April 10, 1945. H. T. WILHELM **2,373,156**

STANDARD FOR ELECTRICAL MEASUREMENTS

Filed Dec. 30, 1943 2 Sheets-Sheet 1

FIG. 1

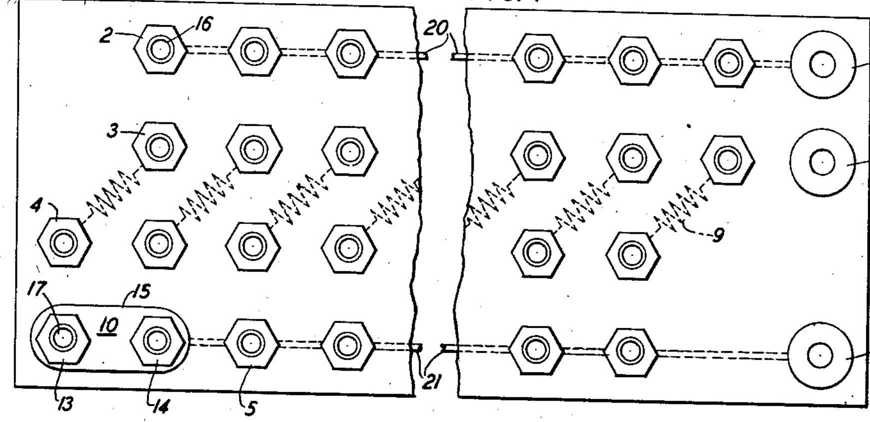


FIG. 2

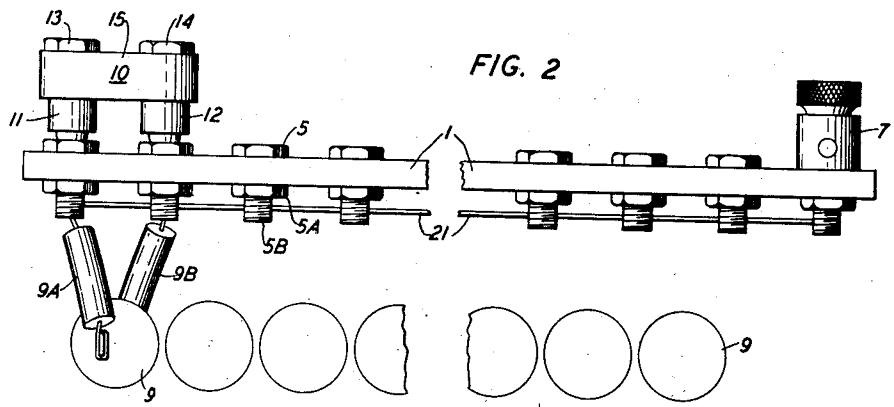


FIG. 3

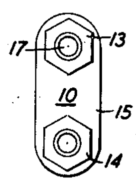


FIG. 4

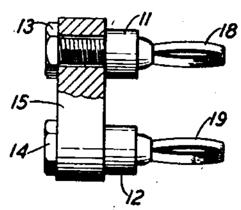


FIG. 5

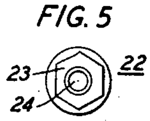


FIG. 6

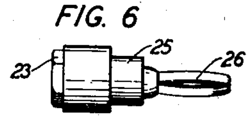
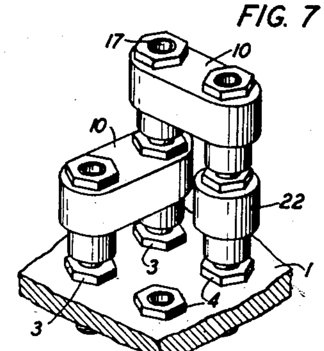


FIG. 7



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STANDARD FOR ELECTRICAL MEASUREMENTS

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FIG. 8

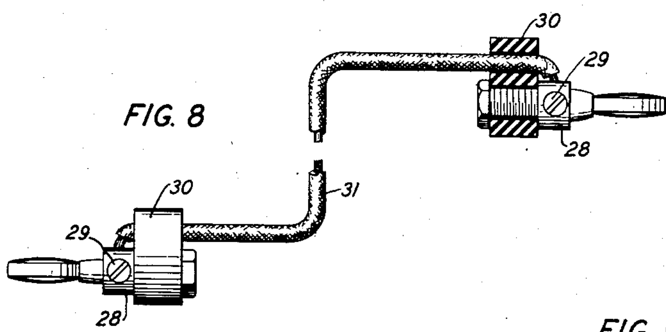
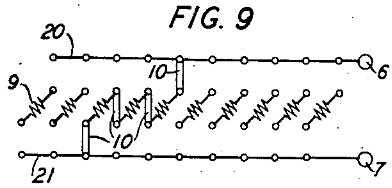
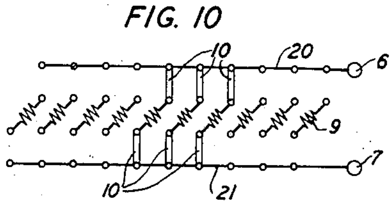


FIG. 9



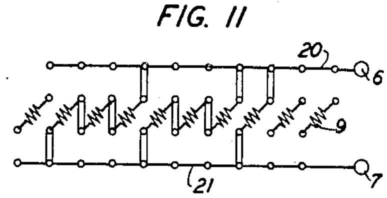
PLUG COMBINATION = 3

FIG. 10



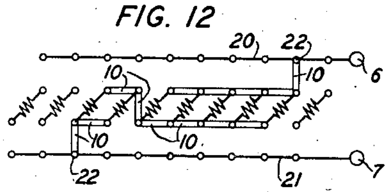
PLUG COMBINATION = 1^3

FIG. 11



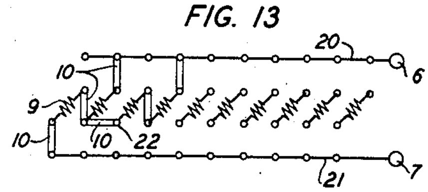
PLUG COMBINATION = 3P3P1

FIG. 12



PLUG COMBINATION = 1^2S1^5

FIG. 13



PLUG COMBINATION = 1S (1P2)

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UNITED STATES PATENT OFFICE

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STANDARD FOR ELECTRICAL MEASUREMENTS

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Application December 30, 1943, Serial No. 516,224

18 Claims. (Cl. 201—61)

This invention relates to standard impedance boxes and more particularly to adjustable impedance standards of the plub box type.

During recent years technological developments have required that high resistance measurements be made to a much higher degree of precision than heretofore. This trend has established more stringent requirements on the accuracy and precision of the resistance standards used and have also necessitated devising such standards having their resistances somewhat more nearly comparable in magnitude to the values of the resistances being measured. This has presented the inherent problem of securing certification of the accuracy of the high resistance standard. Heretofore it was not uncommon to construct the high resistance standard up to a total of one megohm, usually comprising a plurality of series-connected units which may be strapped out of circuit to secure various steps of resistance. The degree of flexibility as to variety of resistance values with this arrangement is quite limited and greater flexibility is desired, not only to secure a greater variety of standard values but also to achieve a higher degree of accuracy and also to permit the same structure to be employed as an adjustable conductance standard. A very desirable arrangement is to provide an adjustable standard having an arithmetic series of decimal fraction steps from 0.1 to 1 and the arithmetic whole number series from 1 to 10, inclusive, which series is available both on a resistance and on a conductance basis. To make such a standard really practicable it is also essential that means be provided for obtaining the various steps conveniently and expeditiously. It is also necessary that the construction should be such as to avoid undesirable leakage paths which will effect the accuracy of the standard unit.

Many of the principles employed in constructing a standard for one type of impedance element can very often be employed for constructing other types. For example, capacitance standards can be built employing substantially the same plug-box construction as that employed for resistance or conductance standards.

It is an object of this invention to provide an adjustable standard containing only ten equal valued circuit elements and which is capable of yielding all of the steps of the arithmetic series from 0.1 to 1 and from 1 to 10, inclusive.

It is a further object of this invention to provide an adjusting means for this standard capable of providing the above stated series of standard values expeditiously and with ease and without introducing undesirable errors due to spurious leakage paths.

A still further object is to provide an adjustable standard having a plurality of standard units which can easily be checked against each other and which can be calibrated at a lower standard value with an effective improvement in precision.

The foregoing objects are attained by this invention by providing an adjustable standard having a plurality of equal valued standard circuit elements electrically isolated from each other, a pair of main conductors to which they may be connected, a connecting means adapted to connect said elements together and to the main conductors in various series and parallel network combinations, thereby providing a large number of different standard values with a limited number of standard elements.

The invention may be better understood by referring to the accompanying drawings in which:

Fig. 1 shows a plan view of the panel of a standard made in accordance with this invention;

Fig. 2 is an elevation view of the standard shown in Fig. 1;

Figs. 3 and 4 are two views of a preferred connector especially adapted for deriving the desired networks from the standard of this invention;

Figs. 5 and 6 show two views of a single-prong connector to be used in conjunction with the double-prong connector of Figs. 3 and 4 for providing additional networks;

Fig. 7 is a perspective view showing how the double-prong connectors of Figs. 3 and 4 may be used in combination with the single-prong connector of Figs. 5 and 6;

Fig. 8 shows a special flexible connector for providing additional networks; and

Figs. 9 to 13, inclusive, show various network combinations typical of those provided by the apparatus of this invention.

Referring now more particularly to Fig. 1, in which reference numeral 1 designates a panel of high quality insulating material having mounted thereon four rows of jacks, 2, 3, 4 and 5, respectively. The jacks in row 2 are all strapped together by bus bar 20 to terminal 6. Jack rows 3 and 4 have connected therebetween a plurality of standard circuit elements 9, each isolated from the other. For illustrative purposes these circuit elements are shown as resistors which are exactly equal to each other to within very close limits. While resistors are used to illustrate the invention it is to be understood that capacitors may also be used. The jacks in row 5 are like those in row 2 in that a bus bar 21 interconnects them and ties them to a terminal 7. Terminal 8 is provided for a connection to ground and is normally connected within the standard enclosure to the shield which is not shown.

It should be noted that the horizontal and vertical distances between adjacent jack centers are all equal. This arrangement is preferable in the practice of this invention, as it enables a very rapid interconnection of the various jack rows by double-prong plugs 10, one of which is shown inserted in the left end of jack row 5. Of course, the particular position of the double-prong plug 10 as shown in jack row 5 makes no useful connection but in the description to follow it will be seen how these plugs are used to form a great variety of useful network combinations.

Fig. 2 shows the elevation view for the panel of Fig. 1. Here it will be seen how the jacks, as for example those of row 5, are assembled. These jacks are commercially available and while they are believed ideal for this purpose, other jacks providing substantially equivalent features can be substituted without departing from the invention. The particular jack illustrated comprises a hollow, hexagonally headed brass bolt, the hollow part being substantially tubular and is designated by reference numeral 16 in row 2 of Fig. 1. These bolts are secured in holes in panel 1 by running a nut 5A on their threaded portions 5B, as shown for one of the jacks in row 5 in Fig. 2. The terminals 6, 7 and 8 are similarly mounted and the bus bars or main conductors 20, 21 are soldered to the threaded parts of the jacks and terminals.

The standard resistance units 9 used to illustrate the invention are shown schematically in Fig. 1. In Fig. 2 their end view shows them to be of the cartridge type but obviously other forms can be used. Where an inequality exists substantially exact equality between these standard elements 9 may be secured by connecting them to the jacks in rows 3 and 4 through padding resistors such as resistor 9A. These padding resistors may be capable of some adjustment in their construction. This technique is well known in laboratory practice and requires no further detailed description. As most resistor materials show a slight increase in resistance due to aging, the padded resistors comprising resistors 9 and padding resistors 9A are made slightly less than the nominal value. A record padding resistor 9B is used to bring the unit to substantial equality with the nominal value. This second padding resistor may be removed or replaced after aging has taken place.

Figs. 3 and 4 show two views of the two-pronged plug 10. Here it will be seen that the plug parts 11 and 12 have resilient ends 18 and 19, respectively, and that like the jacks, they have hollow upper portions 17 which serve in turn as jacks for other plugs for more complex plug combinations. The plug parts 11 and 12 are secured to a heavy conductor 15 by means of nuts 13 and 14 in a manner substantially identical with that described for the jacks in panel 1. It should be understood that the center-to-center distance between the two prongs 18 and 19 is equal to the horizontal and vertical distances between adjacent jacks in panel 1 as shown in Fig. 1. This permits the insertion of this two-prong plug into any two adjacent vertical or horizontal jacks, thereby interconnecting them.

After having once inserted a double-prong plug into a particular pair of jacks, it is occasionally necessary to connect one of these jacks to another vertical or horizontal adjacent jack. This is done by first inserting one of the single-prong plugs 22 shown in Figs. 5 and 6 into that adjacent jack. Then another double-prong assembly 10 can be made to complete the connection. This is shown more clearly by the perspective view of Fig. 7 wherein is shown a plug assembly 10 inserted into two adjacent jacks in row 3, thereby connecting two of the resistors 9 together. Then a single-prong plug assembly 22 is inserted into a jack in row 4 so that a second double-prong plug assembly 10 can connect the first one to the jack in row 4.

The above described double and single-prong plugs 10 and 22 together with the jack arrangement and main conductors or bus bars provided all the necessary connections for the complete arithmetic series of decimal fraction and whole valued standard resistances previously mentioned. As will be hereinafter more fully described, this same structure will also provide a complete arithmetic decimal fraction and whole valued series of conductance standards. In addition to these most desirable standard values a very large number of other values of resistance and conductance can be provided by using these very simple single and double-prong plugs.

In addition to the large number of plug combinations which can be derived from the use of the single-prong and double-prong plugs described above, a large number of additional combinations providing standard resistance and standard conductance values may be obtained by using the flexible two-pronged plug assembly shown in Fig. 8. Each of the plug parts 28 of this flexible assembly corresponds with the similar parts 11 and 12 of Fig. 4 and is also hollow to form a jack similar to that shown at 17 in Fig. 3. These flexible plugs differ from the double-prong plugs of Figs. 3 and 4 primarily in that the solid conductor 15 of Figs. 3 and 4 is replaced by a flexible one 31 as shown in Fig. 8. The insulated flexible conductor 31 passes through holes in spacers 30 which may be of insulating material and the bared ends of this flexible conductor are connected to plugs 28 by inserting them in holes and securing them with set screws 29 in an obviously conventional manner. It is preferable to have spacers 30 made of insulating material to eliminate the possibility of a short-circuit should two of them from different plug assemblies be inserted in adjacent jacks on panel 1. These flexible assemblies are easily used but are not quite so convenient as the solid assemblies of Figs. 4 and 6. Moreover, they are not needed to provide the very desirable resistance and conductance values listed in the tables below which are based upon a standard containing ten of the resistor elements 9, each assumed to be of 1 megohm resistance value:

Table I

Resistance, megohms	Plug combination
0.1	1^{10}
0.2	1^{5}
0.3	$3P1^{3}$
0.4	$2P1^{2}$
0.5	1^{2}
0.6	3P3P1
0.7	$1^{2}S1^{5}$
0.8	4P1
0.9	9P1
1	1
2	2
3	3
4	4
5	5
6	6
7	7
8	8
9	9
10	10

Table II

Conductance, micromhos	Plug combination
0.1	10
0.2	5
0.3	$3S1^{3}$
0.4	5P5
0.5	2
0.6	1S(1P2)
0.7	5P2
0.8	$1S1^{4}$
0.9	$1S1^{5}$
1	1
2	1^{2}
3	1^{3}
4	1^{4}
5	1^{5}
6	1^{6}
7	1^{7}
8	1^{8}
9	1^{9}
10	1^{10}

The symbols used in the foregoing tables are easily followed. Any number appearing in the columns headed "plug combination" without a superscript like an exponent denotes a network of that number of one-megohm units connected in series. The superscripts denote that number of networks of resistance equal to the base numeral which are connected in parallel (the base number in the tables above have been selected to be always equal to one). The letters S and P denote series and parallel respectively and indicate that the series and parallel networks indicated by their adjacent numbers are to be so connected. A network indicated in parentheses denotes this network should first be set up before completing the other indicated operations. If no parenthesis appears, it indicates that it is immaterial in what order the networks are set up. By way of example the numeral 3 indicates a series network of three resistors each of one-megohm resistance making a network resistance of three megohms. The numeral 1^3 denotes that three resistor units each of one-megohm resistance are connected in parallel making a network resistance of one-third megohm. The symbol $3P1^3$ as in Table I denotes that the three series connected resistor units are paralleled with the three parallel connected units making a total network resistance of 0.3 megohm. Taking the 0.6 micromho plug combination in Table II as another example, the network in parentheses should first be set up by connecting two one-megohm resistor units in series, then connecting this series combination in parallel with a one-megohm unit making a network resistance of two-thirds megohm (or conductance of three-havles micromhos). Then this two-thirds micromho network should be connected in series with a one-megohm resistor unit as indicated making a total of one and two-thirds megohms or five-thirds megohm resistance. This, of course, is 0.6 micromho, the required value. From these examples the other symbols are very easily understood.

To more clearly indicate how these connections are so easily and quickly made with the apparatus of this invention, reference is made to Figs. 9 to 13, inclusive, where it is again assumed for illustrative purposes that each of the resistor units **9** has a resistance of one megohm. This corresponds with the value assumed for the resistor units in Tables I and II. The reference numerals are those previously employed. Fig. 9 shows a simple series connection of three units providing a resistance of three megohms. In Fig. 10 a simple parallel connection of three of the resistor units is shown which provides a conductance of three micromhos. In Fig. 11 the plug combination provides a resistance of 0.6 megohm. In Fig. 12 the combination necessary to provide a resistance of 0.7 megohm is shown. Fig. 13 shows a plug combination for a conductance of 0.6 micromho.

Some structures of the prior art will provide many of these combinations but not all of them with so simple an arrangement of parts. For example, the combinations shown in Figs. 11 and 13 are impossible with any known prior art standard resistor or conductance plug-box structure. By reason of the simple addition of the two bus bars **20** and **21**, they are both possible with this invention. These bus bars permit the first series or parallel networks and their series network combinations to be set up on the two middle rows of jacks **3**, **4** and their final parallel connections to be made to the bus bars **20**, **21** through their jacks in rows **2** and **5**. External connections are then made to the bus bar terminals **6** and **7** as previously indicated.

In addition to the most desirable values shown in Tables I and II, a very large number of other valuable combinations are possible. Examples of some of the more interesting of these for resistances are 0.125 megohm derived by plug combination 1^8, 0.25 megohm derived by plug combination 1^4, 0.3333 . . . megohms by plug combination 1^3, 0.375 meghom by plug combination $3P3P1^2$, 0.6666 . . . meghom by combination 2P1, 0.75 megohm by combination 3P1, 0.875 megohm by combination 7P1, and 1.25 megohm by combination $(2S1^2)P(2S1^2)$ or by the more simple combination $1S1^4$. From these examples it is obvious how other ones are derived. It will also be apparent that many of the resistance and conductance values can be derived in different ways from the limited number of ten equal resistors. For the standard in the example above, one megohm can be derived by various plug combinations such at 2^2, 3^3, 4P4P2. Also two megohms can be derived from plug combinations 4^2 and 6P3, and 0.6 megohm may be derived from plug combinations 6P2P1 and 3P3P2P2 or 3^2P2^2. These various combinations, which are substantial identities and provide equal resistance values, are a ready means for further checking the standard resistor units **9** against themselves to detect errors.

Standards laboratories have been hesitant to certify resistance standards having resistances exceeding one megohm in value. The accuracy certified is better for lower resistance values, for example, resistance values of the order of 0.1 megohm or 0.01 megohm. By the peculiar construction afforded by this invention it is possible to take advantage of these lower resistance ranges for high resistance standards thereby securing for the high resistance standard an effective certification substantially equivalent to that secured for the lower resistance ranges. Consequently, where this invention is embodied in the construction of a high resistance standard exceeding a maximum value in the order of one megohm is arranged for calibration at a lower resistance value. It should, of course, be understood that the practice of this invention is not limited to any particular range of resistance values. For example, the standard may have a maximum resistance of only one megohm which may be secured by combining in series ten 0.1 megohm resistors so that calibration may be made with the resistors in parallel producing a resistance of only 0.01 megohm. For these lower resistance standards the same advantages of increased accuracy may be realized.

Other important advantages of constructing a standard in the manner illustrated by this invention are that by reason of having the separate resistor elements isolated from each other it is possible to make insulation resistance measurements between the separate elements either to insure that its effect may be neglected or to evaluate its effect if not negligible. This construction also makes it possible to make a comparison of any one resistor element with any other one in the standard thereby insuring that the individual resistors will remain precisely equal to each other within very close limits. By reason of this high degree of equality together with the precise knowledge of the magnitude of the insulation resistance it is possible to certify the series connection of all of the equal resistors to the same degree of precision as for their parallel connection. The certification of the parallel connection is, therefore, effectively used to certify the series connection which is one hundred times the resistance of the parallel connection where ten resistors are used. This will be recognized by those skilled in this art to be a distinct advantage in the construction, maintenance and certification of resistance and conductance standards.

A preferred method of constructing and calibrating the resistor units of this invention is to first select as stable resistor material as possible with the least resistance temperature and thermal electromotive force coefficients. The several resistor units **9** are then made near to but slightly less than the required nominal value. Following this they are run through temperature cycles to determine their temperature coefficients and aging characteristics. The relative values of the component resistors are measured at a known temperature so the necessary padding resistors **9A** can be connected to make them all equal to within very close limits say, for example, twenty parts per million. It should here be stated that it has been found much easier to pad these units to be equal to within very close limits than to try to adjust them all to be exactly equal to some specified value. The ten padded resistors may then be connected in parallel to form a nominal resistance of one-tenth the unit value and the absolute resistance determined at the known temperature on a precision Wheatstone bridge to an accuracy of 0.005 per cent or better. It will thus be seen that the absolute value of each component resistor unit **9** will be substantially equal to ten times this determined parallel-connected value and to the same order of accuracy. Also this same accuracy is realized by any combination of one or more of the ten padded resistor units.

As a high degree of precision is increasingly more difficult to achieve for the higher valued resistance standards the practical advantage of this invention is best realized for the resistance standards of higher resistance value. From the foregoing description it is clear that in order to practice the teaching of this invention it is necessary that the resistance standard be constructed with a plurality of resistor elements all of which are isolated from each other, that the individual resistor elements must all be equal to within very close limits and that it must be possible to connect all of the separate resistor units in parallel for calibration purposes. Then in order to derive the benefits of great flexibility as taught by this invention it must be possible for these individual resistor elements to be connected in a great variety of series and parallel networks. This latter feature is provided in a very easy and convenient manner by the structure of this invention.

This invention has been described using resistors as the standard circuit elements. It is obvious that a practical capacitance standard may be constructed in accordance with this invention by merely substituting high quality standard capacitors for the resistors **9**. Padding is accomplished by shunting these capacitors with suitable padding capacitors to perform a function analogous to that of the padding resistors **9A**. Calibration is effected by connecting the capacitors all in series to secure a low value. Where ten capacitors are used the parallel connection then provides a capacitance one hundred times as large as the series connection but to the same degree of accuracy. It will, therefore, be seen that the same advantages of flexibility in securing large numbers of standard values as well as the advantages of easy use and accuracy are all achieved for the capacitance standard in the same way as for the resistance standard.

What is claimed is:

1. An adjustable standard for electrical measurements comprising a plurality of standard circuit elements electrically isolated from each other, two main conductors isolated from each other and from the standard element, a pair of main terminals, one of the main terminals being permanently connected to one of said main conductors and the other main terminal to the other main conductor, a plurality of connectors for connecting said standard circuit elements together in various combinations of series and parallel networks, some of said connectors also connecting said series and parallel networks in series or parallel to said two main conductors, whereby adjustments providing a large number of standard values may be derived from a limited number of standard circuit elements.

2. An adjustable standard for electrical measurements comprising a plurality of equal valued standard circuit elements electrically isolated from each other, two main conductors isolated from each other and from the standard element, a pair of main terminals, one of the main terminals being permanently connected to one of said main conductors and the other main terminal to the other main conductor, a plurality of connectors for connecting said standard circuit elements together in various combinations of series and parallel networks, some of said connectors also connecting said series and parallel networks in series or parallel to said two main

conductors, whereby adjustments providing a large number of standard values may be derived from a limited number of standard circuit elements.

3. An adjustable standard for electrical measurements comprising a plurality of standard circuit elements electrically isolated from each other, two main conductors isolated from each other and from the standard elements, a pair of main terminals one of the main terminals being permanently connected to one of said main conductors and the other main terminal to the other main conductor, two connecting terminals for each standard circuit element, a plurality of similar connecting terminals for each of said main conductors, and a plurality of connectors for connecting said connecting terminals together to form various combinations of networks, whereby adjustments providing a large number of standard values may be derived from a limited number of standard circuit elements.

4. An adjustable standard for electrical measurements comprising a plurality of equal valued standard circuit elements electrically isolated from each other, two main conductors isolated from each other and from the standard elements, a pair of main terminals, one of the main terminals being permanently connected to one of said main conductors and the other main terminal to the other main conductor, two connecting terminals for each standard circuit element, a plurality of similar connecting terminals for each of said main conductors, and a plurality of connectors for connecting said connecting terminals together to form various combinations of networks, whereby adjustments providing a large number of standard values may be derived from a limited number of standard circuit elements.

5. An adjustable standard for electrical measurements comprising a plurality of standard circuit elements electrically isolated from each other, two main conductors isolated from each other and from the standard elements, a pair of main terminals, one of the main terminals being permanently connected to one of said main conductors and the other main terminal to the other main conductor, two connecting terminals for each standard circuit element, a plurality of similar connecting terminals for each of said main conductors, each of said connecting terminals being disposed equidistant from its adjacent connecting terminals, and a plurality of connectors for connecting any of said adjacent connecting terminals together to form various combinations of networks, whereby adjustments providing a large number of standard values may be derived from a limited number of standard circuit elements.

6. An adjustable standard for electrical measurement comprising a plurality of equal valued standard circuit elements electrically isolated from each other, two main conductors isolated from each other and from the standard elements, a pair of main terminals, one of the main terminals being permanently connected to one of said main conductors and the other main terminal to the other main conductor, two connecting terminals for each standard circuit element, a plurality of similar connecting terminals for each of said main conductors, each of said connecting terminals being disposed equidistant from its adjacent connecting terminals, and a plurality of connectors for connecting any of said adjacent connecting terminals together to form various combinations of networks, whereby adjustments providing a large number of standard values may be derived from a limited number of standard circuit elements.

7. A combined adjustable resistance and conductance standard for electrical measurements comprising a plurality of standard resistance elements electrically isolated from each other, two main conductors isolated from each other and from the standard elements, a pair of main terminals one of the main terminals being permanently connected to one of said main conductors and the other main terminal to the other main conductor, a plurality of connectors for connecting said resistance elements together in various combinations of series and parallel networks, some of said connectors also for connecting said series and parallel networks in series or parallel to said two main conductors, whereby adjustments providing a large number of standard resistance and conductance values may be derived from a limited number of standard elements.

8. A combined adjustable resistance and conductance standard for electrical measurements comprising a plurality of equal valued standard resistance elements electrically isolated from each other, two main conductors isolated from each other and from the standard elements, a pair of main terminals one of the main terminals being permanently connected to one of said main conductors and the other main terminal to the other main conductor, a plurality of connectors for connecting said resistance elements together in various combinations of series and parallel networks, some of said connectors also for connecting said series and parallel networks in series or parallel to said two main conductors, whereby adjustments providing a large number of standard resistance and conductance values may be derived from a limited number of standard elements.

9. A combined adjustable resistance and conductance standard for electrical measurements comprising a plurality of standard resistance elements electrically isolated from each other, two main conductors isolated from each other and from the standard elements, a pair of main terminals one of the main terminals being permanently connected to one of said main conductors and the other main terminal to the other main conductor, two connecting terminals for each resistor, a plurality of similar connecting terminals for each of said main conductors, and a plurality of connectors for connecting said connecting terminals together to form various combinations of networks, whereby adjustments providing a large number of standard resistance and conductance values may be derived from a limited number of standard elements.

10. A combined adjustable resistance and conductance standard for electrical measurements comprising a plurality of equal valued standard resistance elements electrically isolated from each other, two main conductors isolated from each other and from the standard elements, a pair of main terminals one of the main terminals being permanently connected to one of said main conductors and the other main terminal to the other main conductor, two connecting terminals for each resistor, a plurality of similar connecting terminals for each of said main conductors, and a plurality of connectors for connecting said connecting terminals together to form various combinations of networks, whereby adjustments providing a large number of standard resistance and

conductance values may be derived from a limited number of standard elements.

11. A combined adjustable resistance and conductance standard for electrical measurements comprising a plurality of standard resistance elements electrically isolated from each other, two main conductors isolated from each other and from the standard elements, a pair of main terminals one of the main terminals being permanently connected to one of said main conductors and the other main terminal to the other main conductor, two connecting terminals for each resistor, a plurality of similar connecting terminals for each of said main conductors, each of said connecting terminals being disposed equidistant from its adjacent connecting terminals, and a plurality of connectors for connecting any of said adjacent connecting terminals together to form various combinations of networks, whereby adjustments providing a large number of standard resistance and conductance values may be derived from a limited number of standard elements.

12. A combined adjustable resistance and conductance standard for electrical measurements comprising a plurality of equal valued standard resistance elements electrically isolated from each other, two main conductors isolated from each other and from the standard elements, a pair of main terminals one of the main terminals being permanently connected to one of said main conductors and the other main terminal to the other main conductor, two connecting terminals for each resistor, a plurality of similar connecting terminals for each of said main conductors, each of said connecting terminals being disposed equidistant from its adjacent connecting terminals, and a plurality of connectors for connecting any of said adjacent connecting terminals together to form various combinations of networks, whereby adjustments providing a large number of standard resistance and conductance values may be derived from a limited number of standard elements.

13. The combination in accordance with claim 1 wherein the standard circuit elements comprise standard electrical capacitors.

14. The combination in accordance with claim 2 wherein the standard circuit elements comprise standard electrical capacitors.

15. The combination in accordance with claim 3 wherein the standard circuit elements comprise standard electrical capacitors.

16. The combination in accordance with claim 4 wherein the standard circuit elements comprise standard electrical capacitors.

17. The combination in accordance with claim 5, wherein the standard circuit elements comprise standard electrical capacitors.

18. The combination in accordance with claim 6 wherein the standard circuit elements comprise standard electrical capacitors.

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