April 26, 1955 F. M. BROWN ET AL 2,707,222

VOLTAGE DIVIDER

Original Filed Feb. 19, 1953

Fig. 1.

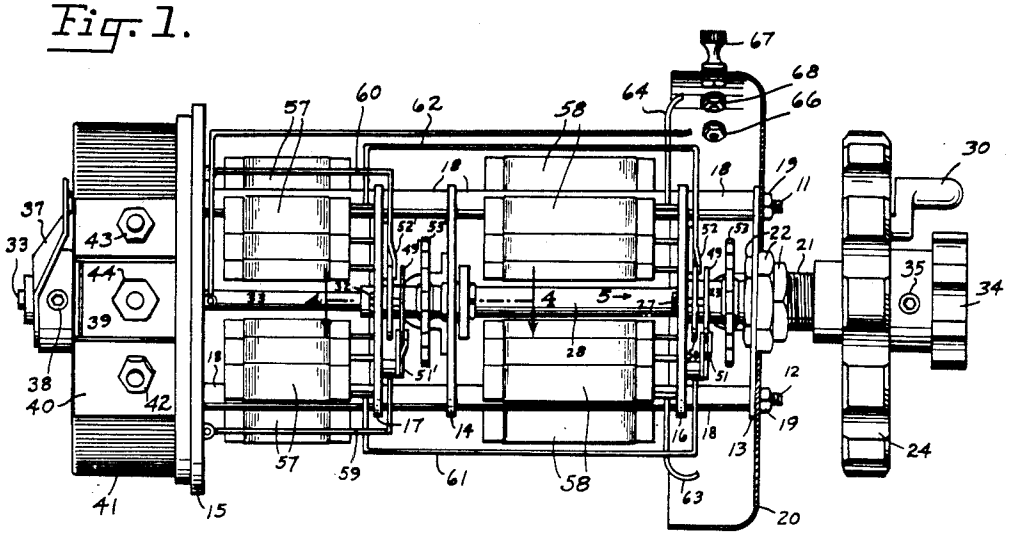


Fig. 2.

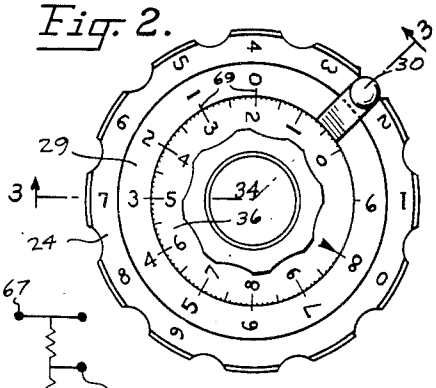


Fig. 3.

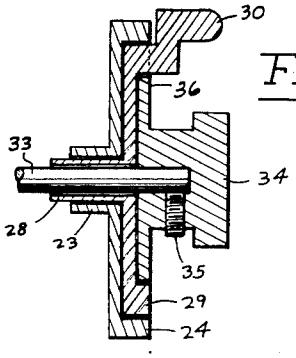


Fig. 4.

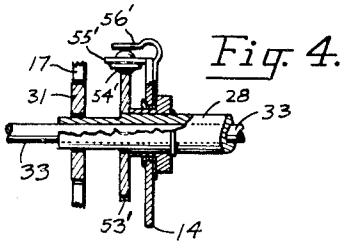


Fig. 6.

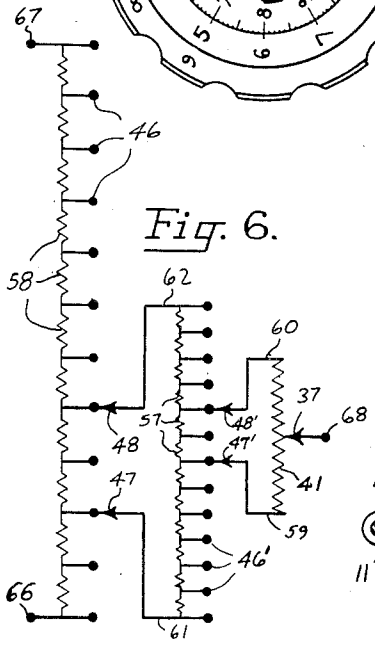
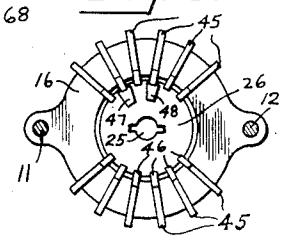


Fig. 5.



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VOLTAGE DIVIDER

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Continuation of application Serial No. 337,852, February 19, 1953. This application March 15, 1954, Serial No. 416,025

16 Claims. (Cl. 201—56)

This invention pertains to voltage dividers and relates particularly to a novel and simplified construction of a voltage divider which affords increased convenience of operation and accuracy of performance. This application is a continuation of our application filed February 19, 1953, under Serial No. 337,852, now forfeited, and entitled Voltage Divider.

It is the principal object of this invention to provide a highly accurate voltage divider in which the voltage values are read directly upon concentric operating dials.

Another important object of the present invention is to provide a voltage divider which is extremely compact in arrangement and yet affords maximum heat dissipation, thereby providing for higher wattage utilization in a minimum of space.

A further important object of this invention is the provision of a voltage divider construction which accommodates use of any type of impedance element desired.

A still further important but specific object of the present invention is the provision of a voltage divider which accommodates use of fixed resistances, thereby affording maximum frequency response and linearity and permitting pre-stabilization of the said resistances to insure maximum accuracy over a long operating period.

A further important object of this invention is the provision of a voltage divider which accommodates the use of fixed impedance elements, thereby allowing individual impedance elements to be replaced in the event of damage or burn-out.

Still another object of the present invention is to provide a voltage divider 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 voltage divider embodying the features of the present invention, a portion thereof being broken away to disclose details of construction;

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

Figure 3 is a sectional view taken along the line 3—3 in Figure 2 showing the coaxial arrangement of the operating shafts and the concentric arrangement of the operating dials;

Figure 4 is a fragmentary sectional view of the switch positioning means as taken along the line 4—4 in Figure 1;

Figure 5 is an end view of the switch means as viewed in the direction of arrow 5 in Figure 1; and

Figure 6 is a schematic diagram of the electrical circuit employed in the voltage divider illustrated in Figure 1.

Stated broadly, the present invention involves a shunting arrangement of interpolating impedances in such manner that the value of the shunting impedance Z_s is determined by the equation

$$Z_s = Z\frac{(nm)}{(n-m)}$$

wherein Z is the value of the impedance shunted, n is the number of impedances shunted and m is the number of impedances through which the shunting impedance is to interpolate.

Referring to the drawing the mechanical assembly illustrated in Figure 1 is designed particularly to accommodate the type of voltage divider circuit shown in Figure 6. This assembly includes a frame comprising a pair of parallel rods **11**, **12** maintained in spaced relation by the transverse forward plate **13**, the intermediate plate **14** and the rear plate **15**.

Supported on the parallel rods are the switch members **16** and **17** disposed, respectively, adjacent the plates **13** and **14** but slightly rearward thereof. The transverse plates **13**, **14**, **15** and switch members **16**, **17** are maintained in properly spaced relation on the rods by means of interposed sections of spacer tubing **18** carried by the rods. The foregoing elements are drawn into firm placement by tightening the nuts **19** upon 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 the 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 **13** and is secured thereto by the locking nuts **22**. Extending axially through said bushing is a hollow shaft **23**. This shaft is secured at its forward end to the outer operating dial **24**. The rear end of shaft **23** extends through the key slot **25** in the central rotary section **26** (Figure 5) of the switch member **16**, the said rear end of shaft **23** being provided with a key **27** by which to secure the shaft and rotary section **26** together.

A second hollow shaft **28** extends through the hollow outer shaft **23**. This second shaft **28** is secured at its forward end to the intermediate operating dial **29** which nests freely within the central depression formed in the outer dial **24**. The projection **30** extending from the dial **29** functions as a handle by which to manipulate the dial. The rear end of shaft **28** extends through the key slot in the central rotary section **31** of the switch member **17**, a key **32** being provided on the rear end of shaft **28** for securing said shaft and rotary section **31** together.

A third shaft **33** extends through the hollow second shaft **28**. The forward end of this third shaft is secured to knob **34**, as by Allen set screw **35**, the knob being secured firmly to the inner dial **36** which nests within the central depression formed in the intermediate dial **29**. The rear end of shaft **33** extends through the rear plate **15** and the electrical contact arm **37** is secured thereto by means of the Allen screw **38**.

Referring particularly to Figure 3 of the drawing, it is to be observed that the faces of the concentric dials **24**, **29**, **36** 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.

A circular flange **39** of electrically non-conductive material extends rearwardly from the plate **15** and serves as a mounting for the electrically non-conductive band **40** upon which is helically wound the resistance wire **41**. The opposite ends of the wire **41** are connected to the terminals **42**, **43**, respectively, while the contact arm **37** is connected electrically to terminal **44**. The arm **37** is arranged for sliding contact with the circular band of resistance wire **41** as the shaft **33** is rotated by knob **34**.

Referring now to Figure 5 of the drawing, the switch member **16** is shown to include twelve connecting elements **45** each having a contact end **46** which is disposed adjacent the central rotary section **26**. A pair of contact brushes **47**, **48** are mounted on the rotary section **26** in spaced relation in such manner that in any position of rotation of the rotary section they make sliding contact with any two of the contact ends **46** which are separated by one contact end. This arrangement is designed specifically to accommodate the voltage divider circuit of Figure 6. The width of the brushes **47**, **48** is preferably such that contact is made with an end **46** before contact is broken with the end **46** preceding it in the direction of rotation of the brushes.

Contact brush is connected electrically to the outer collector ring **49** mounted on the opposite side of the rotary

section 26, while contact brush 48 is connected electrically to the inner collector ring 50 (Figure 1). Contacts 51 and 52 are mounted on the fixed section of the switch member 16 and make sliding contact with the respective collector rings 49 and 50.

It is common practice in the art on occasion to provide a plurality of electrically connected contact ends 46 and a plurality of electrically connected cooperating brushes 47, 48 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.

The assembly of switch member 17 is substantially identical with that of switch member 16 and therefore like numerals are employed, but are distinguished therefrom by use of a prime (') superscript.

Means is provided to insure that the brushes 47, 48 and 47', 48' will stop in precise alignment with the desired two contact ends 46 and 46', respectively. The means illustrated in the drawing and shown best in Figure 4 comprises a peripherally notched wheel 53 secured to shaft 23 (and wheel 53' secured to shaft 28). A ball 54 is supported in a holder 55 secured to the forward transverse plate 13 and also to the intermediate plate 14, and the ball is urged toward the notched wheel by means of the overlying spring member 56. The notches in the wheel correspond precisely with the angular positions of the contact ends 46 and 46'.

Referring now to Figures 1, 5 and 6 of the drawing, there are shown eleven fixed resistance elements 57 each wound upon an insulating plate and secured between and supported by two of the connecting elements 45' of switch member 17. These resistance elements are connected together in series, the last element being attached at one end to the twelfth connecting element 45'. Similarly, a second set of eleven series-connected fixed resistance elements 58 is provided, each being secured between and supported by two of the connecting elements 45 of switch member 16.

It is to be observed that each of the fixed resistances in the two sets extends 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 13, 14, 15. This arrangement is particularly advantageous, for it accommodates the fixed resistances within a minimum of space and yet offers maximum efficiency in heat dissipation and avoids the development of local concentrations of heat.

The electrical circuitry is as follows: Conductor 59 connects one end of the interpolating resistance 41 from its terminal 42 to the contact 51' of collector ring 49' and thence to brush 47', while conductor 60 connects the opposite end of resistance 41 from its terminal 43 to the contact 52' of collector ring 50' and thence to brush 48'. Conductor 61 leads from one end of the series resistance 57 to the contact 51 of collector ring 49 of switch member 16 and thence to brush 47. Conductor 62 connects the opposite end of the series resistance 57 to the contact 52 of collecter ring 50 and thence to brush 48.

Conductors 63 and 64 lead from opposite ends of the series resistance 58, while conductor 65 leads from the terminal 44 of the rotary contact arm 37 of the interpolating resistance 41. For convenience these conductors are secured to terminal posts 66, 67 and 68, respectively, mounted in the rim of the protective cap 20. The posts 66 and 67 are the input terminals and posts 67 and 68 are the output terminals.

It will be observed that the voltage divider 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 such as a computing machine.

A typical circuit construction of the voltage divider illustrated in the drawing is as follows: Interpolating resistance 41 is 400 ohms; each of the eleven fixed resistances 57 is 200 ohms; and each of the eleven fixed resistances 58 is 1000 ohms. Thus, it is seen that the 400 ohms of interpolating resistance 41 is equal to the resistance of any pair 57 with which it is in parallel. Further, the maximum resistance of 2000 ohms in the series 57 is equal to the resistance of any pair of 58 with which it is in contact. The constant input resistance of the circuit, i. e. between terminals 66, 67 is 10,000 ohms.

By the foregoing arrangement it has been made possible to calibrate the operating dials to give a direct indication of the decimal fraction of voltage output. Although the calibration indications shown in Figure 2 of the drawing are represented in the base ten, other bases such as the binary base, may be employed. The calibration illustrated affords precise readings to four decimals, and the fifth place may be estimated with a high degree of accuracy. For example, the dial reading for the setting shown in Figure 6 is 0.73500, as shown in Figure 2. This represents the decimal fraction of input voltage appearing across the output terminals.

In Figure 2 of the drawing, the dials are read from left to right on the left side of the center knob 34. The inner dial 36 cooperates with the interpolating resistance 41 and therefore its calibrations are divided into smaller fractions than are the calibrations of dials 29 and 24. A mark 69 is inscribed adjacent each of the numerals on the intermediate dial 29 in order to provide an index line for the markings on the inner dial. No such marks are required on the outer dial 24 because the provision of the notched wheels 53, 53' and resiliently mounted balls 54, 54' insure accurate alignment of the numerals on the dials 24 and 29.

In the illustrated arrangement the readings are made along an imaginary horizontal index line projected through the index marks 69 and the markings on the inner dial, such as is indicated by the cross section line 3—3. However, a positive index mark may be provided adjacent the outer dial 24 to clearly identfy the point of reading, if desired. Such a marker may be provided, for example, by an index arm (not shown) secured to bushing 21, or by a visible line or dot imprinted upon a mounting panel (not shown) or upon the face of cap 20.

The structure of the present invention accommodates various modifications in the electrical circuitry associated therewith. For example, in the foregoing exemplified construction of the circuit shown in Figure 6 the dial 36 is employed to interpolate between two adjacent numbers on the intermediate dial 29. If desired, an arrangement may be provided in which the inner dial 36 is calibrated in three successive groups of ten numers, i. e. the range of the dial calibration is increased by a factor of three. Such an arrangement is of advantage, for example, when the voltage divider is used to record rapidly fluctuating voltages, for the inner dial thereby has a range encompassing, and thereby is capable of interpolating between, three units of the intermediate dial 29. By this arrangement the operator does not have to switch said intermediate dial to cover the range.

To provide the inner dial 36 with a scale expanded by the foregoing factor of three, whereby to interpolate through three of the fixed resistances 57, the electrical circuit shown in Figure 6 is modified as follows: The brushes 47', 48' are spaced apart sufficiently so that four of the fixed resistances 57 are included between said brushes. The value of the interpolating resistance 41 is also changed in accordance with the equation

$$R_s = R\frac{(nm)}{(n-m)}$$

wherein Rs is the value of the shunting resistance 41, R is the value of each of the fixed resistances 57, n is the number of fixed resistances 57 shunted and m is the number of fixed resistances 57 through which it is desired to interpolate. It is to be noted that in this equatiton n is always greater than m, and this condition is assumed to exist in those claims wherein the equation is set forth. Using the exemplified construction described hereinbefore, wherein the resistances 57 are each 200 ohms, the value of R_s for the expanded dial is calculated to be 2400 ohms, with four of the resistances 57 shunted thereby.

It will be observed that the above equation also holds for the circuit arrangement shown in Figure 6. In this case the value of resistance 41 is equal to the sum of the two resistances 57 shunted. Whenever the dial calibration is expanded by an integer the value of resistance 41 is greater than the sum of the resistances 57 by some integer.

It will also be observed that the foregoing equation is applicable to determine the sum of resistances 57 for shunting the main resistances 58. In the event it is de-

sired to expand the calibration of the intermediate dial **29** in the manner of dial **36** described above, the equation is equally applicable. In any case the series of resistances **57** functions as the interpolating resistance for the resistances **58**.

Another circumstance which is accommodated by the voltage divider construction of the present invention is that in which rapid control of a slightly varying voltage is desired. In such instance the inner dial **36** may be expanded by a fraction of an integer, for example by one-tenth. This expansion permits the operator to follow the sightly varying voltage across the value at which he would normally have to change the setting of the intermediate dial **29**. This arrangement affords rapid control and eliminates switching transients and voltage surges. In this arrangement it will be recognized that the value of the interpolating resistance **41** is greater than the sum of the resistances **57** shunted.

There are many inherent advantages in the voltage divider construction of the present invention: The use of the fixed primary resistances **57** and **58** enhances the frequency response of the system, as compared with the conventional potentiometer type instruments, by reducing the shunt capacitance and series inductance substantially below the values characterizing the latter type. The fixed resistances may be of any type and may be stabilized before being installed in the device. The interpolating resistance **41** is but a small fraction of the complete circuit and therefore the effect of its lesser accuracy is decreased proportionately. This resistance may be made of heavier wire which contributes to longer operating life.

Greater accuracy and linearity is achieved in the voltage divider construction of this invention. The zero resistance is greately reduced by use of the fixed resistances. The deleterious effect of small variations in switch contact resistance is reduced considerably by the fact that such resistances are associated only with a large resistance which is in parallel with a small fraction of the main resistances **58**. Since the accuracy of the resistances increases from the interpolating resistance **41** through the fixed resistances **57** to the main resistances **58**, the effects of the lesser accuracies in the preceding resistances is greatly reduced by the fact that they are arranged in parallel with more accurate resistances.

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 are made in the same manner as the digits would be written, thereby eliminating possible confusion and error. The position 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 wheels **53**, **53'** and ball catch assembly assures a very high degree of accuracy in reproducing any desired voltage reading.

The mechanical arrangement of fixed resistances operated by coaxial shafts from concentric dials provides a construction which is very compact and yet highly efficient in the dissipation of heat. 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 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 **45** may be mounted on the rotary section **26** and the brushes **47**, **48** mounted on the fixed section **16**, to reverse the relative positions of the resistance units and contact brushes. The illustrated arrangement is preferred, however. The dial calibrations may be changed to permit reading on the right side of knob **34** from left to right, i. e. from the inner dial outward, or from a vertical line.

By means of the structure described hereinbefore, the Thompson-Varley shunt circuit illustrated in Figure 6 provides a voltage divider of high efficiency and precision. In addition, it has been discovered that various novel modifications of the circuit are rendered entirely practicable, as described hereinbefore. Thus, the number of units of fixed resistances in series and the corresponding number of concentric dials may be varied. The number of resistances shunted by the next preceding group may also be varied, it being necessary only that the relationship between the resistance shunted and the shunting resistance follow the equation set forth hereinbefore.

Although the interpolating resistance **41** is illustrated herein as being a continuous wire contacted by the rotary arm **37**, it will be apparent that a series of fixed resistances may be employed in lieu thereof. In such a case the resistances may each be connected to a rotary switch having a contact arm, similar to the switch arrangement described hereinbefore. It is to be understood that the term interpolating resistance identifies the last shunting resistance unit in a given combination.

Since the present invention is a voltage divider, it will be apparent that any type of impedance element may be utilized therein. Thus, for example, the resistance elements may be replaced by elements which provide capacitive or inductive impedance, and the term impedance element as recited in the appended claims is intended to include such elements. Accordingly, the equation set forth hereinbefore may be generalized as follows:

$$Z_s = Z\frac{(nm)}{(n-m)}$$

wherein Z_s is the value of shunting impedance and Z is the value of each of the impedances shunted.

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 our invention and the manner in which the same may be used, what we claim as new and desire to secure by Letters Patent is:

1. A voltage divider comprising, in combination, a plurality of fixed impedance means connected together in series, interpolating impedance means, and adjustable connecting means for releasably connecting the opposite ends of the interpolating impedance means in shunt with at least one of the fixed impedance means in such manner that the value of the shunting impedance means Z_s is determined by the equation

$$Z_s = Z\frac{(nm)}{(n-m)}$$

wherein Z is the value of each of the impedance means shunted, n is the number, other than two, of impedance means shunted and m is the number, other than one, of impedance means through which the shunting impedance means is to interpolate.

2. A voltage divider comprising, in combination, a plurality of series-connected fixed impedance means, interpolating impedance means, adjustable connecting means for releasably connecting the opposite ends of the interpolating impedance means in shunt with at least one of the fixed impedance means next suceeding it in order, adjustable connecting means for releasably connecting the opposite ends of each series-connected fixed impedance means in shunt with at least one of the fixed impedance means next succeeding it in order, said shunt connections being so arranged that the value of the shunting impedance means Z_s is determined by the equation

$$Z_s = Z\frac{(nm)}{(n-m)}$$

wherein Z is the value of each of the impedance means shunted, n is the number, other than two, of impedance means shunted and m is the number, other than one, of impedance means through which the shunting impedance means is to interpolate.

3. A voltage divider comprising, in combination, a frame, switch means mounted on the frame and having a fixed section and a rotary section, one of said sections carrying a plurality of contact means and the other section carrying a pair of spaced brush means arranged for sliding engagement with each contact means, a plurality of fixed impedance means each connected between two of the contact means and connected together in series, interpolating impedance means mounted on the frame and having a rotary section aligned axially with the rotary section of the switch means, means connecting the opposite ends of the interpolating impedance means to the pair of brush means, and operating means connected to the said

rotary sections of the switch means and interpolating means.

4. The voltage divider of claim 3 wherein the value of the shunting impedance means Z_s is determined by the equation

$$Z_s = Z\frac{(nm)}{(n-m)}$$

wherein Z is the value of each of the impedance means shunted, n is the number of impedance means shunted and m is the number of impedance means through which the shunting impedance means is to interpolate.

5. The voltage divider of claim 3 wherein the pair of brush means is so positioned with respect to the contact means that the value of the fixed impedance means shunted by the interpolating impedance means is at least equal to the maximum value of said interpolating impedance means.

6. The voltage divider of claim 3 wherein the pair of brush means is so positioned with respect to the contact means that the value of the fixed impedance means shunted by the interpolating impedance means is equal to the maximum value of said interpolating impedance means.

7. The voltage divider of claim 3 wherein the impedance means comprises resistances.

8. The voltage divider of claim 3 wherein the said operating means comprises an operating dial connected to each of said shafts, the dials being arranged concentrically with each other, and calibrations on the dial faces arranged for alignment along an index line.

9. A voltage divider comprising, in combination, an elongated frame, switch means mounted on the frame and having a fixed section and a rotary section, one of said sections carrying a plurality of contact means and the other section carrying a pair of spaced brush means arranged for sliding engagement with each contact means, a plurality of fixed impedance means each connected between two of the contact means and connected together in series, interpolating impedance means mounted on the frame and having a rotary section aligned axially with the rotary section of the switch means, means connecting the opposite ends of the interpolating impedance means to the pair of brush means, a pair 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.

10. A voltage divider comprising, in combination, an elongated frame, a plurality of spaced switch means mounted on the frame and each having a fixed section and a rotary section, one of said sections carrying a plurality of contact means and the other section carrying a pair of spaced brush means arranged for sliding engagement with each contact means, the rotary sections being an axial alignment, a plurality of fixed impedance means each connected between two of the contact means, the impedance means connected to each switch means being connected together in series, interpolating impedance means mounted on the frame and having a rotary section aligned axially with the rotary section of each switch means, means connecting the opposite ends of the interpolating impedance means to the pair of brush means associated with the series of impedance means next succeeding it in order, means connecting the opposite ends of each series of fixed impedance means to the pair of brush means associated with the series of impedance means next succeeding it in order, each pair of brush means being so positioned with respect to the contact means that the value of the fixed impedance means shunted by the next preceding impedance means is at least equal to the maximum value of said next preceding impedance means, 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.

11. The voltage divider of claim 10 wherein the impedance means comprise resistances and wherein the valve of each shunting resistance R_s is determined by the equation

$$R_s = R\frac{(nm)}{(n-m)}$$

wherein R is the value of each of the resistances shunted, n is the number of resistances shunted and m is the number of resistances through which the shunting resistance is to interpolate.

12. The voltage divider of claim 10 wherein the said operating means comprises an operating dial connected to each of said shafts, the dials being arranged concentrically with each other, and calibrations on the dial faces arranged for alignment along an index line to indicate the value of voltage division as the said dials are operated.

13. The voltage divider of claim 10 wherein the dial calibrations are proportioned and arranged to indicate the decimal fraction of voltage division.

14. A voltage divider comprising, in combination, an elongated frame, a pair of spaced switch means mounted on the frame and each having a fixed section and a rotary section, one of said sections carrying a plurality of contact means and the other section carrying a pair of spaced brush means arranged for sliding engagement 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 connected to each switch means being connected together in series to form a first and second series, interpolating impedance means mounted on the frame and having a rotary section aligned axially with the rotary section of each switch means, means connecting the opposite ends of the interpolating impedance means to the pair of brush means associated with the first series of impedance means, means connecting the opposite ends of the first series of fixed impedance means to the pair of brush means associated with the second series of impedance means, each pair of brush means being so positioned with respect to the contact means that the value of the fixed impedance means shunted by the next preceding impedance means is at least equal to the maximum value of said next preceding impedance means, three coaxial shafts supported by the frame and each connected to one of the said rotary sections, an operating dial connected to each of said shafts, the dials being arranged concentrically with each other, and calibrations on the dial faces arranged to indicate the value of voltage division as the said dials are operated.

15. The voltage divider of claim 14 wherein the interpolating impedance means comprises a resistance of 400 ohms, the first series of impedance means comprises eleven fixed resistances of 200 ohms each, and the second series of impedance means comprises eleven fixed resistancs of 1000 ohms each.

16. The voltage divider of claim 14 wherein the dial calibrations are proportioned and arranged to indicate the decimal fraction of voltage division.

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