serving as the main movable contact 100 of the switch 40. A small clearance is provided between rotary element 78 and the stationary annulus 80 which supports the several stationary contacts 90 of switch 40. This annular stationary element of the switch is supported by means of a pair of bolts or the like, as may better be seen in FIG. 1. Contact 122 on stationary member 80 is considerably longer than the other stationary contacts 90 thereon, and thus provides a brush for the slip ring formed by the conductive ring 121 on the rotary member 78. Resistor 104 is connected between contact 122 and another stationary contact 124, the latter being mounted on the wafer face opposite to that shown in FIG. 5.

It can be seen that each of the switch wafers, such as that indicated at 80, includes twelve circumferentially spaced positions for the stationary contacts thereon. On the switch faces shown in FIG. 5, eleven of the twelve positions on each face are occupied by stationary contacts (including the longer contact which acts as a brush for completing a circuit to the slip ring mounted on the rotary element of each switch). As will be understood, each of these twelve positions corresponds to a seated position of the rotary detent means 74 as discussed in connection with FIGS. 1 and 3. In both FIGS. 5 and 6, the wiring has been removed from the several contacts, with the exception of the leads to the three resistors 104, 110 and 116.

The three switches 38, 40 and 42 are substantially identical as to structure and arrangement, and the detailed description herein has been limited to the switch assembly 40 as exemplary of all three, with the several elements of switches 38 and 42 corresponding to like elements of switch 40 both in number and arrangement.

FIG. 6 shows the faces of the three switches opposite shown in FIG. 5, and it may be seen in FIG. 6 that the rotary element 78 of switch 40 also carries a conductive ring 126, which includes a projecting contact finger or the like indicated at 102. The rotary position of shaft 46 is the same in FIG. 6 as that shown in FIG. 5, and it will thus be seen that the two rotary fingers 100 and 102 are spaced apart rotationally (i.e., circumferentially of the wafer 80) a distance equal to approximately one-half of the circumferential spacing between the stationary contacts 90. Only eleven of the twelve detent positions have terminals therein on the side of the wafer shown in FIG. 6, with one of the eleven being occupied by the slip-ring contacting finger 124. The resistor 104 is connected between terminal 124 and terminal 122, as shown.

It will be appreciated that the paired terminals or stationary contacts lying in circumferential registry on the opposite faces of the wafer 80 are connected together electrically, as may be seen in FIG. 1. Further, terminal 122, which is continuously connected to rotating contact 100 through slip-ring 121, is connected to one end of winding 84, as by the conductor 128 shown in FIG. 4. Similarly, the slip-ring brush 130 of switch 38 is connected to one end of winding 86, and the brush 132 of switch assembly 42 is connected to one end of the potentiometer resistance element 118.

Proceeding now to the operation of the apparatus as described above, the input voltage is applied to the terminals 92, 94 and is thereby placed across the first stage winding 82. Assuming that it is desired to provide an output potential which is not less than eight-tenths of the

input potential, knob 20 is rotated until the numeral 8 appears in the aperture 36 of the housing 26 (see FIG. 2).

This adjustment moves the rotary contact 100 of the switch assembly 40 into contact with the eighth stationary contact from the bottom or common end of winding 82, whereby eight-tenths of the input voltage will appear on conductor 128. If the precise fractional output desired is, say, 0.866547, the remaining knobs 22 and 24 are set to the positions shown in FIG. 2, as is the potentiometer control knob 32 (as indicated by the counter or register 30 connected thereto). This adjustment of knobs 22 and 24 positions the movable contacts 106 and 112 of the switches 38 and 42, respectively, in registry with the "sixth" stationary contacts of each of the windings 84 and 86. In a manner well known to those skilled in the art of helical potentiometers, the aforementioned adjustment of the knob 32 serves to move an adjustable rotary slider or tap (not shown) along the resistance element 118 of the helical potentiometer 54 to a point at which the voltage appearing at the terminal 98 is equal to the voltage appearing at movable contact 112 plus the selected potentiometer ratio, viz., 0.547 multiplied by the potential existing across auxiliary winding 120. Inasmuch as the potential across the auxiliary winding is equal to the potential between adjacent taps on winding 86, the adjustable potentiometer serves to interpolate this potential.

Due to the fact that the three windings 82, 84 and 86 are wound on a toroidal common core 88 and thus have common magnetic fields, the energization of winding 82 by the application of the input voltage across it serves also to energize windings 84 and 86 by means of the well-known inductive action of a transformer. Since winding 84 has only a tenth of the total number of turns found in winding 82, with winding 86 having, in turn, only a tenth of the total number of turns of winding 84, the voltages induced in windings 84 and 86 are, respectively, one tenth and one hundredth of the input potential applied across winding 82 at terminals 92 and 94. Thus, the voltage induced across each of the entire windings 84 and 86 is equal to the voltage appearing across each of the segments between adjacent taps of the respective preceding windings 82 and 84.

Assuming now, for the sake of convenience in description, that the input potential applied across winding 82 is one hundred volts, the voltage then appearing across winding 84 is ten volts, and that across winding 86 is one volt. The voltage appearing across the auxiliary winding 120 is one-tenth of a volt. With the several adjustable elements of the apparatus set to the positions discussed above (and shown in the drawings), the voltage appearing on conductor 128 is eighty volts, that appearing at contact 106 is eighty plus six, or eighty six, and that appearing at brush 112 is eighty six plus six-tenths, or 86.6 volts. To this voltage appearing on brush 112 is added a portion of the voltage appearing across auxiliary winding 120. The portion added is determined by the resistive dividing element 118 and its associated movable contact connected to the output terminal 98. In this specific example, the resistive divider element 118 is set to add 0.547 of the voltage appearing across auxiliary winding 120. The net result is a voltage of 86.6547 volts at terminals 98, 96. It will be understood that while terminals 94 and 96 are shown as separate terminals in FIG. 4, they will conveniently comprise a single terminal in actual equipment, and the two are so indicated in FIG. 1 as the single terminal 96.

The mechanical operation of switches is easily understood by reference to FIG. 3. As knob 22, for example, is rotated, the hollow shaft 58 to which this knob is secured is correspondingly rotated to position the spur gear 64 in the desired rotational position. Rotation of spur gear 64 causes corresponding movement of the meshed gear 68, resulting in rotation of shaft 46 and

the rotary element 78 of switch 40 mounted thereon. Rotation of the remaining knobs 20 and 24 causes similar rotation of the respective shafts 56 and 60, each carrying a respective spur gear 64 and 66. These latter gears mesh with corresponding gears such as 69 for causing the desired rotational positioning of the rotary elements of the remaining switching assemblies 38 and 42.

Considering the showings of FIGS. 5 and 6 together, it is seen that the main movable contact 100 of this switch is in registry with the eighth stationary contact. This corresponds to the position shown in the electrical circuit of FIG. 4. Similarly, the auxiliary contact 102 is midway between the seventh and eighth contacts. In the same manner, rotation of the rotary elements of switches 38 and 42 to the aforementioned positions corresponding to the knob positions shown in FIG. 2 moves main contacts 106 and 112 into registry with the sixth stationary contacts of the respective switches (see FIG. 5). This positions the respective auxiliary contacts 108 and 114 between the fifth and sixth stationary contacts of the respective switches 38 and 42 (FIG. 6). In each of the three switches, as the rotary element thereof is rotated to move the main and auxiliary contacts into engagement with succeeding lower-numbered ones of the stationary contacts, the auxiliary contacts make connection with the next stationary contact before the associated main contact breaks the connection made with the stationary contact that is then in the circuit, thereby effectively eliminating the transient surges that would otherwise appear in the conductors connected to the respective main contacts if the auxiliary contacts and the associated resistors were not employed. In like manner, when the rotary elements of the switches are moved in a direction which moves the movable contacts toward the higher-numbered stationary contacts, the main contacts make the new circuit connection with the next succeeding stationary contacts prior to the breaking of the circuits previously established and still held by means of the auxiliary contacts in series with the respective resistors.

Reference has been made above to certain variants in the wiring arrangement, and these are illustrated in the schematic diagram of FIG. 7. Parts which are the same as those earlier described are given the same reference numerals.

While the resolution capabilities of an instrument as already described can be extended indefinitely by the addition of larger and larger windings on the same core, it will be realized that for a decimal scheme, the smallest winding will have ten turns, and the next two larger windings will have a hundred turns and a thousand turns. If a fourth decade were to be added, it would require 10,000 turns, and while this is technically possible, using very fine wire and a core of substantial size, the practical limit has already been reached. FIG. 7 illustrates how the decades may be extended by using a separate additional core, common to several decades, and energizing this added core from flux in the first core. Thus, an added core 188 has a first winding (say of a thousand turns) at 182, and this winding is connected to a single-turn winding 220 linking the core 88, in a manner similar to the way in which voltage divider 118 was linked to that core in FIG. 4. The reason for a single turn coupling loop is that for interpolation, the loop has to have a number of turns equal to the number between taps of the winding being interpolated. Winding 186 has ten turns, or one turn between taps.

In effect, the second core 188 and its windings, taps and switches (the second and further windings are omitted in FIG. 7 since they will be identical to the first core windings) act as a precision interpolator in place of the resistive voltage divider 118. However, such a resistive divider may be applied to the last winding of this added core 188 precisely as shown in FIG. 4. Since the impedance of the one-turn coil 220 is negligible, the current drawn through it by the winding 182 will have a wholly

negligible effect on the flux in core 88 from the loading standpoint.

FIG. 7 also illustrates a useful variation, already mentioned, in the number of taps connected to windings of the core 88. At the upper end of each such winding, an eleventh fixed tap is shown as at 190, 290 and 390. These taps are marked "1" to distinguish them from the lower-most taps but one, which are marked "1" meaning one-tenth of the way along the winding. With this slight addition, the ratio divider will read ratios up to 1.111+, because it is now possible to obtain an output voltage equal to the full sum of each entire decade—namely, $1.0+0.1+0.01$ and so on, as contrasted with a maximum sum of $0.9+0.09+0.009$ and so on in the case of FIG. 4. With the FIG. 7 contact arrangement, an additional significant figure will of course also be marked on the dial knobs shown in FIG. 2, in the position just beyond the present "9" digit markings.

Obviously, either of the foregoing variations can be applied to a ratio divider independently of the other, the purpose herein being merely to illustrate several of such possibilities. Other variations falling within the spirit of the invention will occur to those skilled in this art, and it is intended to include herein all such as fall within the scope of the appended claims.

What is claimed is:

1. A compartmentalized electrical device, comprising an elongate housing therefor, a centrally located shaft within said housing extending lengthwise thereof and mounted for rotation with respect thereto, a first rotary knob secured to said centrally located shaft at one end thereof, a first electrical component having a rotary element attached to the other end of said centrally located shaft and operated thereby, a support plate mounted within said elongate housing transverse of the length thereof and dividing said housing into two compartments, said first electrical component being mounted on said support plate and extending into a first of said compartments, a plurality of other electrical components each having a rotary element and being mounted within the other of said compartments, said other electrical components being spaced circumferentially about said central axis and in substantial alignment with one another lengthwise of said elongate housing, a rotary control knob for the rotary element of each of said other electrical components, said rotary control knobs each being mounted on a respective shaft coaxial with said centrally located shaft, and drive means independently connecting each of said rotary elements of said other electrical components to a respective one of said coaxial shafts where by rotation of each of the rotary control knobs causes corresponding rotation of the rotary element connected thereto; each of said other electrical components comprising an electrical switching means each having a movable contact and a plurality of stationary contacts and including a plurality of multi-tapped electrical impedance means each associated with a respective one of said electrical switching means, an electrical input circuit connected across a first of said electrical impedance means, the several taps of said first electrical impedance means being connected to respective ones of the stationary contacts of a first of said electrical switching means, the movable contact of said first switching means being connected to one end of a second of said electrical impedance means, the several taps of said second and successive electrical impedance means being connected to respective ones of the stationary contacts of respective successive ones of the remaining ones of said switching means, the movable contact of each of said successive ones of said switching means except the last being connected to one end of a succeeding one of said impedance means, the movable contact of the last of said switching means being connected to one side of an output circuit, and the other side of said output circuit being connected to one side of said input circuit.

2. A compartmentalized electrical device in accordance

with claim 1, wherein each of said electrical impedance means comprises a multi-tapped inductance, all of said inductances being wound upon a common core and being mounted within said other compartment.

3. A compartmentalized electrical device in accordance with claim 2, wherein said movable contact of the last of said electrical switching means is connected to said one side of said output circuit through an electrical voltage divider, said movable contact of said last electrical switching means being directly connected to one end of the voltage divider, an auxiliary inductive winding on said common core connected in shunt with said voltage divider, and a movable tapping contact of said voltage divider being connected to said one side of said output circuit.

4. An electrical device in accordance with claim 3, in which said electrical voltage divider is a resistive potentiometer.

5. A compartmentalized electrical device in accordance with claim 2, and including an auxiliary movable contact for each of said electrical switching means, each of said auxiliary contacts being electrically connected to a respective one of said first-mentioned movable contacts through a resistor and being mounted in spaced relation to said respective first-mentioned movable contact, the spacing between each pair of auxiliary and first-mentioned movable contacts being substantially equal to one half of the spacing between the several stationary contacts of each of the electrical switching means, whereby each of said auxiliary contacts lies between a pair of adjacent stationary contacts when the associated first-mentioned movable contact is in substantial registry with one of the contacts of such pair of stationary contacts.

6. A compact, adjustable voltage-dividing device including a generally cylindrical casing adapted for panel mounting by bodily insertion through a circular panel aperture, impedance means in said casing defining a multiplicity of impedance sections provided with terminals connected thereto to define a plurality of decades of impedance value, a rotary selecting switch providing decimal impedance-selective contact positions for each of said sections, said switches being clustered laterally about a central longitudinal axis of said casing, and each switch including detent means defining at least ten individual contact positions corresponding to the respective decades of the selected impedance value in circuit: a stepped-diameter plurality of concentric operating knobs mounted on said central axis at one end of the casing and all provided with numerical indicia corresponding to the decade switch positions of said respective switches, and coaxial shaft means centered on said casing axis and individually connecting one each of said switches to a respective one of

said knobs; whereby the settings of said switches can be read off the knob indicia as a connected multi-digit numeral.

7. A compact, adjustable voltage-dividing device including an elongated casing having a longitudinal central axis, impedance means in said casing defining a multiplicity of impedance sections provided with terminals connected thereto to define a plurality of decades of impedance value, a rotary selecting switch providing decimal impedance-selective contact positions for each of said sections, said switches being clustered laterally about the central longitudinal axis of said casing, and each switch including detent means defining at least ten individual contact positions corresponding to the respective values of impedance of the corresponding section; a stepped-diameter plurality of concentric operating knobs mounted on said central axis at one end of the casing and individually provided with spaced indicating numerals about their rims corresponding to the decade switch positions of said respective switches, and coaxial shaft means centered on said casing axis and individually connecting one each of said switches to a respective one of said knobs; whereby the settings of said switches can be read by the aligned knob numerals as a connected multi-digit numeral.

8. A device in accordance with claim 7, in which said impedance means includes a continuously adjustable auxiliary interpolating impedance having an adjustment shaft lying on the said central axis of the casing and extending through said cluster of switches and said knobs; and a vernier knob on the last-named shaft superimposed centrally upon the array of said operating knobs, said vernier knob providing a digital indication of the adjustment of said auxiliary impedance in linear alignment with the indicia of said operating knobs.

9. A device in accordance with claim 7, including means defining an inspection aperture bracketing the aligned numerals of said operating knobs indicative of the selected value of impedance.

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