March 19, 1957 D. C. STRAIN 2,786,122

RESISTANCE UNIT

Filed July 29, 1954

Fig. 4.

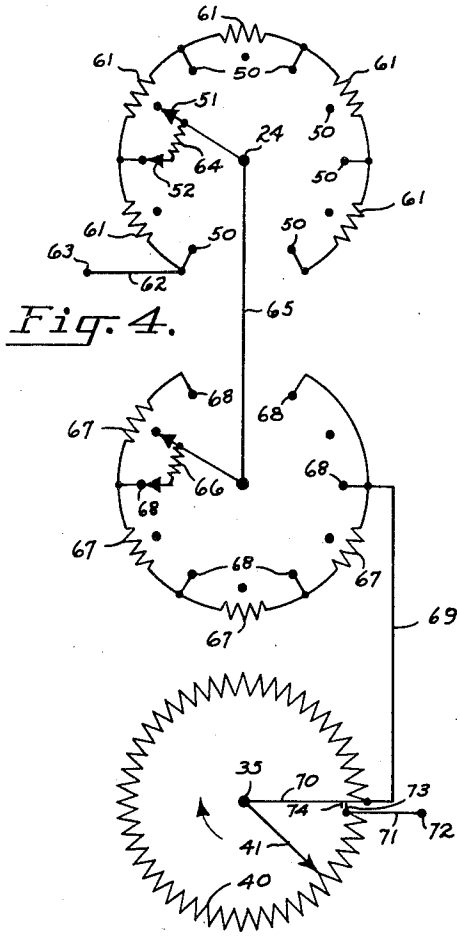


Fig. 2.

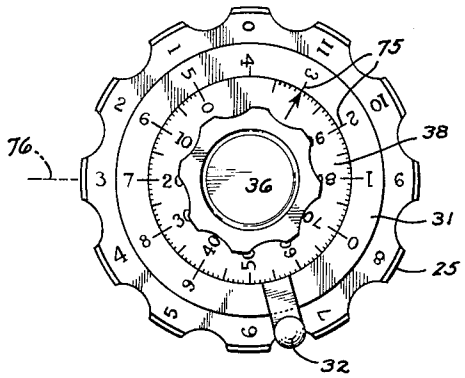


Fig. 1.

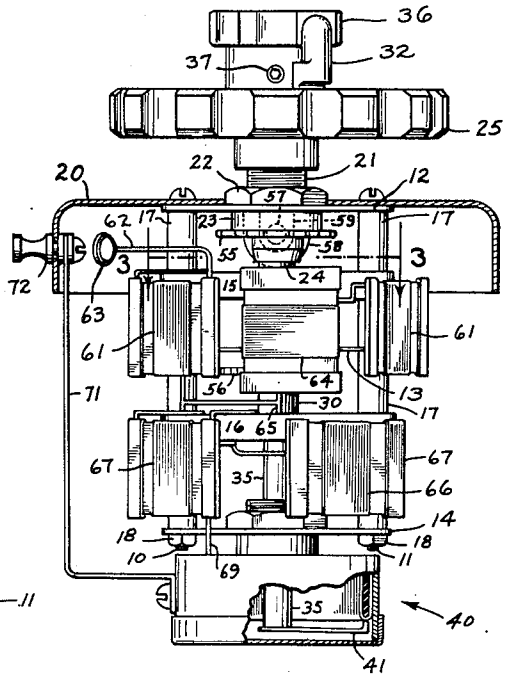
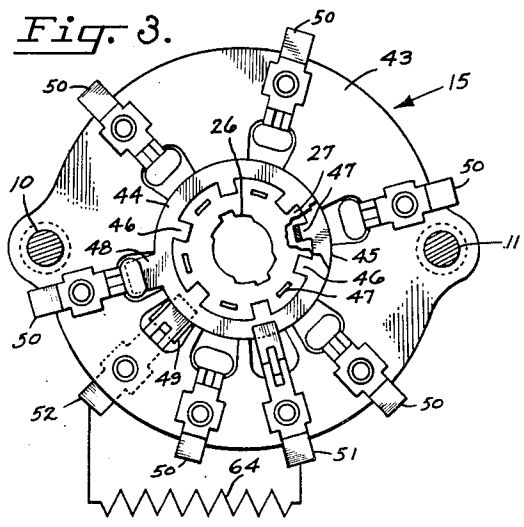


Fig. 3.



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2,786,122

RESISTANCE UNIT

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15 Claims. (Cl. 201—48)

This invention pertains to impedance units and relates particularly to a novel and simplified construction of a resistance unit which affords increased convenience of operation and accuracy of performance.

It is a principal object of this invention to provide a resistance unit wherein the number of resistance value selections is almost twice the number of resistance elements employed in the unit, whereby to afford economy of production and maximum compactness of assembly.

Another important object of this invention is to provide a resistance unit which employs only two sizes of resistance elements, thereby effecting further economies of production.

A further important object of this invention is the provision of a resistance unit which employs only two sizes of resistance elements, whereby to effect equalization of power dissipation and to afford higher current and power ratings.

Still another important object of the present invention is to provide an impedance unit which utilizes a single wafer switch which is economically produced and provides for symmetrical arrangement of the impedance elements and affords continuous rotation of but one current carrying contact through all positions without the development of undesirable switching transients.

A still further important object of this invention is to provide a resistance unit in which switching transients due to open or short circuits are minimized without the usually complex construction required for synchronizing the switching contacts.

It is another important object of the present invention to provide a resistance unit employing resistance elements of low maximum value to produce high resistance units.

Another important object of this invention is the provision of a highly accurate impedance unit in which the impedance values selected are read directly upon concentric operating dials.

Still another important object of the present invention is to provide an impedance unit which is of simplified construction for economical manufacture, which requires but a single hole for mounting on a panel and which is operated with maximum facility and precision.

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

Figure 1 is a plan view of a resistance unit embodying features of the present invention, portions thereof being broken away to disclose details of construction;

Figure 2 is a front elevation of the concentric operating dials, as viewed from the top in Figure 1;

Figure 3 is a sectional view taken along the line 3—3 in Figure 1 showing details of construction of one of the wafer switch elements; and

Figure 4 is a schematic diagram of the electrical circuit employed in the resistance unit illustrated in Figure 1.

Stated broadly, the present invention involves a series arrangement of fixed impedance elements, with each element connected at its ends to contacts arranged in a circular pattern for selective engagement by another fixed impedance element having a value of one-half the impedance values of the said series connected impedance elements, whereby to provide interpolation between each of the series connected elements. A plurality of these impedance units may be connected together in series, with each succeeding series being composed of elements having a fractional value, preferably one-tenth of its preceding unit. In this latter arrangement, it is preferred to terminate the succession of units with a continuously variable impedance having a total value at least equal to the impedance value of the next preceding interpolating impedance.

Referring to the drawings, the mechanical assembly illustrated in Figure 1 is designed particularly to accommodate the type of resistance unit circuit shown in Figure 4. This assembly includes a frame comprising a pair of parallel rods **10**, **11** maintained in spaced relation by the transverse forward plate **12**, intermediate plate **13**, the rear plate **14**, and the first switch member **15** and second switch member **16**. These switch members are disposed to the rear of the front and intermediate plates, respectively. The plates and switch members are maintained in properly spaced relation on the rod by means of interposed sections of spacer tubing **17** carried on the rods, and the assembly is drawn into firm placement by tightening the nuts **18** on the threaded ends of the rods.

Also supported by the parallel rods at the forward ends thereof is a cap **20**. A cylindrical can (not shown) encloses a major portion of the apparatus and functions by a friction or other connection with the cap to seal and electrically shield the apparatus therein.

A hollow externally threaded bushing **21** extends through the axial center of the forward plate **12** and is secured thereto by the locking nut **22** and collar **23** disposed on opposite sides of the forward plate. Extending axially through said bushing is a hollow shaft **24**. This shaft is secured at its forward end to the outer operating dial **25**. The rear end of shaft **24** extends through the key slot **26** in the central rotary section **27** of the first switch member **15**, the said rear end of the shaft being provided with a key by which to secure the shaft and rotary section together.

A second hollow shaft **30** extends through the hollow outer shaft **24** and is secured at its forward end to the intermediate operating dial **31** which nests freely within a central depression formed in the outer dial **25**. The projection **32** extending from the dial **31** functions as a handle by which to manipulate the dial. The rear end of shaft **30** extends through the key slot in the central rotary section of the second switch member **16**, a key being provided on the rear end of shaft **30** for securing said shaft and rotary section together.

A third shaft **35** extends through the hollow second shaft **30**. The forward end of this third shaft is secured to knob **36**, as by the Allen set screw **37**, the knob being secured firmly to the inner dial **38** which nests within a central depression formed in the intermediate dial **31**. The rearward end of shaft **35** extends through the rear plate **14** and through the axial center of the interpolating resistance **40** for supporting the contact arm **41** of the latter.

Referring particularly to Figures 1 and 2 of the drawing, it is to be observed that the faces of the concentric dials **25**, **31**, **38** lie in a common plane. This arrangement affords maximum compactness of construction and also enables the said dial faces to carry calibrations, such as those illustrated in Figure 2 and described in detail hereinafter.

Referring now to Figure 3 of the drawing, the first

switch member 15 is shown to include a fixed section 43, supported upon the spaced rods 10, 11, and the central rotary section 27 previously mentioned, both of which sections are preferably constructed of electrically non-conducting material. The rotary section supports a pair of collector rings 44, 45 disposed upon opposite sides of the rotary section and secured thereto by means of the fingers 46, 47, respectively. Collector ring 44 is provided with a projecting brush 48, while collector ring 45 is provided with the projecting brush 49. These brushes are displaced angularly from each other, for purposes described in detail hereinafter.

The fixed section 43 of the wafer switch shown in Figure 3 supports a plurality of contact elements 50, which are arranged in a symmetrically spaced pattern circumferentially about the rotary section for selective engagement by the brushes 48, 49. In the construction illustrated in Figure 3, there are twelve contact elements 50 arranged in pairs on opposite sides of the fixed section, thereby providing six pairs of contacts arranged circumferentially at 60° intervals.

There is also shown in Figure 3 the contact elements 51, 52 which are mounted upon opposite sides of the fixed section of the switch, with contact 51 engaging collector ring 44 and contacts 52 engaging collector ring 45. These contacts are disposed at a 60° angle from each other and at a 30° angle from the adjacent contacts 50.

It is to be noted that the projecting brushes 48, 49 are also disposed at a 30° angle from each other so that engagement with the contacts 50 is made only by one brush at a time. However, the brushes are of sufficient width that engagement of one brush with a contact 50 is made before disengagement of the other brush from another of said contacts is effected. In this manner switching transients are reduced to a minimum.

The second switch member 16 is of substantially identical construction as the first switch member described hereinbefore.

It is common practice in the art on occasion to provide a plurality of electrically connected contact members 50 and, if desired, a plurality of collector rings and brushes in order to insure positive contact and faithful operation. It is to be understood that such an arrangement may be employed herein if so desired.

Means are provided to insure that the brushes 48, 49 of the switch member 15, and also the brushes for the second switch 16, will stop in precise alignment with the desired contact 50. The means illustrated in the drawing, Figure 1, comprises a peripherally notched wheel 55 secured to shaft 24 associated with the first switch member 15 (and wheel 56 secured to shaft 30 associated with the second switch member 16). A ball 57 is supported in a holder 58 secured to each of the forward and intermediate transverse plates 12, 13 and the ball is urged toward the notched wheel by means of an overlying spring member 59. The notches in the wheel correspond precisely with the angular positions of the contact members 50, 51, 52.

Referring now to Figures 1 and 4 of the drawing, the first switch member functions to support five resistance elements 61 which are connected in series, and each resistance element being connected between adjacent pairs of the contact elements 50, as best shown in Figure 4. One end of the series-connected resistance chain is connected through electrical conductor 62 to a terminal post 63 mounted in the cap 20. The other end of the resistance chain is open.

A sixth resistance element 64 is connected between the contact members 51, 52, which are in permanent sliding contact with the collector rings 44, 45, respectively. One end of this resistance 64 is connected through electrical conductor 65 to one end of a similar interpolating resistance 66 supported between the corresponding contacts of the second switch member 16, said contacts being in permanent sliding engagement with the collector rings of said second switch.

The second switch member 16 supports four resistance elements 67 connected together in series and each mounted between adjacent contacts 68 supported by the fixed section of said switch member, in the manner best illustrated in Figure 4.

The series chain of resistances supported by the second switch member is opened at one end and is connected at the other end through electrical conductor 69 to one end of the continuously variable resistance 40 and also through a collector ring arrangement, indicated by line 70 in Figure 4, to the rotary contact arm 41 which is controlled by shaft 35. The opposite end of the continuously variable resistance is connected through electrical conductor 71 to the terminal post 72 mounted upon the cap 20.

In order to permit continuous rotation of the contact arm 41 in either direction without incurring undesirable transients as the contact arm moves from one end of said resistance to the other, there are provided at said opposite ends of the resistance the electrical conductors 73, 74 which overlap each other in spaced relation. Thus, as the electrical contact arm 41 is moved between the ends of the resistance element 40, it bridges the spaced conductors 73, 74, and thus electrical continuity is maintained to prevent development of undesirable transients.

The values of the various resistance elements may be varied within wide limits, depending upon the total resistance desired, as well as the magnitude and type of stepwise graduations. As an illustration, a resistance unit having diverse practical uses is provided by employing resistance values as follows: Fixed resistance elements 61 each have a value of 2,000 ohms, with the associated interpolating resistance 64 having a value of 1,000 ohms; fixed resistance elements 67 each have a value of 200 ohms, with the associated interpolating resistance 66 having a value of 100 ohms; and the continuously variable interpolating resistance 40 has a maximum value of at least 100 ohms. This arrangement provides a maximum resistance of 12,000 ohms with stepwise selection in units of 1 ohm.

Referring to Figure 2, it is to be noted that the inner dial 38 is calibrated in one hundred five divisions. The variable resistance 40 is also provided in a resistance of 105 ohms. This provision of a resistance and a dial calibration in excess of 100 ohms affords the advantage of permitting an overrun on the variable interpolating resistance in order to establish a proper resistance balance without having to switch the second unit 16 back and forth between fixed resistances, in the event that the balance occurs in the upper range of the variable resistance.

In Figure 2 of the drawing, the dials are read from left to right on the left side of the center knob 36. The inner dial 38 cooperates with the interpolating resistance 40, and hence its calibrations are divided into smaller fractions than are the calibrations of dials 31 and 25. A mark 75 is inscribed adjacent each of the numerals on the intermediate dial 31 in order to provide an index line for the markings on the inner dial. No such marks are required on the outer dial 25 because the provision of the notched wheels 55, 56 and resiliently mounted balls insure accurate alignment of the numerals on the dials 25 and 31.

In the illustrated arrangement the readings are made along an imaginary horizontal index line, indicated by the dashed line 76 in Figure 2, projected through the index marks 75 and the markings on the inner dial. However, a positive index mark may be provided adjacent the outer dial to clearly identify the point of reading, if desired.

The calibration illustrated affords precise readings to four digits, and the fifth may be estimated with a high degree of accuracy. For example, the dial reading for the resistance setting shown in Figure 4 is indicated in

Figure 2 to be 3,720.0 ohms. This value may be derived by tracing the electrical circuit from the terminal post **63** through the first fixed resistance **61**, thence through interpolating resistance **64** and electrical conductor **65** through the second interpolating resistance **66**, thence through the three fixed resistance elements **67** (counterclockwise) through electrical conductor **69** and rotary contact **41**, then counterclockwise through the small segment of the continuously variable resistance **40** and through electrical conductor **71** to terminal post **72**.

It is to be observed that each of the fixed resistances in the two sets extend from the connecting elements of the switch members in spaced relation and in a radial pattern about the coaxial shafts and that they substantially fill the space between the transverse plates **12**, **13**, **14**. This arrangement is particularly advantageous, for it accommodates the fixed resistance within a minimum of space and yet offers maximum efficiency in heat dissipation and avoids the development of local concentrations of heat.

It will also be observed that the resistance unit construction of the present invention permits mounting on an instrument panel with maximum facility. The only requirement is a single hole in the panel to receive the bushing **21**. A lock nut is then tightened upon the threads of the bushing, whereupon the panel is secured between said lock nut and the forward lock nut **22**. This feature, together with the compact construction of the device, is of particular advantage when the device is to be incorporated into the main case of an electrical measuring instrument.

There are many inherent advantages in the resistance unit construction of the present invention: The use of fixed resistances enhances the frequency response of the system, as compared with the conventional potentiometer type instrument. The fixed resistances may be of any type and may be stabilized before being installed in the device, and may be replaced with maximum facility.

The compact arrangement of the concentric calibrated dials affords rapid adjustment to any position. The combination of dials provides an exceptionally long calibrated scale, by which to obtain increased accuracy of reading. The scale readings may be made in the same manner as the digits would be written, thereby eliminating possible confusion and error. The juxtaposed arrangement of the calibrations on the concentric operating dials, as compared with separate locations, not only simplifies the construction and installation but also greatly simplifies the operating procedure.

The use of fixed resistances and the provision of the switch positioning notched wheels and ball catch assemblies assure very high degree of accuracy in reproducing any desired resistance reading. The mechanical arrangement affords rapid and accurate assembly, thereby minimizing the cost of manufacture.

It will be apparent to those skilled in the art that the present invention affords the construction of resistance units of various sizes and types. For example, a complete resistance unit may be formed of the resistance elements mounted upon the first switch member **15** (the top section shown in Figure 4). In this case, it is to be noted that an eleven step unit is provided with but six resistance elements. As another example, a resistance unit may be formed with the five resistance elements mounted upon the second switch member, in which case a nine step resistance unit is provided with but five resistance elements. As a further example, a resistance unit may be formed from the combination of resistance elements mounted upon the two switch members, or from either of these in combination with the continuously variable interpolating resistance **40**.

It will also be apparent that the continuously variable interpolating resistance **40** may be replaced by one or more sections of fixed resistances of the type preceding it.

It will be further apparent to those skilled in the art that various changes may be made in the structural details described hereinbefore without departing from the scope and spirit of this invention. For example, if desired, the connecting elements **50**, **68** may be mounted upon the rotary section of the switch members and the brushes **48**, **49** mounted upon the fixed section, to reverse the relative positions of the resistance unit and contact brushes. The illustrated arrangement is preferred, however. The dial calibrations may be changed to permit readings on the right side of knob **36** from left to right, i. e. from the inner dial outward, or from a vertical line, as desired. The number of resistance elements of each section may be varied, as may the number of sections, as indicated hereinbefore.

Those skilled in the art will also recognize that the electrical connections between the several sections of the resistance unit may be changed from the arrangement shown in Figure 4. For example, the series connections may extend from contact **51** through interpolating resistance **64**, through fixed resistance **61**, then through a conductor to the second interpolating resistance **66** and through the three series-connected resistances **67** and conductor **69** to rotary contact **41**. Other circuit arrangements may also be provided, as desired.

It will be further apparent to those skilled in the art that impedance elements other than the resistance elements illustrated and described hereinbefore, may be utilized in the circuitry and mechanical assembly of the present invention. Thus, for example, the resistance elements may be replaced by elements which provide inductive impedance, and the term impedance element, as recited in the appended claims, is intended to include such elements.

The foregoing and other changes may be made without departing from the scope and spirit of the present invention. Accordingly, it is to be understood that the detailed description presented herein is merely illustrative of the invention and is not to be construed in a limiting sense.

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

1. An impedance unit comprising fixed impedance means having a terminal end, fixed interpolating impedance means having a terminal end, and adjustable connecting means releasably connecting the opposite ends of the interpolating impedance means one end at a time selectively to one end at a time of the opposite ends of the first named impedance means.

2. An impedance unit comprising a plurality of fixed impedance means connected together in series and having a terminal end, fixed interpolating impedance means having a terminal end, and adjustable connecting means releasably connecting the opposite ends of the interpolating impedance means one end at a time selectively to one end at a time of any of said series-connected impedance means.

3. An impedance unit comprising a plurality of chains of impedance means, each chain including a plurality of impedance means connected together in series and each chain having a terminal end, fixed interpolating impedance means associated with each chain and each having a terminal end, adjustable connecting means releasably connecting the opposite ends of the interpolating impedance means selectively to one end of any of the associated series-connected impedance means, and electrical conductor means connecting the said terminal ends together in series.

4. The impedance unit of claim 3 wherein the value of each impedance means in a chain is ten times the value of each impedance means in the chain next preceding it and the value of each fixed interpolating impedance means is one-half the value of each impedance means in the associated chain.

5. An impedance unit comprising a plurality of first

fixed impedance means connected together in series and having a terminal end, first fixed interpolating impedance means having a terminal end, adjustable connecting means releasably connecting the opposite ends of the first interpolating impedance means selectively to one end of any of said series-connected first impedance means, a plurality of second fixed impedance means connected together in series and having a terminal end, second fixed interpolating impedance means having a terminal end, adjustable connecting means releasably connecting the opposite ends of the second interpolating impedance means selectively to one end of any of said series-connected second impedance means, and electrical conductor means interconnecting one of the terminal ends of the first and second impedance means.

6. An impedance unit comprising a plurality of fixed impedance means connected together in series and having a terminal end, fixed interpolating impedance means having a terminal end, adjustable connecting means releasably connecting the opposite ends of the interpolating impedance means selectively to one end of any of said series-connected impedance means, variable interpolating impedance means having an impedance element and a relatively movable electric contact, the impedance element and contact each having a terminal end, and electrical conductor means interconnecting one of the terminal ends of the fixed impedance means and the variable impedance means.

7. An impedance unit comprising a plurality of first fixed impedance means connected together in series and having a terminal end, first fixed interpolating impedance means having a terminal end, adjustable connecting means releasably connecting the opposite ends of the first interpolating impedance means selectively to one end of any of said series-connected first impedance means, a plurality of second fixed impedance means connected together in series and having a terminal end, second fixed interpolating impedance means having a terminal end, adjustable connecting means releasably connecting the opposite ends of the second interpolating impedance means selectively to one end of any of said series-connected second impedance means, electrical conductor means interconnecting one of the terminal ends of the first and second impedance means, variable interpolating impedance means having an impedance element and a relatively movable electric contact, the impedance element and contact each having a terminal end, and electrical conductor means interconnecting one of the terminal ends of the second fixed impedance means and the variable impedance means.

8. The impedance unit of claim 7 wherein each of the first series-connected impedance means is ten times the value of each of the second series-connected impedance means, each fixed interpolating impedance means is one-half the value of each of the associated series-connected impedance means, and the value of the variable impedance means is at least equal to the value of the second interpolating impedance means.

9. The device of claim 7 wherein each of the first series-connected impedance means is a 2,000 ohm resistance, the first fixed interpolating impedance means is a 1,000 ohm resistance, each of the second series-connected impedance means is a 200 ohm resistance, the second fixed interpolating impedance means is a 100 ohm resistance, and the variable impedance means is at least 100 ohm rheostat.

10. An impedance unit comprising, in combination, a frame, switch means mounted on the frame and having a fixed section and a rotary section, one of the sections carrying a plurality of contact means and the other section carrying a pair of brush means electrically insulated from each other and arranged for sliding engagement one brush at a time with each contact means in sequence, a plurality of fixed impedance means each connected between two of the contact means and connected together in series and having a terminal end, fixed interpolating impedance means connected electrically between the spaced brush means and having a terminal end, and operating means mounted on the frame and connected to the said rotary section for rotating the latter.

11. An impedance unit comprising, in combination, a frame, switch means mounted on the frame and having a fixed section and a rotary section, one of the sections carrying a plurality of contact means and the other section carrying a pair of brush means electrically insulated from each other and arranged for sliding engagement separately with each contact means, a plurality of fixed impedance means each connected between two of the contact means and connected together in series and having a terminal end, fixed interpolating impedance means connected electrically between the spaced brush means and having a terminal end, variable interpolating impedance means mounted on the frame and having a fixed section and a rotary section aligned axially with the rotary section of the switch means, the fixed and rotary sections of the variable impedance means each having a terminal end, conductor means connecting one of the terminal ends of the variable impedance means and the impedance means on the switch means together, and a plurality of coaxial shafts supported by the frame and each connected to one of the said rotary sections, and operating means connected to each shaft for rotating the latter.

12. An impedance unit comprising, in combination, a frame, a plurality of switch means mounted on the frame and each having a fixed section and a rotary section, one of the sections carrying a plurality of contact means and the other section carrying a pair of brush means electrically insulated from each other and arranged for sliding engagement separately with each contact means, the rotary sections being in axial alignment, a plurality of fixed impedance means each connected between two of the contact means, the impedance means on each switch means being connected together in series and having a terminal end, fixed interpolating impedance means connected electrically between the spaced brush means of each switch means and each having a terminal end, conductor means connecting one of the terminal ends of the impedance means on each switch means together, and a plurality of coaxial shafts supported by the frame and each connected to one of the said rotary sections, and operating means connected to each shaft for rotating the latter.

13. An impedance unit comprising, in combination, a frame, a plurality of switch means mounted on the frame and each having a fixed section and a rotary section, one of the sections carrying a plurality of contact means and the other section carrying a pair of brush means electrically insulated from each other and arranged for sliding engagement separately with each contact means, the rotary sections being in axial alignment, a plurality of fixed impedance means each connected between two of the contact means, the impedance means on each switch means being connected together in series and having a terminal end, fixed interpolating impedance means connected electrically between the spaced brush means of each switch means and each having a terminal end, variable interpolating impedance means mounted on the frame and having a fixed section and a rotary section aligned axially with the rotary sections of the switch means, the fixed and rotary sections of the variable impedance means each having a terminal end, conductor means connecting one of the terminal ends of the variable impedance means and the impedance means on each switch means together in series, and a plurality of coaxial shafts supported by the frame and each connected to one of the said rotary sections, and operating means connected to each shaft for rotating the latter.

14. The impedance unit of claim 13 wherein the value of each impedance means in a chain is ten times the value of each impedance means in the chain next preced-

ing it and the value of each fixed interpolating impedance means is one-half the value of each impedance means in the associated chain, and the value of the variable interpolating impedance means is at least equal to the value of the fixed interpolating impedance means next succeeding it in order.

15. The impedance unit of claim 13 wherein the plurality of impedance means comprises a first and second chain of series-connected resistances wherein each of the resistances of the first chain is 2,000 ohms and each of the resistances of the second chain is 200 ohms, the fixed interpolating impedance means are first and second

resistances having values of 1,000 ohms and 100 ohms, respectively, and the variable interpolating impedance means is a rheostat having a value of at least 100 ohms.

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