May 17, 1932. W. KOENIG, JR 1,858,364

MULTIPLE SLIDE WIRE POTENTIOMETER

Filed May 14 1929 2 Sheets-Sheet 1

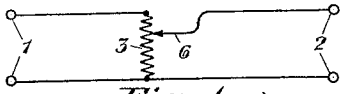


Fig. 1a

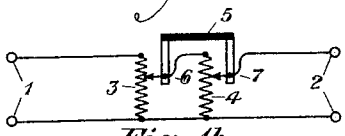


Fig. 1b

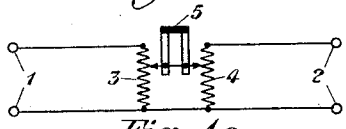


Fig. 1c

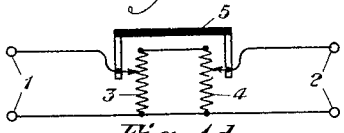


Fig. 1d

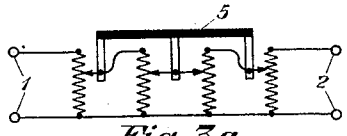


Fig 3a

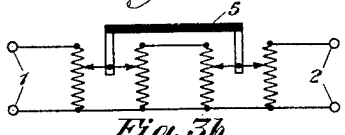


Fig. 3b

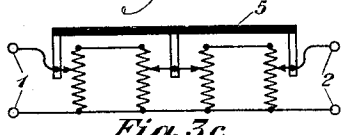


Fig. 3c

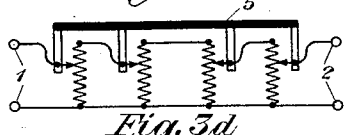


Fig. 3d

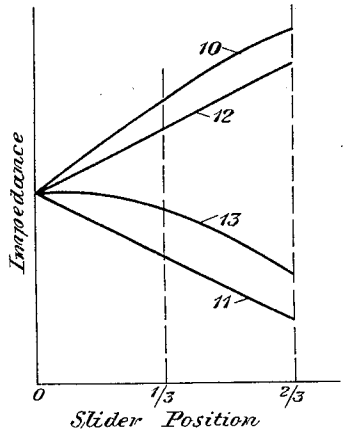


Fig. 2

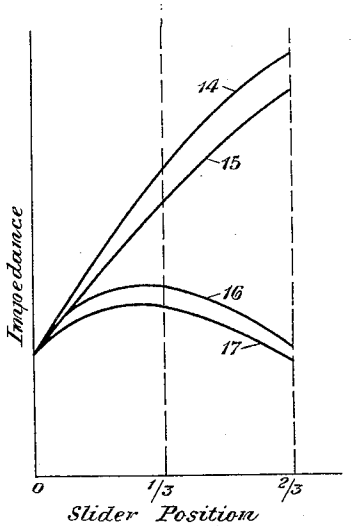


Fig. 4

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MULTIPLE SLIDE WIRE POTENTIOMETER

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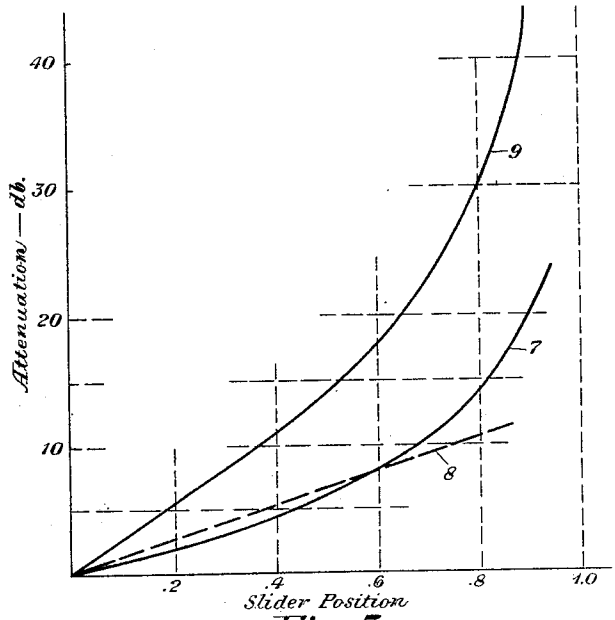


Fig. 5

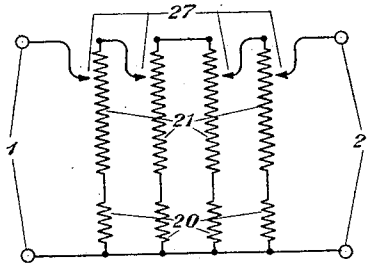


Fig. 6

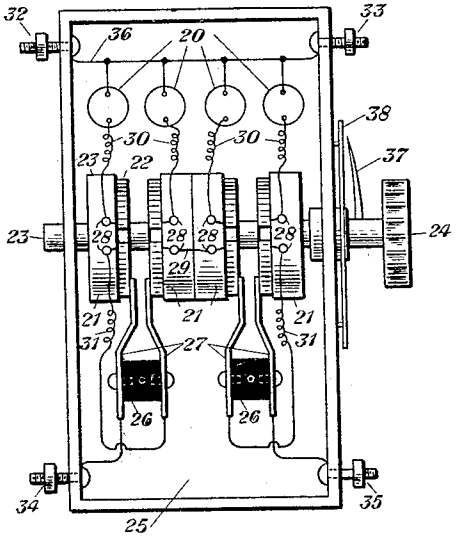


Fig. 7

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Patented May 17, 1932 1,858,364

UNITED STATES PATENT OFFICE

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MULTIPLE SLIDE WIRE POTENTIOMETER

Application filed May 14, 1929. Serial No. 363,069.

This invention relates to devices for attenuating currents or voltages in electrical systems, and more particularly to devices of this type for varying the attenuation continuously over a certain range, and discloses an attenuator comprising a plurality of slide wire potentiometers connected in succession between input and output terminals, together with a single control element for varying simultaneously the setting of all the potentiometers thus connected.

The primary object of the invention is to furnish an attenuator of the class disclosed which is economical in construction, quickly and easily adjusted to a desired attenuation value, and one that will accurately cover a much wider range of attenuation values and have more constant impedance characteristics than is obtainable with the ordinary types of slide wire potentiometers well known to the art.

While there is no theoretical limit to the attenuation range that can be covered by the usual type of slide wire potentiometer comprising a slide wire impedance element having an adjustable contact associated therewith, there are serious practical difficulties in the way of obtaining large attenuations with such a device. For instance, the change in attenuation increases rapidly after the slider has moved over more than about two-thirds of the slide wire. To obtain attenuations exceeding 20 db. (20 db. or "decibels" corresponds to a current attenuation ratio of 1:10) requires setting the slider more than nine-tenths of the wire from the minimum attenuation end, which results in crowding toward the end of the range with consequent reduced accuracy. Thus, if the potentiometer is constructed of a size just sufficient to provide accurate settings of the slider up to 20 db. attenuation, it will become increasingly difficult to obtain accurate settings as the attenuation is increased beyond this value. On the other hand, if the potentiometer is constructed sufficiently large to obtain accurate settings for attenuations exceeding 20 db., then for attenuations less than this amount, the accuracy of setting is greater than required; or in other words, there is a waste of material, and the device becomes unduly expensive.

To avoid the waste of material thus involved, a potentiometer of tapering resistance may be obtained by winding the slide wire on a tapering mandrel. With such an arrangement, the change in attenuation per unit movement of the slider remains more nearly constant over the entire range than is the case with the uniformly wound slide wire. Manufacturing difficulties, however, make the tapered potentiometer expensive where attenuations exceeding 30 or 40 db. are required.

In addition to the objections mentioned above to the ordinary types of slide wire attenuators, such devices are open to the additional drawback for certain uses, that the output impedance thereof varies over a considerable range as the slider is moved. For an attenuation range of 40 db. such impedance may vary by a factor of 100.

The present invention discloses a slide wire attenuator which overcomes to a large extent the objections mentioned above to existing types of such devices. The invention will be best understood by immediate reference to the drawings of which Figure 1*a* shows in schematic form the ordinary type of a simple slide wire potentiometer; Figs. 1*b* to 1*d*, inclusive, show in schematic form various modifications of attenuators embodying the novel features of the present invention; Fig. 2 shows the output and input impedance characteristics of the attenuators of Figs. 1*b* to 1*d*, inclusive, for various positions of the sliders associated therewith. Figs. 3*a* to 3*d*, inclusive, show in schematic form other modifications of attenuators embodying the novel features of the present invention; while Fig. 4 shows the corresponding output and input impedance curves for various positions of the sliders. Fig. 5 illustrates the manner in which the attenuation varies with the slider position for attenuators of the type shown in Figs. 1*a* to 1*d* and 3*a* to 3*d*, inclusive. Fig. 6 shows in schematic form a preferred circuit modification of an attenuator embodying the features of the invention. Fig. 7 shows in plan view, the structural details of an atten-

uator of the type indicated schematically in Fig. 6.

The attenuator shown in Fig. 1*a* comprises input terminals 1 and output terminals 2. Interposed between the input and output terminals is a simple slide wire potentiometer comprising the slide wire impedance element 3 and the sliding contact 6 associated therewith. Referring now to Fig. 5, curve 7 shows the manner in which the attenuation of the device illustrated in Fig. 1*a* varies with the slider position. In Fig. 5 the ordinates represent the attenuation in db., while the abscissæ show the fraction of the total impedance 3 of Fig. 1*a* that the slider 6 is down from the top. Thus, in Fig. 5, for the slider position zero, the slider 6 of Fig. 1*a* is connected to the top of impedance 3, which is the position of minimum attenuation, while for the slider position 1.0 (Fig. 5) the slider 6 would be at the bottom of impedance 3, which is the position of maximum attenuation between the input and output terminals 1 and 2, respectively.

Referring again to curve 7 of Fig. 5, it will be noted that the attenuation varies almost uniformly for movements of the slider over about two-thirds of the total range. This is shown by comparison with curve 8 drawn for comparative purposes only, which shows proportional variation of attenuation with slider position.

As the slider is moved past the two-thirds position, the attenuation increases very rapidly per unit movement of the slider, and for slider positions between .9 and 1.0 the attenuation per unit movement of the slider increases so rapidly as to make almost impossible an accurate setting of the slider to obtain a given attenuation. Curve 7, therefore, clearly brings out the manner in which crowding occurs in the region of large attenuations and thus, in general, prevents the use of this region for obtaining accurately, large values of attenuation.

If it were desirable to obtain for a given position of the slider, twice the attenuation that results from the use of a single potentiometer, this might be accomplished by connecting two potentiometers in succession between the output and input terminals, in the manner shown, for example, by Fig. 1*b*. In Fig. 1*b*, two identical potentiometers 3 and 4 are connected between the input and output terminals 1 and 2, respectively, with the variable portion of potentiometer 3 connected to the fixed portion of potentiometer 4, and the variable portion of the latter in turn connected to the output terminals 2, as shown. The fixed portion of potentiometer 3 would, of course, be connected across the input terminals 1. By connecting the sliders 6 and 7 associated with both potentiometers 3 and 4 to a rigid member 5, as shown, then both potentiometers could be adjusted simultaneously by moving the handle 5 up or down as desired. The handle 5 is of insulating material or contains means for insulating the slider 6 from the slider 7.

With an attenuator arrangement such as is shown in Fig. 1*b* it, of course, becomes obvious that the attenuation for a given position of the slider will be approximately double that obtained with the single element potentiometer shown in Fig. 1*a*. In Fig. 5 curve 9 shows the attenuation plotted against the slider position for the device shown in Fig. 1*b*. Curve 9 is approximately the same shape as curve 7 with the exception that for a given slider position the ordinate of the former is approximately double that of the latter. As a result of the similarity in the shapes of these curves, it would not be advisable to use the attenuator of Fig. 1*b* in the region beyond the two-thirds position on the slider, due to the crowding effect. Up to the two-thirds position, however, the device of Fig. 1*b* would have double the attenuation range of that of Fig. 1*a*.

If it were desired to obtain triple the attenuation range of a single element potentiometer, three potentiometers could be connected in succession between the input and output terminals after the manner shown in Fig. 1*b*, and a handle 5, associated with all the sliders for providing simultaneous adjustment of the potentiometer elements. Or, in the general case, any number of potentiometers could be connected in succession between the input and output terminals in this manner to provide for a given position of the slider any multiple of the attenuation attained for the same slider position with a single element potentiometer.

The idea of utilizing a plurality of potentiometers in succession in this manner between a pair of input and output terminals in order to obtain multiple attenuation as compared to a single potentiometer element, comprises the essential feature of the present invention. The potentiometers could, of course, be adjusted individually, but much more efficient and rapid operation is obtained by affixing all the slider elements to a single rigid member for controlling simultaneously the setting of all the potentiometers.

The method shown in Fig. 1*b* for connecting a plurality of potentiometers in succession to increase the available attenuation range without crowding is, however, not the most favorable arrangement from the standpoint of variation in the input and output impedance with the position of the slider. This can be seen by reference to the curves of Fig. 2. In Fig. 2 the ordinates are proportional to the output and input impedances of the attenuator plotted against the position of the slider in percentage of the total distance down from the top. Curve 10 shows for the attenuator of Fig. 1*b*, the variation of

the impedance as seen from terminals 1 with the slider position, while curve 11 shows the variation in impedance of the same device as seen from terminals 2. Thus, as the slider is moved downward from the top to the two-thirds position, the impedance looking into terminals 1 increases to about double its initial value, while the impedance looking into terminals 2 decreases to about one-half its initial value. With the arrangement of Fig. 1*b*, therefore, the impedance not only varies over a considerable range with movement of the slider, but also the output impedance would be different from the input impedance. Both of these features are objectionable in certain cases, and in fact it may be said that they are objectionable in general.

Figs. 1*c* and 1*d* show the additional available schemes of connecting two potentiometers between input and output terminals to obtain multiple attenuation. In Fig. 1*c* each pair of terminals 1 and 2 is connected across the fixed portion of a potentiometer and the variable portions of the potentiometers are then interconnected. In Fig. 1*d* the fixed portions of the two potentiometers are connected in multiple with the variable portions connected to the output and input terminals, respectively. Curve 12 (Fig. 2) shows the impedance characteristic for the arrangement of Fig. 1*c*, while curve 13 shows the corresponding curve for the arrangement of Fig. 1*d*. Since for both Figs. 1*c* and 1*d* the potentiometers are symmetrically connected between the input and output terminals, the input and output impedance curves will be identical for either of these arrangements. The reason for the different output and input impedance curves for the arrangement of Fig. 1*b* was, of course, due to the unsymmetrical manner in which the two potentiometer elements are connected as respects the output and input terminals. Since in general, with attenuators of this type, it is desirable to have the output impedance vary in the same manner as the input impedance, a symmetrical manner of connecting the potentiometer elements between the output and input terminals is advisable.

It will be noted, in comparing the impedance curves of Fig. 2, that curve 13 is the most nearly constant of any of the curves shown. The reason for this will become apparent from an examination of Fig. 1*d*. With the slider at an intermediate position, as shown, the impedance as seen from either terminals 1 or 2 comprises the portion of the first potentiometer which is below the slider connected in shunt, with the portion of the first potentiometer which is above the slider in series with the fixed impedance of the second potentiometer. Thus, as the slider is moved downwards, while the impedance of the portion of the first potentiometer below the slider decreases the impedance in shunt therewith increases, and the increase of the latter tends to compensate for the decrease of the former and thus tends to maintain the resultant impedance constant, as seen from the input or output terminals.

In contrast with the arrangement of Fig. 1*d* is the arrangement of Fig. 1*c* in which the impedance, as seen from the output and input terminals, comprises the impedance of the portion of the first potentiometer which is above the slider in series with the shunt circuit comprising the portions of both potentiometers which are below the sliders. For this case, as the slider is moved downward, the impedance of the series portion of the slider increases in direct proportion to the slider movement, while the impedance of the shunt portion below the slider decreases rapidly. In other words, the impedances of the series and shunt portions vary in such manner as to cause a rapid variation in the total impedance as seen from the input or output terminals, due to the movement of the slider.

If four potentiometers are used instead of two even better impedance characteristics can be obtained, than are disclosed in Fig. 2. Figs. 3*a* to 3*d*, inclusive, show the possible symmetrical arrangements utilizing four potentiometers for obtaining multiple attenuation. Each potentiometer comprises four potentiometer elements connected in succession between input terminals 1 and output terminals 2. A rigid insulating handle 5 is associated with the sliders of all the potentiometers in each case so that movement of the handle will simultaneously vary the position of all the sliders by the same amount. The unsymmetrical arrangements were not considered for the case of four potentiometers, due to the difference between the input and output impedance characteristics pointed out above.

Fig. 4 shows the impedance characteristics of the attenuators shown in Figs. 3*a* to 3*d*, respectively. Curve 14 shows the impedance variation for the device of Fig. 3*a*, curve 15 the impedance of the device of Fig. 3*b*, curve 16 that for Fig. 3*c* and curve 17 that for Fig. 3*d*.

It will be noted that the impedance for the attenuators of Figs. 3*a* and 3*b* varies over a much wider range than in the case of Figs. 3*c* and 3*d*. This, of course, is at once apparent by comparing curves 14 and 15 with curves 16 and 17, respectively. The reason why this result is obtained is due to the fact that for Figs. 3*c* and 3*d* the compensating impedance effect discussed above in connection with Fig. 1*d* is obtained, while for Figs. 3*a* and 3*b* this effect is absent. It will be noted by comparing Figs. 1*d*, 3*c* and 3*d* with Figs. 1*c*, 3*a* and 3*b* that this compensating effect which tends to equalize the input or output impedance, is in all cases obtained

when the input and output terminals are connected across the variable portions of the terminal potentiometers in the succession.

Comparing curves 14 to 17 of Fig. 4, it will be noted that curve 17 shows the least impedance variation with slider position of any of the arrangements shown. Hence, the attenuator arrangement shown in Fig. 3*d* constitutes the most suitable device of any for obtaining multiple attenuation. Incidentally it might be pointed out here that the attenuation curves for all of the devices shown in Figs. 1 and 3 are similar in shape to the curves of Fig. 5. The corresponding curves for all of the attenuators could be obtained from curve 7 of Fig. 5 by multiplying each ordinate thereof by a suitable factor dependent upon the number of potentiometers used and the method of connection in each instance.

It was pointed out above that it is not advisable, due to the crowding effect, to utilize any of the attenuators discussed, beyond the two-thirds position of the slider. This, of course, means that in general the lowest third of the potentiometer would never be used in actual practice. This suggests the possibility of replacing the lower one-third of each potentiometer by a fixed impedance, i. e., in each instance utilizing potentiometers having a maximum range only two-thirds of what would be normally required, and connecting in series with the lower terminal of each, a fixed impedance equal to one-half the fixed portion of the potentiometer.

An attenuator constructed on this principle and utilizing the method of connection shown in Fig. 3*d*, is shown in Fig. 6. Referring to Fig. 6, the input and output terminals are again shown at 1 and 2. Four potentiometer elements 21 are utilized with each potentiometer connected in series with a fixed resistance 20 individual thereto, as shown. Each resistance 20 has half the magnitude of the fixed portion of the corresponding potentiometer 21 so that when the slider has been moved to its lowest position the slider will still be across one-third of the total resistance. With an arrangement such as this it is not possible to move the potentiometer past the two-thirds position, which will ensure the utilization only of the accurate range for obtaining attenuation values.

Fig. 7 shows in plan view, the structural features of an attenuator of the type shown schematically in Fig. 6. The resistances 20 of Fig. 6 are shown by the elements 20 in Fig. 7. The potentiometers are shown at 21, and are of a well known type, each comprising a coil of wire 22 wound on an insulating core and bent into a circle and fitted into an insulating base 23, usually of porcelain or the like. All of the potentiometers 21 are rigidly mounted on a common shaft 23 having affixed to one end thereof a handle 24. Rotation of the handle 24, of course, thus rotates all of the potentiometers simultaneously. Affixed to the receptacle 25 which holds the attenuator equipment, are two insulating segments 26, and affixed to either side of a segment 26 are two contact clips 27 with each contact 27 bearing against the slide wire 22 of a potentiometer 21, a different potentiometer for each such clip. The contact clips 27 of Fig. 7, of course, correspond to the sliding contacts 27 of Fig. 6. The slide wire 22 of each potentiometer 21 is connected between a pair of terminals 28. The lower terminals of the two central potentiometers are interconnected by means of a strap 29, while the other terminal of each of these potentiometers is connected to a resistance 20 by means of a lead 30, as shown. One terminal of each of the end potentiometers is connected to a resistance 20 over a lead 30, while the other terminal thereof is connected to an inner spring clip 27 over a lead 31, as shown. The two outer spring clips are connected respectively to the terminals 34 and 35, as shown. One terminal of each of the resistances 20 is connected to lead 36, extending between the terminals 32 and 33. Terminals 32 and 34 constitute the input terminals 1 of Fig. 6, and terminals 33 and 35 the output terminals 2 of Fig. 6. Each lead 30 and 31 is longer than normally required as is indicated by the coiled portion of the lead, in order that the potentiometers may be able to rotate with the shaft 23 without injury to the equipment.

In order that an operator may set the attenuator to introduce a known amount of attenuation into a circuit a dial 38 and pointer 37 is provided. The dial 38 is preferably disk shaped and is rigidly mounted on the enclosing receptacle 25 surrounding the spindle 23, as shown. The pointer 37 is affixed to the spindle 23 and hence rotates therewith. The dial is preferably marked off in db. to indicate the attenuation introduced for any setting of the pointer.

The operation of the device is, of course, simple. By merely turning the knob 24 all of the potentiometers 21 may be rotated to any position, and since the spring clip contacts 27 are stationary the contacts may be set at any relative position on the slide wires 22.

Fig. 7, of course, shows only one specific mode of constructing an attenuator of the type disclosed herein, but the invention is, of course, not limited by the specific device shown.

What is claimed is:

1. An attenuator for use in electrical systems comprising in combination, an input and an output section, together with a plurality of potentiometers disposed in succession between said sections, with the variable portion of each intermediate potentiometer connected to the adjacent potentiometer on

one side thereof and with the fixed portion of said potentiometer connected to the adjacent potentiometer on the other side thereof, and with the terminal potentiometers of said succession connected respectively to said input and output sections, and a single control element for simultaneously adjusting by the same amount the attenuation setting of each of said plurality of potentiometers.

2. An attenuator for use in electrical systems comprising in combination, an input and an output section, together with a plurality of similar potentiometers comprising an even number thereof connected in succession between said input and output sections, with the variable portions of the terminal potentiometers in said succession connected respectively to said input and output sections, and commencing with the terminal potentiometers of said succession and extending toward the center, with the fixed portion of each of said potentiometers connected to the variable portion of that immediately succeeding, and with the fixed portion of the two central potentiometers in the succession connected in multiple, and means for adjusting simultaneously and by the same amount the attenuation setting of each of said plurality of potentiometers.

3. An attenuator for use in electrical systems comprising in combination, an input and an output section, a pair of similar potentiometers having their fixed portions connected in multiple, and with the variable portion of each said potentiometer connected to the fixed portion of a second similar potentiometer individual thereto, a connection from the variable portion of one said second potentiometer to said input section, a connection from the variable portion of the other said second potentiometer to said output section, and a single control element for adjusting simultaneously and by the same amount the attenuation setting of each of said plurality of potentiometers, whereby multiple attenuation is obtained as compared to that of a single potentiometer.

4. An attenuator for use in electrical systems comprising in combination, an input and an output section, a plurality of potentiometers disposed in succession between said sections and interconnected to have the variable portion of any intermediate potentiometer in said succession connected to the adjacent potentiometer on one side, and with the fixed portion of said potentiometer connected to the adjacent potentiometer on the other side thereof, with the terminal potentiometers in said succession connected respectively to said input and output sections, a plurality of similar fixed impedance elements individual to said potentiometers and connected in series with the impedance thereof, for providing a minimum gain adjustment for said potentiometers, and a single control element for simultaneously adjusting the attenuation setting of said plurality of potentiometers.

5. An attenuator for use in electrical systems comprising an input and an output section, a plurality of potentiometers comprising an even number thereof disposed in succession between said sections, with said input and output sections connected respectively across the variable portions of the terminal potentiometers in said succession, and with the fixed portion of each potentiometer connected across the variable portion of that succeeding, passing toward the center from each end of said succession, and with the fixed portions of the two central potentiometers of said succession connected in multiple, a plurality of equal resistances individual to said potentiometers and in series with the fixed portions thereof for providing a minimum attenuation setting, and a single control element for adjusting simultaneously the gain setting of said plurality of potentiometers.

6. A device for attenuating electrical currents or voltages, comprising in combination, an input and an output section, a plurality of intermediate and a plurality of variable terminal attenuating means interposed in succession between said sections, for dividing a plurality of times in succession, current or voltage delivered to said input section, and a single control element for adjusting simultaneously the settings of said plurality of potentiometers.

7. An attenuator for use in electrical systems comprising in combination, an input and an output section, a plurality of intermediate and a plurality of terminal slide wire potentiometers disposed in succession between said sections and interconnected to provide approximately multiple attenuation between said sections as compared to a single potentiometer, and a single control element for adjusting simultaneously all the sliding contacts individual to said plurality of potentiometers, said input and output sections being connected respectively to the variable portions of the terminal potentiometers in said succession for minimizing the variation of terminal impedance with slider adjustment.

8. An attenuator for use in electrical systems comprising in combination, an input and an output section, a plurality of slide wire potentiometers comprising an even number thereof, disposed in succession between said sections for obtaining approximately multiple attenuation compared to a single potentiometer, and a single control element for adjusting simultaneously all the sliding contacts individual to said plurality of potentiometers, said input and output sections being connected respectively to the variable portions of the terminal potentiometers in said succession, with the fixed portions of

the latter connected respectively to the variable portions of the next succeeding potentiometers in said succession extending toward the center, and so on for the remaining potentiometers with the fixed portions of the two central subscribers connected in multiple, for minimizing the variation in terminal impedance with adjustment of said control element.

9. An attenuator for use in electrical systems comprising in combination, an input and an output section, a plurality of intermediate and a plurality of variable terminal slide wire potentiometers disposed in succession between said sections and interconnected to provide approximately multiple attenuation between said sections as compared to a single potentiometer, and a single control element for adjusting simultaneously all the sliding contacts individual to said plurality of potentiometers, and indicating means to indicate the amount of attenuation introduced into a circuit for a given setting of said control element.

10. An attenuator for use in electrical systems comprising in combination, an input and an output section, together with a plurality of potentiometers disposed in succession between said sections, with the variable portion of each intermediate potentiometer connected to the adjacent potentiometer on one side thereof and with the fixed portion of said potentiometer connected to the adjacent potentiometer on the other side thereof, and with the terminal potentiometers of said succession connected respectively to said input and output sections, and a single control element for simultaneously adjusting by the same amount the attenuation setting of each of said plurality of potentiometers, and indicating means associated with said control element for indicating the attenuation introduced into a circuit for a given setting of said control element.

11. An attenuator for use in electrical systems comprising in combination, an input and an output section, together with a plurality of potentiometers comprising an even number thereof connected in succession between said input and output sections, with the variable portions of the terminal potentiometers in said succession connected respectively to said input and output sections, and commencing with the terminal potentiometers of said succession and extending toward the center, with the fixed portion of each of said potentiometers connected to the variable portion of that immediately succeeding, and with the fixed portion of the two central potentiometers in the succession connected in multiple, and means for adjusting simultaneously and by the same amount the attenuation setting of each of said plurality of potentiometers.

12. An attenuator for use in electrical systems comprising in combination, an input and an output section, a pair of potentiometers having their fixed portions connected in multiple, and with the variable portion of each said potentiometer connected to the fixed portion of a second potentiometer individual thereto, a connection from the variable portion of one said second potentiometer to said input section, a connection from the variable portion of the other said second potentiometer to said output section, and a single control element for adjusting simultaneously and by the same amount the attenuation setting of each of said plurality of potentiometers, whereby multiple attenuation is obtained as compared to that of a single potentiometer.

13. An attenuator for use in electrical systems comprising in combination, an input and an output section, a plurality of potentiometers disposed in succession between said sections and interconnected to have the variable portion of any intermediate potentiometer in said succession connected to the adjacent potentiometer on one side, and with the fixed portion of said potentiometer connected to the adjacent potentiometer on the other side thereof, with the terminal potentiometers in said succession connected respectively to said input and output sections, a plurality of fixed impedance elements individual to said potentiometers and connected in series with the impedance thereof, for providing a minimum gain adjustment for said potentiometers, and a single control element for simultaneously adjusting the attenuation setting of said plurality of potentiometers.

In testimony whereof, I have signed my name to this specification this 13th day of May 1929.

WALTER KOENIG, JR.