Oct. 23, 1951 D. F. WALKER 2,572,545

VARIABLE IMPEDANCE DEVICE

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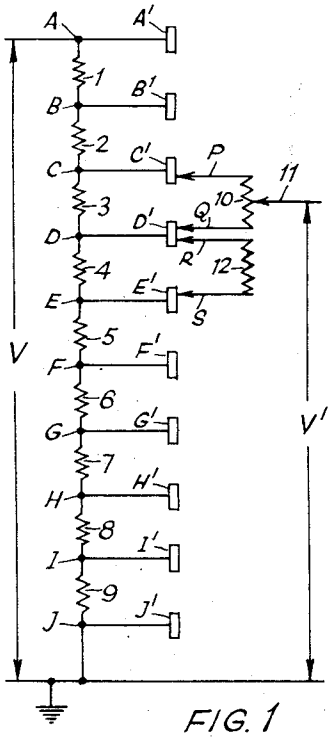


FIG. 1

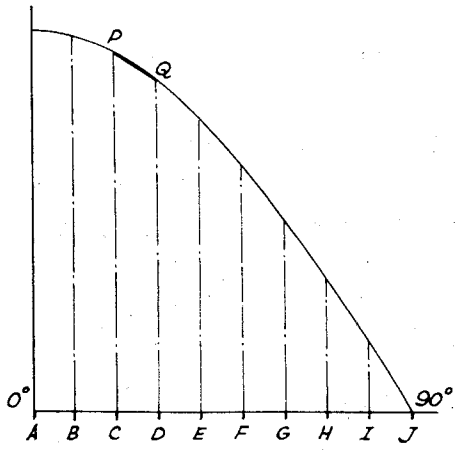


FIG. 3

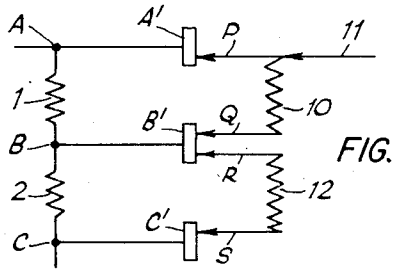


FIG. 2a

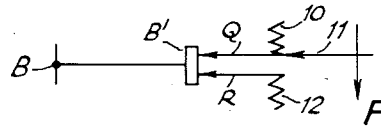


FIG. 2b

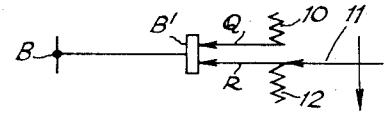


FIG. 2c

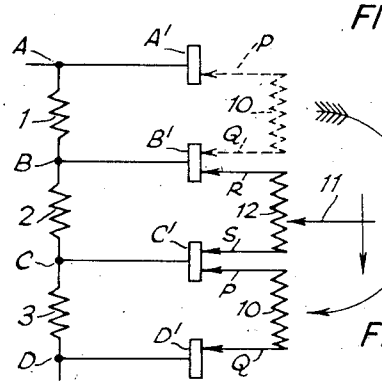


FIG. 2d

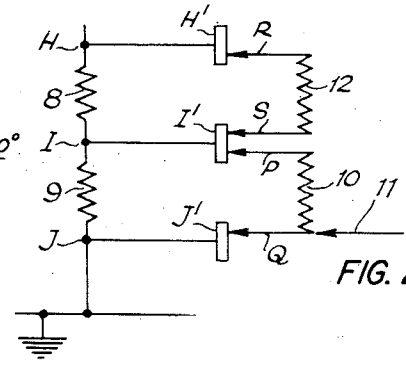


FIG. 2e

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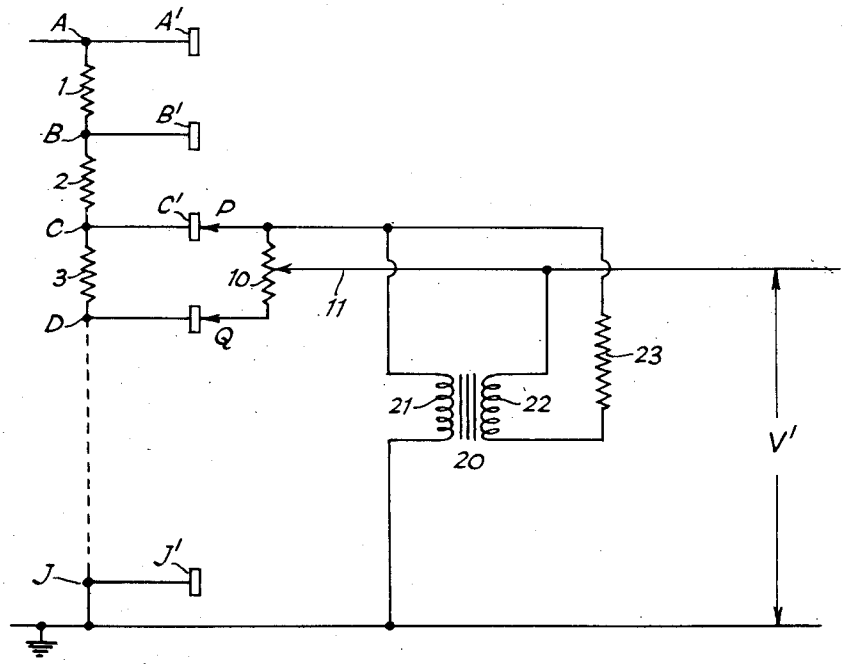


FIG. 4

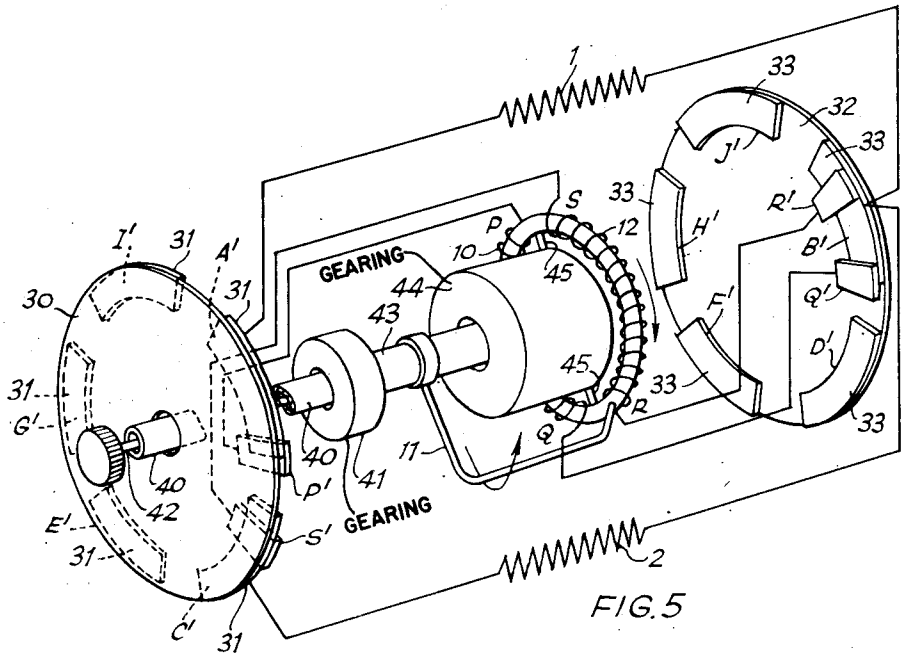


FIG. 5

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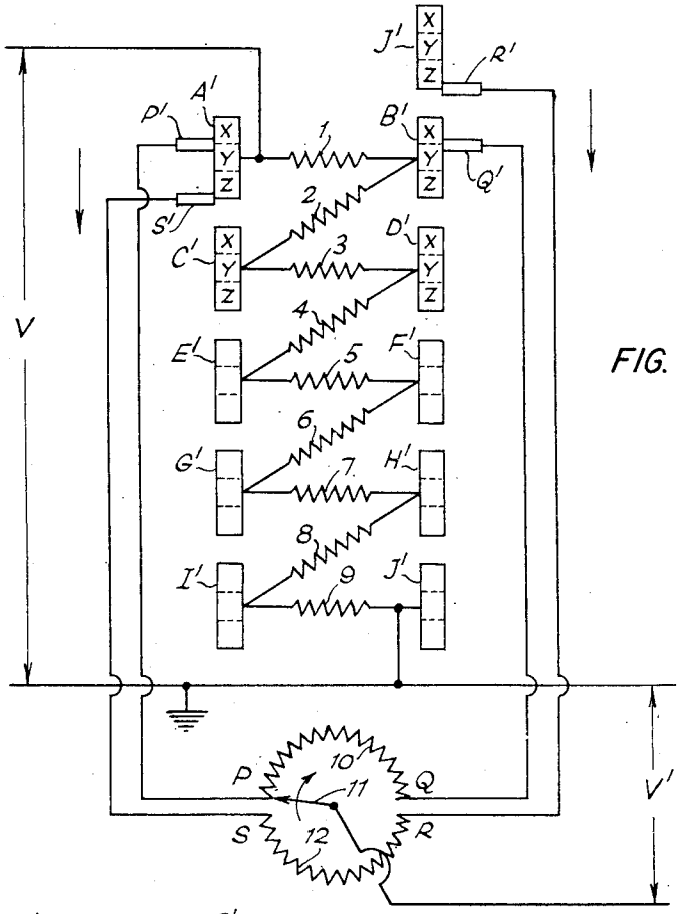
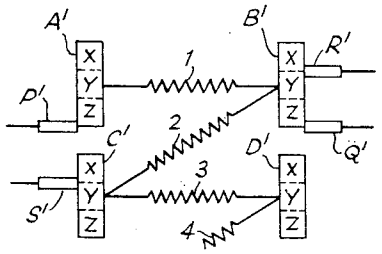


FIG. 6a.



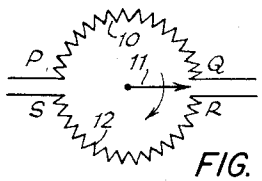
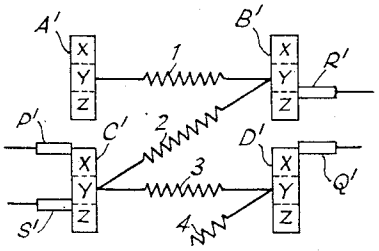


FIG. 6b.



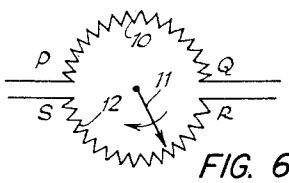


FIG. 6c.

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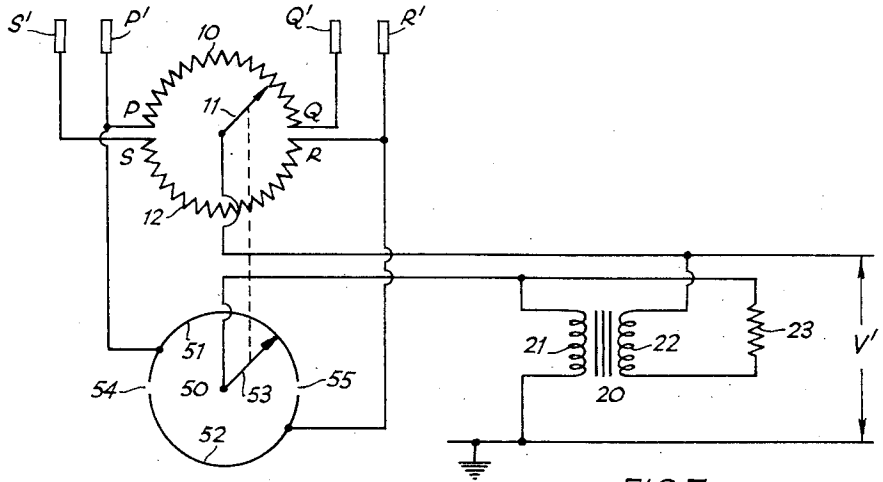


FIG. 7

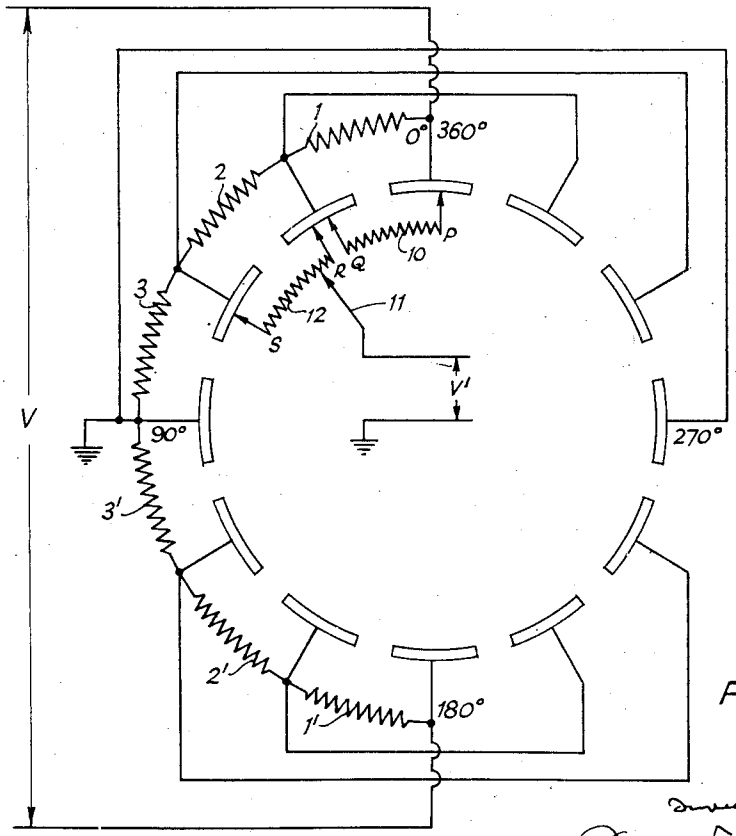


FIG. 8

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UNITED STATES PATENT OFFICE

2,572,545

VARIABLE IMPEDANCE DEVICE

Donald Ferguson Walker, Edinburgh, Scotland

Application November 26, 1948, Serial No. 62,169
In Great Britain November 28, 1947

11 Claims. (Cl. 323—43.5)

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This invention relates to variable impedance devices of the type comprising a closed or open chain of at least three serially-connected impedance elements energized by an input voltage applied across appropriate points of the chain if closed or across the ends of the chain if open, the chain being designed to yield a variation of output voltage which is related to the movement of a control in accordance with some given law.

Impedances of this type are frequently used—for example in electrical computers—but are liable to be rendered inaccurate by inaccuracies in the mechanical control of the sliders (or like tapping devices) and, in the case of wire-wound potentiometers, by the fact that as a slider usually makes contact with only one point on each turn of wire the output voltage does not change smoothly but in a series of "steps" each of which represents the voltage drop across one turn. It is true that the "height" of each step may be reduced—for example by increasing the number of turns of the winding—but such procedure is often inconvenient to apply. These inaccuracies may be accentuated by the various expedients usually resorted to in order to ensure approximate conformity with the given law, such as winding the wire on a specially shaped former, or winding it linearly and moving the slider in accordance with the law by means of some mechanical contrivance.

The object of the invention is to provide a variable impedance device of the type stated of simple construction in which the law relating the variation of output voltage to the movement of the control is observed to a high degree of accuracy.

In accordance with the present invention in a variable impedance device of the type stated the impedances of the said elements are such that the several total impedances between a datum point in said chain and successive common points between said elements and between said datum point and the ends, if any, of said chain are in accordance with said law, there being provided impedance components the impedance of each of which is high compared with the impedance of any of said elements and the number of which is greater than unity and less than the number of said elements, tapping means for connecting one of said components across any element and the remaining component or components across a like number of successive elements and/or off positions each to each, disposed on one side of said element, a common variable tapping means adapted to engage two or more adjacent components successively, means for deriving said output voltage between said common variable tapping means and said datum point in said chain, and means actuated by said control (*a*) for transferring one of said remaining components to connection across the adjacent element on the other side of said element, and (*b*) for traversing said common variable tapping means along said one of said components whilst said component remains connected across said element, then, without substantial change of said output voltage, onto said one of said remaining components after transference thereof, and then along said last-mentioned component whilst it remains connected across said adjacent element.

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Also in accordance with the invention, in a variable impedance device of the type stated said elements comprise resistors, the resistances of which are such that the several total resistances between a datum point in said chain and successive common points between said elements and between said datum point and the ends, if any, of said chain are in accordance with said law, there being provided two resistive potentiometers the resistance of each of which is high compared with the resistance of any of said elements, tapping means for connecting one of said potentiometers across any element and the other potentiometer across an adjacent element or off-position, disposed on one side of said element, a common variable tapping adapted to engage said potentiometers successively, means for deriving said output voltage between said common variable tapping and said datum point in said chain, and means actuated by said control (*a*) for transferring said other potentiometer to connection across the adjacent element on the other side of said element, and (*b*) for traversing a common variable tapping along said one of said potentiometers whilst said potentiometer remains connected across said element, then, without substantial change of said output voltage, onto said other potentiometer after transference thereof, and then along said other potentiometer whilst it remains connected across said adjacent element.

Compensation means may be provided for increasing the accuracy of said device when said common variable tapping means is situated between the ends of any one of said components or when said common variable tapping is situated between the ends of either of said resistive potentiometers, as the case may be.

In the accompanying drawings,

Figures 1 and 2*a* to 2*e* illustrate the principle of operation of the invention,

Figure 3 is a curve showing a typical law observed by apparatus in accordance with the invention,

Figure 4 shows diagrammatically compensation means,

Figure 5 shows an embodiment of the invention in mechanically simplified form,

Figures 6*a* to 6*c* illustrates the operation of the embodiment shown in Figure 5,

Figure 7 shows diagrammatically an embodiment of the compensation means of Figure 4 as applied to the apparatus of Figure 5,

Figure 8 illustrates the principle of a further embodiment of the invention.

A simplified form of the invention will now be described in order to make clear the principle of operation. The variable impedance device chosen in this example follows a cosine law between the angles 0° and 90°, so that in response to movements of the control spindle, e. g. of a predictor, in dependence on some variable angle θ the output voltage between a slider and a datum point is always proportional to cos θ. In this device—see Figure 1—nine impedance elements in the form of resistors 1 to 9 are connected in series to form an open chain between end points A and J, across which points is applied an input voltage V. End point J, which is earthed, is the datum point referred to above. The eight common points between the resistors are B, C, D . . . . I: resistor 1 is thus connected between points A and B, resistor 2 between points B and C, and so on, resistor 9 being connected between I and J. The resistances of the resistors are such that the voltages between the end point or common points and earthed end point J follow a cosine law with end point A representing zero degrees, common point B representing 10°, C representing 20°, and so on, with earthed end point J representing 90°. The actual resistance of each resistor is determined from the fact that the ratio of the total resistance between B and J to that between A and J is cos 10°, or 0.9848; the ratio of the total resistance between C and J to that between A and J is cos 20°, or 0.9397, and so on.

The end points and common points are brought out to tapping means in the form of studs similarly designated A^1 to J^1, across certain pairs of which may be connected the ends P and Q of a first resistive potentiometer 10 the resistance of which is very high compared with that of any of the chain resistors.

Potentiometer 10 is shown in Figure 1 connected across resistor 3, with the ends P and Q of the potentiometer respectively engaging studs C^1 and D^1. It will be clear that when slider 11 of potentiometer 10 is at the end P the potential of the slider is the same as that of the point C so that the output voltage V^1 developed between the slider and the datum or earthed point J represents cos 20°. When the slider is at the end Q the output voltage represents cos 30°. And when the slider occupies some intermediate position between the ends P and Q the output voltage approximately represents the cosine of some angle between 20° and 30°. By moving potentiometer 10 to other consecutive pairs of studs the whole range of angles from 0° to 90° can thus be traversed, the gradations of the scale being determined by the number of turns on potentiometer 10.

It will be noticed that there will be an interruption in the potential of slider 11 every time potentiometer 10 is moved to another pair of studs. To avoid this interruption and ensure a smooth change of potential throughout the scale a second component, in the form of a second potentiometer 12, is provided, exactly similar to the first potentiometer; the ends of the second potentiometer are R and S, and in Figure 1 it is shown connected across resistor 4 with ends R and S engaging studs D^1 and E^1. Instead of each having a slider the two potentiometers share the same common variable tapping or slider 11. By a mechanical arrangement, hereinafter described, these two potentiometers always occupy adjacent pair of studs—that is, they are always connected to three consecutive studs in the centre one of which is shared by both potentiometers. In Figure 1 they are shown occupying consecutive studs C^1 to E^1 and sharing stud D^1. The control effecting the movement of slider 11 in dependence on the angle θ automatically ensures that when the slider reaches an end of a potentiometer the other potentiometer is already in position across the next vacant resistor element (if any) to receive it so that the slider can move smoothly from the one potentiometer to the other without substantial change of output voltage. Upon the slider reaching the end of the second potentiometer the control has provided for the first potentiometer to be transferred to the next vacant resistor element beyond the second potentiometer and thus the potentiometers and the slider continue their travel along the chain of resistors.

The above arrangement will be made clearer from considering (with reference to Figure 2) the use of the equipment in operation, in which the full range starting from 0° and finishing at 90° is traversed. The two potentiometers are to being with (see Figure 2*a*) connected across the first two resistors 1 and 2 at the end A of the chain so that the ends P, Q and R, S are connected to studs A^1, B^1 and B^1, C^1 respectively. The end Q of potentiometer 10 is thus at the same potential as the end R of potentiometer 12, this potential being that of the common point B. The common slider 11 is at the end P; its output voltage thus represents cos 0°. The slider is now moved by the control towards the end Q, thereby covering the angles between 0° and 10°. When it reaches this end Q its potential is that of point B, see Figure 2*b*. The slider here is transferred to the end R of potentiometer 12, see Figure 2*c*, its potential remaining steady at that of the point B during this process owing to the close proximity of the end turns of the two potentiometers. Slider 11 continues its traverse by moving towards the end S, thereby covering the angles between 10° and 20°. As the slider nears the end S the control causes potentiometer 10 to be transferred, "hand-over-hand" fashion, see Figure 2*d*, to the studs C^1, D^1 so that when the slider reaches the end S of potentiometer 12 the end P of potentiometer 10 is in position to receive it. As the slider, continuing its traverse, nears the end Q, potentiometer 12 is similarly transferred "hand-over-hand" to the studs D^1, E^1. In this way the entire scale is smoothly covered without any interruption. Towards the end of the scale potentiometer 10 is transferred from the studs G^1H^1 to the last pair of studs I^1J^1, after which of course no further transference takes place in this direction, the slider finishing its traverse at the end Q of potentiometer 10, see Figure 2*e*, where its potential becomes that of point J and thus represents cos 90° or zero.

The system works in the reverse direction in an exactly similar manner.

The precise moment in each "hand-over-hand" operation when a transference of a potentiometer is effected is unimportant but it should for convenience take place whilst the slider is moving from the midpoint of the other potentiometer towards one end of it.

It will be noticed that the resistor elements may be divided into two groups—those across which

potentiometer 10 may be connected and those across which potentiometer 12 may be connected. Potentiometer 10 may be connected across the odd numbered resistors 1, 3, 5, 7, 9 but not across the even numbered resistors 2, 4, 6, 8, whilst the reverse applies to potentiometer 12.

By lengthening the chain by another nine resistors beyond the earthed point J and by connecting the source of constant voltage across the ends of the lengthened chain the equipment may be adapted to cover the range 0°–180° instead of 0°–90°. In this case the output voltage is of course that between the slider and earthed point J, which remains the datum point, this voltage being negative when the slider is operating in the 90°–180° half of the chain.

In practice there are many more resistors in the chain than the nine which in order to simplify the explanation were assumed above. The series of potential "steps" between successive common points are therefore many and small, whilst the effect of a high resistance potentiometer connected across a pair of adjacent common points is to smooth out the step concerned into almost exact coincidence with the corresponding section of the cosine curve relating output potential to slider displacement. Moreover, no difficulty is experienced in providing the series of separate resistors each of which has a resistance that can be readily determined from tables of cosines, instead of a resistor that varies along its length as in the prior art.

It will be appreciated that the potential of the slider does not adhere to the cosine law with strict accuracy when the slider is at any position on a potentiometer other than at its ends. The potential between these ends in fact follows a linear law and may be represented by a straight line joining the two adjacent plots on the cosine curve that represent the potentials of the two common points across which the potentiometer is connected. This is illustrated in Figure 3 which shows a cosine curve between 0° and 90° referenced in correspondence with Figure 1, with the ends P, Q of potentiometer 10 connected to the points C, D. Where there are many resistors these plots lie close together and the straight lines connecting the plots therefore lie very close to the curve. Should however exceptional accuracy be required some form of error compensation may be necessary. The design of such compensation must allow for the facts that the extent of divergence of the straight line from the curve varies with the position on the curve of the plots representing the two common points concerned, being (in the case of a cosine curve) most at 0° and least at 90°, and that the error is such as to render the slider potential too low when at any position except the ends. Any compensating potential must therefore vary with the position of the resistor in the chain, must be zero when the slider is at either end of the potentiometer across it, and be additive when the slider is between those ends.

One example of a compensating circuit for a cosine potentiometer as above described, the supply voltage of which is alternating, is shown in Figure 4. This incorporates a transformer 20 the primary 21 of which is connected between earth and the higher potential end of that potentiometer with which the slider 11 at any given moment is engaged, in this case potentiometer 10. The secondary 22 of the transformer is connected, in series with a very high resistance 23, between slider 11 and the higher potential end of potentiometer 10. If the resistance of the resistor to

which the potentiometer is connected (resistor 3 in this case) is assumed zero in comparison with the resistance of potentiometer 10 it will be seen that the secondary current creates a compensating potential difference in the potentiometer only when slider 11 is not at one of the ends; when the slider is at the end P the secondary current does not flow in potentiometer 10 at all and when the slider is at the end Q the secondary current is almost entirely diverted by resistor 3. Secondary 22 is connected in such sense that the compensating potential increases the potential of slider 11 in all other positions. It will also be seen that the value of the compensating potential difference varies with the position of the resistor in the chain, since primary 21 is connected to the potentiometer across this resistor.

In the above description it has been assumed that the equipment operates in accordance with a cosine law. It may however operate in accordance with other laws, for example a sine law or a square law, the necessary alteration of the resistor values or of the compensating circuit will be obvious to those skilled in the art.

An embodiment of the invention will now be described by way of example as applied to the cosine potentiometer form first described with reference to Figures 1 to 3, having as before an open chain of nine resistors and two potentiometers to cover the range 0°–90°. This is illustrated by Figure 5, in which details of mechanical construction have been much simplified in order to clarify the principle of operation. Reference letters and numerals corresponding to those of Figures 1 to 3 are used where applicable.

A first contact bank is formed by mounting on the face of a first insulating disc 30 near the periphery five metallic contacts or sectors 31 insulated from each other and equally spaced round the disc. They correspond to alternate studs A^1, C^1, E^1, G^1 and I^1; stops (not shown) are provided between adjacent sectors A^1 and I^1. A second contact bank is formed by mounting on a second disc 32, similar to the first disc, five contacts or sectors 33 corresponding to the remaining studs—B^1, D^1, F^1, H^1 and J^1, the stops (not shown) being between sectors B^1 and J^1. Discs 30 and 32 are mounted in fixed relative coaxial position with the sector sides of the discs facing each other. The sectors of the two discs are interconnected exteriorly by the appropriate resistors, e. g. sector A^1 on disc 30 is connected to sector B^1 on disc 32 by resistor 1, sector B^1 to sector C^1 (on disc 30) by resistor 2 and so on. The remaining resistors are omitted from the drawing for simplicity. It will be seen that as the total number of resistors is odd, the chain begins at the end contact or sector A^1 of the first bank and ends on end contact or sector J^1 of the second bank, the supply being applied as before across these end sectors, of which sector J^1 is earthed.

In between and coaxial with the discs is a ring 34 of insulating material bearing the toroidal windings of the two potentiometers 10 and 12; half the ring, circumferentially, comprises potentiometer 10 and the other half potentiometer 12. Rotatably coaxial with the equipment so far described is a single slider 11 designed to traverse round the two potentiometer windings. The ends P and Q of potentiometer 10 are adjacent to the ends S and R respectively of potentiometer 12, the last turn at each end of one potentiometer being so close to the last turn of the other potentiometer as to allow the slider to touch both together and thus to

allow the slider to pass from one potentiometer to the other without a sudden change of potential, as described above. These turns are shown less closely spaced to avoid confusing the drawing. The ends P and S of the potentiometers are led to two brushes P^1 and S^1 that engage the sectors of disc **30** and the ends Q and R are led to two brushes Q^1 and R^1 engaging the sectors of disc **32**. The brushes are fixed relative to the potentiometer ring by means not shown and rotate with it. The positions of the brushes relative to each other and to the sectors will appear later. The brushes are not wide enough to bridge successive sectors.

Slider **11** and potentiometer ring **34** are rotated relative to the fixed discs by the following system of gearing, in which provision is made for the introduction of a fixed angle α if desired, so that the output may be proportional to $\cos(\theta \pm \alpha)$ instead of to $\cos\theta$. A hollow control shaft **40** the angular position of which represents the angle θ passes freely through the centre of disc **30** and operates a first input member (not shown) of a differential gear **41** the second input member of which (also not shown) is operated by a solid shaft **42** coaxially within shaft **40**; the angular position of shaft **42** represents the fixed angle α. The output from gear **41** is the shaft **43**; this drives slider **11** direct and, through 4:1 reduction gear **44**, the potentiometer ring **34**, in a direction opposite to slider **11** by means of radial spokes **45**. Shaft **42** may of course be set to zero if only $\cos\theta$ is required. It will be seen that as the five sectors are equally spaced round each disc the potentiometer ring **34** rotates one-fifth of a revolution whilst each brush moves from its position on one sector to the corresponding position on the next sector. Owing to the reduction gear **44** the slider makes four-fifths of a revolution during this period and will accordingly make one complete revolution relative to the potentiometer ring, thus traversing both potentiometers.

In order to understand the operation of this equipment, reference should be made to Figure 6 in which the electrical part of the equipment is shown in developed form with the sectors straight instead of curved and referenced to correspond to Figure 1. It is convenient to consider each sector as being hypothetically divided circumferentially into three parts (as shown by dotted lines) labelled X, Y, and Z in the direction of the earthed end of the chain. The circumferential length of the insulated space between adjacent sectors is the same as that of one part. Each part or space therefore subtends 18° at the centre of the disc. The spaces will be referred to by the letters of the bounding sectors; thus "space A^1C^1" is the insulated space between sectors A^1 and C^1; space J^1B^1" is between sectors J^1 and B^1, and so on.

In operation shaft **42** (see Figure 5) is set (if desired) to represent some fixed angle α and is secured to shaft **40**, which is then rotated in accordance with the variable input angle θ. The potential of slider **11** thus varies in accordance with $\cos(\theta \pm \alpha)$. In traversing the full range, as before, from $(\theta \pm \alpha) = 0°$ to $(\theta \pm \alpha) = 90°$, the position at the commencement is shown in Figure 6*a*. Slider **11** is at the end P of potentiometer **10**, which is engaging resistor **1** by way of brushes P^1, Q^1 and sectors A^1, B^1. The positions of the brushes are as follows: P^1 and Q^1 between parts X and Y of sectors A and B respectively; R^1 and S^1 entering spaces J^1B^1 and A^1C^1 from sectors J^1 and A^1 respectively. The positions of brush R^1 on sector J^1 (which is shown again at the top of the figure for convenience) and brush S^1 on sector A^1 at this stage has no electrical significance; their positions merely correspond to the off position of potentiometer **12**. The arm (not shown) that carries brushes R^1 and Q^1 is now against the stop, above referred to, between sectors B^1 and J^1. The similar arm carrying the other brushes P^1 and S^1 is now against the stop between sectors A^1 and I^1.

Whilst the slider is traversing potentiometer **10** from P to Q each brush moves a distance equal to the length of two parts. During this period the brushes R^1 and S^1 move from sectors J^1 and A^1 to sectors B^1 and C^1 respectively, thus transferring potentiometer **12** from the off position between sectors J^1 and A^1 (between which is no resistor) into position across resistor **2** in the "hand-over-hand" manner above described. When therefore the slider leaves the end Q of potentiometer **10** for the end R of potentiometer **12**—see Figure 6*b*—the brushes have reached the following positions: P^1 and Q^1 on parts Z of sectors A^1 and B^1 respectively but about to leave them; and R^1 and S^1 on sectors B^1 and C^1 respectively, between parts X and Y. Potentiometer **12** is thus engaging resistor **2** when the slider moves onto it. This is the position occupied by the brushes in Figure 5. Whilst potentiometer **12** is engaged by the slider and its brushes are moving along sectors B^1 and C^1 the brushes P^1 and Q^1 of potentiometer **10** first traverse spaces A^1C^1 and B^1D^1 respectively and then reach parts X of sectors C^1 and D^1 (see Figure 6*c*), thus transferring potentiometer **10** to the next resistor **3** in the "hand-over-hand" manner. It will be seen that, as shown with reference to Figure 1, potentiometer **10** may be connected across only the odd-numbered resistors—i. e. those disposed horizontally in Figure 6—whereas potentiometer **12** may be connected across only the even-numbered resistors—i. e. those disposed obliquely.

The rest of the operation follows closely that already described, until the end of the scale is reached with the slider at the end Q of potentiometer **10**, connected across resistor **9**, and with potentiometer **12** in an off position with its brushes on sectors J^1 and A^1. The essential requirements are that the brushes change sectors only when their potentiometer is not engaged by the slider, and, conversely, that as long as a potentiometer is so engaged its brushes remain on their respective sectors. So long as one potentiometer is in position across the next resistor before the slider reaches the end of the other potentiometer the precise relative positions of the brushes is not of importance.

The compensation circuit previously described with reference to Figure 4 may easily be applied to this embodiment, the only adaptation necessary being the provision of means for effecting a connection to the higher potential end of whichever potentiometer is engaged by the slider. A simple way of doing this is to provide a commutator **50** (see Figure 7) having two semi-circular segments **51** and **52** connected respectively to ends P and R of potentiometers **10** and **12**; the associated brush **53** is ganged with slider **11** of potentiometers **10** and **12** so as to rotate in synchronism with it. The two gaps **54**, **55** between the segments are so located relative to brush **53** that whilst slider **11** is engaging potentiometer **10**, brush **53** is engaging segment **51**, so that the higher potential end P of this potentiometer is connected to brush **53** by way of this segment.

Similarly whilst slider 11 is engaging potential end 12, brush 53 is engaging segment 52, so that the higher potentiometer R of this potentiometer is connected to brush 53. The connections from slider 11 and brush 53 to the compensating transformer are as described with reference to Figure 4, the lead to the end P of potentiometer 10 in that figure being now connected instead to brush 53. The operation is the same as before.

The above-described embodiments may be modified to cover the range 0°–360° instead of 0°–90°. This may be effected by employing only double the number of resistors required for the 0°–90° range and adding sufficient additional sectors to raise the total number of sectors to equality with the total number of resistors. This is shown in single diagrammatic form in Figure 8, in which for simplicity the range 0° to 90° is covered by only three resistors—referenced 1, 2, and 3—instead of by the nine resistors of the above embodiments. The part of the arrangement covering this range is otherwise similar to Figure 1 and is correspondingly referenced. To cover the range 90° to 180° another three resistors are added, each being referenced by the primed number of the corresponding resistor in the 0° to 90° range. To cover the range 180° to 360° (or 180° back to 0°) no more resistors are required: the sectors of this range are cross-connected as shown to the sectors of the 0° to 180° range. The chain is now a closed one. The input voltage is applied to the sectors at the 0° and 180° points whilst the 90° and 270° points are earthed and are the datum points. The application of this arrangement to the above-described embodiment is quite straightforward: alternate sectors are located on disc 30 the remainder on disc 31. In this arrangement continuous rotation of the potentiometer ring is of course permissible and the stops and off positions referred to above are not required.

The arrangement described in the foregoing paragraph may be modified very simply to operate in accordance with a sine rather than a cosine law. This may be effected merely by rotating the calibrations (see Figure 8) clockwise through 90°, leaving the connections to the supply and to earth as they were before. The earthed datum points of zero output now correspond to 0° and 180°.

The above embodiments are described in order to illustrate the invention and are not intended to limit its scope, which embraces various modifications of the equipment that should be readily apparent. The resistors may for instance be replaced by other forms of impedance elements, for example chokes; the impedance components or potentiometers may be in the form of tapped autotransformers; there may be more than two components, though of course their number must be at least one less than the number of impedance elements so as to leave at least one unbridged element for one of the components to be transferred to, this component being any of the ones not engaged by the common variable tapping at the time. The tapping means may be in the form of a common variable tapping traversing all components as described above, or may take the form of a separate tapping for each component combined with a simple selector switch that transfers the output lead from connection to the tapping of one component at the end of the traverse of that tapping along that component, to connection to the tapping of the next component. The compensation circuit described for application to a variable impedance device operates under a sine or cosine law may be modified in detail; for example the connection from the unearthed end of the primary of the transformer may be made to the lower potential end of the potentiometer engaged by the slider rather than to the higher potential end, and the connection from the secondary may be made to the end of this potentiometer that is not connected to the primary. Moreover the mechanical part of the control may be of a different type from that described.

What I claim is:

1. A variable impedance device comprising in combination, at least three impedance elements connected in series and having impedances satisfying a predetermined law; two impedance components each having a high impedance in comparison with the impedance of any of said elements; tapping means for connecting said components in shunt to any two consecutive ones of said elements, respectively; a tapping member adapted to engage either of said components; means for changing the shunt connection of said component not engaged by said tapping member from one element adjacent the other shunted element to the other element adjacent thereto; and means for traversing said tapping member along any of said components while said component is connected in shunt to one of said elements.

2. A variable impedance device comprising in combination, at least three impedance elements connected in series and having impedances satisfying a predetermined law; means for applying a voltage to the series connection of said elements; two impedance components each having a high impedance in comparison with the impedance of any of said elements; tapping means for connecting said components in shunt to any two consecutive ones of said elements, respectively; a tapping member adapted to engage either of said components; means for changing the shunt connection of said component not engaged by said tapping member from one element adjacent the other shunted element to the other element adjacent thereto; means for traversing said tapping member along any of said components while said component is connected in shunt to one of said elements; means connected to said tapping member for compensating the error of the device when said tapping member engages a point between the ends of any of said components; and means for deriving a voltage between said tapping member and a predetermined point of the series connection of said elements.

3. A variable impedance device comprising in combination, at least three resistor elements connected in series and having resistances satisfying a predetermined law; two resistive potentiometers each having a high resistance in comparison with the resistance of any of said elements; tapping means for connecting said potentiometers in shunt to any two consecutive ones of said elements, respectively; a tapping member adapted to engage either of said potentiometers; means for changing the shunt connection of said potentiometer not engaged by said tapping member from one element adjacent the other shunted element to the other element adjacent thereto; and means for traversing said tapping member along any of said potentiometers while said potentiometer is connected in shunt to one of said elements.

4. A variable impedance device comprising in

combination, at least three resistor elements connected in series and having resistances satisfying a predetermined law; means for applying a voltage to the series connection of said elements; two resistive potentiometers each having a high resistance in comparison with the resistance of any of said elements; tapping means for connecting said potentiometers in shunt to any two consecutive ones of said elements, respectively; a tapping member adapted to engage either of said potentiometers; means for changing the shunt connection of said potentiometer not engaged by said tapping member from one element adjacent to the other shunted element to the other element adjacent thereto; means for traversing said tapping member along any of said potentiometers while said potentiometer is connected in shunt to one of said elements; and means for deriving a voltage between said tapping member and a predetermined point of the series connection of said elements.

5. A variable impedance device comprising in combination, at least three resistor elements connected in series and having resistances satisfying a predetermined law; means for applying a voltage to the series connection of said elements; two resistive potentiometers each having a high resistance in comparison with the resistance of any of said elements; tapping means for connecting said potentiometers in shunt to any two consecutive ones of said elements, respectively; a tapping member adapted to engage either of said potentiometers; means for changing the shunt connection of said potentiometer not engaged by said tapping member from one element adjacent the other shunted element to the other element adjacent thereto; means for traversing said tapping member along any of said potentiometers while said potentiometer is connected in shunt to one of said elements; means connected to said tapping member for compensating the error of the device when said tapping member engages a point between the ends of any of said potentiometers; and means for deriving a voltage between said tapping member and a predetermined point of the series connection of said elements.

6. A variable impedance device comprising in combination, a plurality of resistance elements connected in series and including odd numbered elements and even numbered elements, said elements having resistances satisfying a predetermined law; means for applying a voltage to the series connection of said elements; two banks of contacts, the successive junctions of said resistor elements being connected to successive contacts in each of said banks alternately; two pairs of brushes each being arranged for cooperation with one of said banks, respectively, said brushes being adapted to engage the contacts of said banks without bridging any two contacts; a first resistive potentiometer; a second resistive potentiometer, said potentiometers each having a high resistance in comparison with the resistance of any of said elements; a connection between one of said brushes cooperating with one of said banks and one end of said first potentiometer; a connection with one of said brushes cooperating with the other of said banks and the other end of said first potentiometer; connections between the ends of said second potentiometer and the remaining ones of said brushes, said brushes being disposed in relation to said banks for said potentiometers being adapted to bridge, respectively, consecutive ones of said odd numbered elements and said even numbered elements; a tapping member adapted to engage either of said potentiometers; means for changing the shunt connection of said potentiometer not engaged by said tapping member from one element adjacent the other shunted element to the other element adjacent thereto; means for traversing said tapping member along any of said potentiometers while said potentiometer is connected in shunt to one of said elements; and means for deriving a voltage between said tapping member and a predetermined point of the series connection of said elements.

7. A variable impedance device comprising in combination, a plurality of resistance elements connected in series and including odd numbered elements and even numbered elements, said elements having resistances satisfying a predetermined law; means for applying a voltage to the series connection of said elements; two banks of contacts, the successive junctions of said resistor elements being connected to successive contacts in each of said banks alternately; two pairs of brushes each being arranged for cooperation with one of said banks, respectively, said brushes being adapted to engage the contacts of said banks without bridging any two contacts; a first resistive potentiometer; a second resistive potentiometer, said potentiometers being disposed end-to-end on a circle and each having a high resistance in comparison with the resistance of any of said elements; a connection between one of said brushes cooperating with one of said banks and one end of said first potentiometer; a connection with one of said brushes cooperating with the other of said banks and the other end of said first potentiometer; connections between the ends of said second potentiometer and the remaining ones of said brushes, said brushes being disposed in relation to said banks for said potentiometers being adapted to bridge, respectively, consecutive ones of said odd numbered elements and said even numbered elements, each pair of adjacent ends of said potentiometers being connected to those of said brushes which engage contacts of the same of said banks; a tapping member being adapted to rotate about the center of the circle and to engage either of said potentiometers; means for changing the shunt connection of said potentiometer not engaged by said tapping member from one element adjacent the other shunted element to the other element adjacent thereto; means for traversing said tapping member along any of said potentiometers while said potentiometer is connected in shunt to one of said elements, whereby said tapping member upon leaving one of said potentiometers engages the other of said potentiometers; and means for deriving a voltage between said tapping member and a predetermined point of the series connection of said elements.

8. A variable impedance device comprising in combination, a plurality of resistance elements connected in series and including odd numbered elements and even numbered elements, said elements having resistances satisfying a predetermined law; means for applying a voltage to the series connection of said elements; two banks of contacts, the successive junctions of said resistor elements being connected to successive contacts in each of said banks alternately; two pairs of brushes each being arranged for cooperation with one of said banks, respectively, said brushes being adapted to engage the contacts of said banks without bridging any two contacts; a first

resistive potentiometer; a second resistive potentiometer, said potentiometers being disposed end-to-end on a circle and each having a high resistance in comparison with the resistance of any of said elements; a connection between one of said brushes cooperating with one of said banks and one end of said first potentiometer; a connection with one of said brushes cooperating with the other of said banks and the other end of said first potentiometer; connections between the ends of said second potentiometer and the remaining ones of said brushes, said brushes being disposed in relation to said banks for said potentiometers being adapted to bridge, respectively, consecutive ones of said odd numbered elements and said even numbered elements; a tapping member being adapted to rotate about the center of the circle and to engage either of said potentiometers; gearing means associated with said tapping member and said brushes and ensuring that said tapping member traverses the entire length of one of said potentiometers while said brushes connected to said tapping member remain on the same of said contacts of said banks interconnected by a resistor element, and prior to the transference of said tapping member to the other of said potentiometers said brushes connected to the other of said potentiometers are transferred to the pair of contacts interconnected by the adjacent resistor element; and means for deriving a voltage between said tapping member and a predetermined point of the series connection of said elements.

9. A variable impedance device comprising in combination, a plurality of resistance elements connected in series and including odd numbered elements and even numbered elements, said elements having resistances satisfying a predetermined law; means for applying an alternating voltage to the series connection of said elements; two banks of contacts, the successive junctions of said resistor elements being connected to successive contacts in each of said banks alternately; two pairs of brushes each being arranged for cooperation with one of said banks, respectively, said brushes being adapted to engage the contacts of said banks without bridging any two contacts; a first resistive potentiometer; a second resistive potentiometer, said potentiometers being disposed end-to-end on a circle and each having a high resistance in comparison with the resistance of any of said elements; a connection between one of said brushes cooperating with one of said banks and one end of said first potentiometer; a connection with one of said brushes cooperating with the other of said banks and the other end of said first potentiometer; connections between the ends of said second potentiometer and the remaining ones of said brushes, said brushes being disposed in relation to said banks for said potentiometers being adapted to bridge, respectively, consecutive ones of said odd numbered elements and said even numbered elements; a tapping member being adapted to rotate about the center of the circle and to engage either of said potentiometers; gearing means associated with said tapping member and said brushes and ensuring that said tapping member traverses the entire length of one of said potentiometers while said brushes connected to said tapping member remain on the same of said contacts of said banks interconnected by a resistor element, and prior to the transference of said tapping member to the other of said potentiometers said brushes connected to the other of said potentiometers are transferred to the pair of contacts interconnected by the adjacent resistor element; a transformer including a primary and a secondary, said primary being connected between a predetermined point of the series connection of said resistor elements and either end of said potentiometer being traversed by said tapping member, said secondary being connected between said tapping member and either end of said potentiometer being traversed by said tapping member; and means for deriving a voltage between said tapping member and an alternating predetermined point of the series connection of said elements, whereby the voltage derived between said tapping member and the predetermined point of the series connection of said elements is corrected when said tapping member is located between the ends of said potentiometer.

10. A variable impedance device as claimed in claim 9, a commutator having a first semi-circular segment and a second semi-circular segment, said first semi-circular segment being connected between said primary and said potentiometer being traversed by said tapping member, said other semi-circular segment being connected to the other potentiometer; and a brush connected to said primary and traversing said commutator in synchronism with said tapping member whereby said brush always engages said segment connected to said potentiometer engaged by said tapping member.

11. A variable impedance device as claimed in claim 10, the connection between said secondary and said potentiometer being completed by way of said commutator.

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REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
734,438	Skinner	July 21, 1903
2,114,143	Hunter	Apr. 12, 1938