Aug. 20, 1963 P. LUGER 3,101,465

INDEFINITELY LONG POTENTIOMETER

Filed April 21, 1960 3 Sheets-Sheet 1

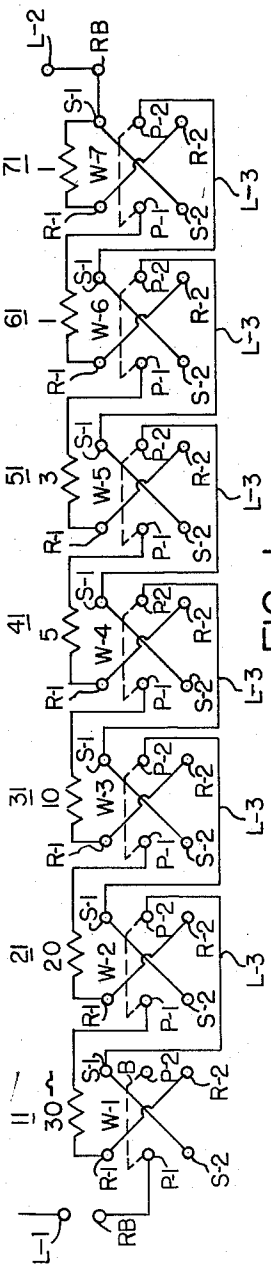


FIG.-1

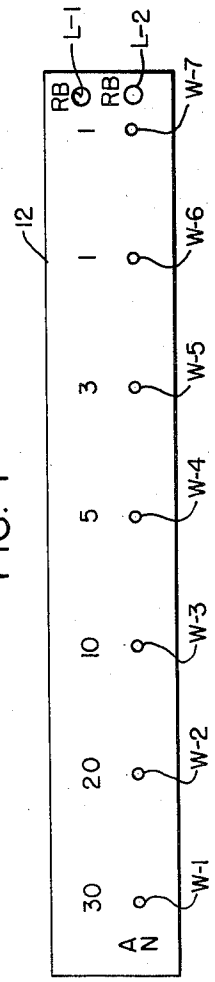


FIG.-2

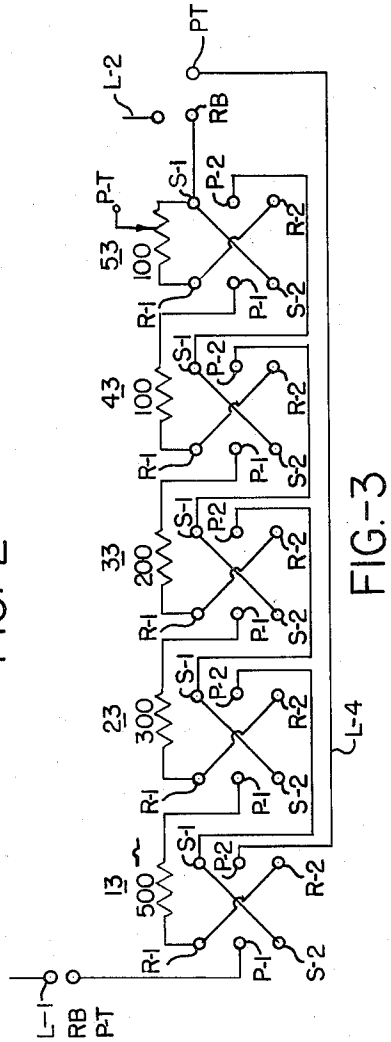


FIG.-3

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INDEFINITELY LONG POTENTIOMETER

Filed April 21, 1960 3 Sheets-Sheet 2

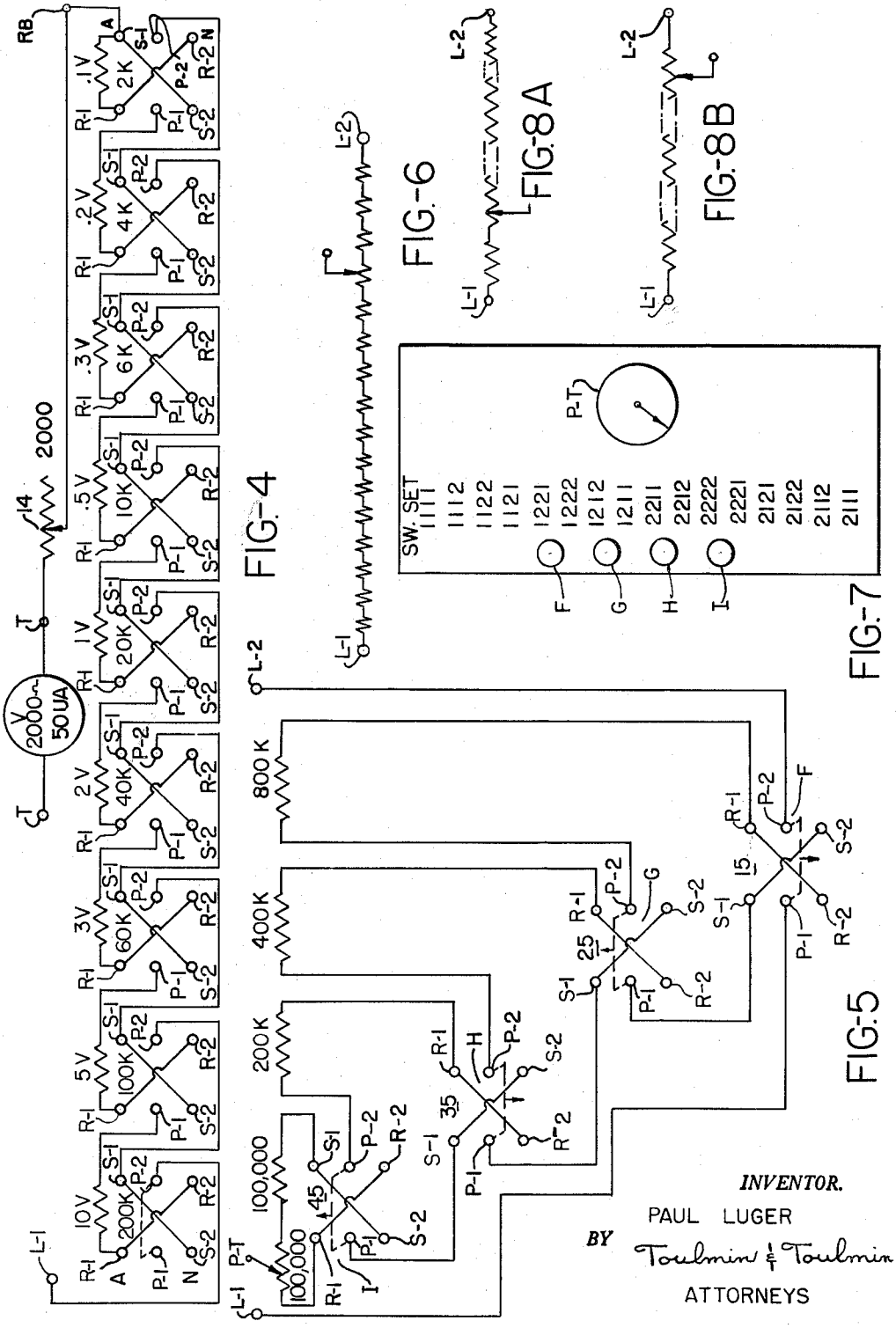


FIG-4

FIG-5

FIG-6

FIG-7

FIG-8A

FIG-8B

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Aug. 20, 1963 P. LUGER 3,101,465

INDEFINITELY LONG POTENTIOMETER

Filed April 21, 1960 3 Sheets-Sheet 3

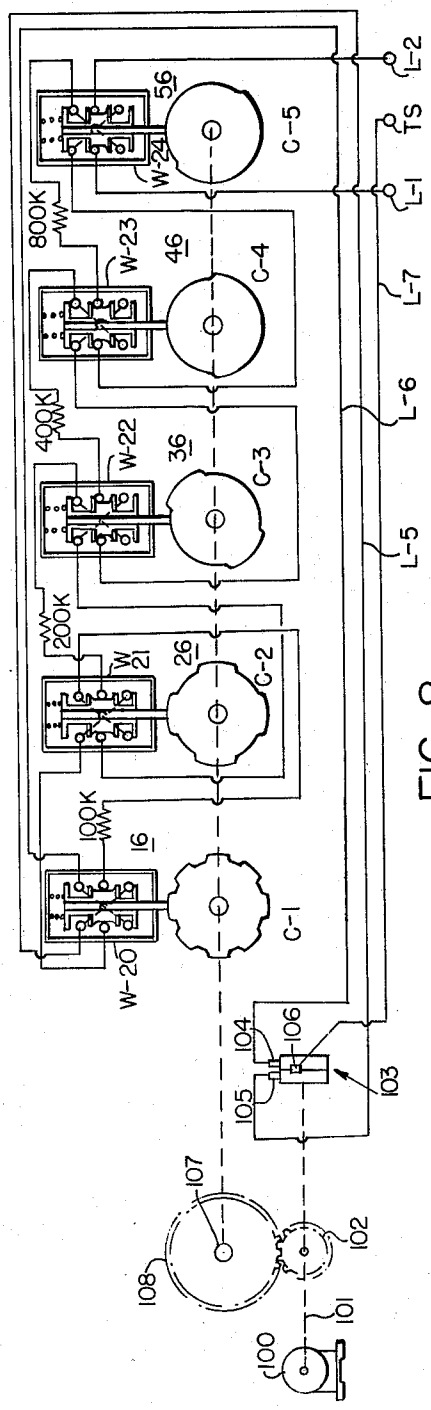


FIG-8

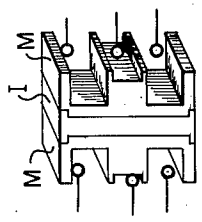


FIG-8C

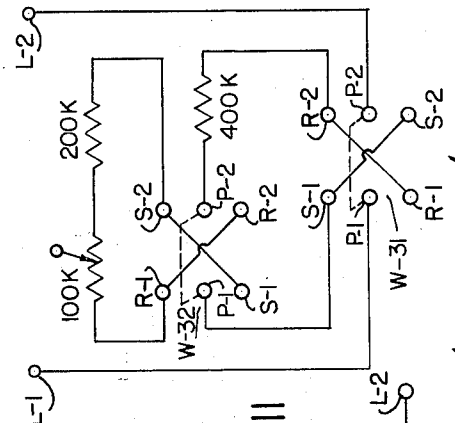


FIG-11

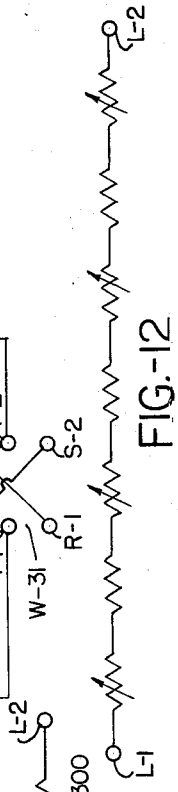


FIG-12

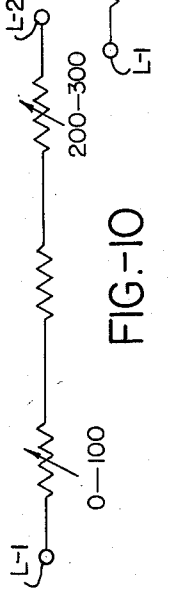


FIG-10

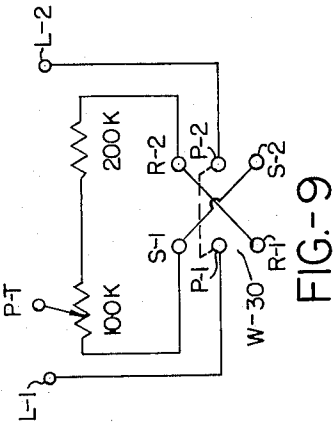


FIG-9

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United States Patent Office 3,101,465 Patented Aug. 20, 1963

3,101,465

INDEFINITELY LONG POTENTIOMETER

Paul Luger, Seattle, Wash., assignor to Seattle University, Seattle, Wash.

Filed Apr. 21, 1960, Ser. No. 23,816
14 Claims. (Cl. 338—128)

This invention relates to impedance networks such as resistance boxes, potentiometers and the like, and more particularly to an improved switching arrangement of the impedance of such networks.

The apparatus which is the principal object of the present invention utilizes as a basic stage a combination of a resistance device and a switch member; a plurality of such stages are normally connected together between terminals to form a resistance box—or, in addition suitable connections are provided to form a potentiometer. In the resistance box the resistance device is suitably a resistance element of fixed value with one stage variable, if desired, while in the potentiometer one stage may have as its resistance device a resistance of fixed value in electrical connection with a conventional potentiometer.

A resistance box provided in accordance with the present invention permits the attainment of resistance values over a range from that of the smallest value of resistance present to the total of all of the resistances; a decimal system of resistance values is preferably but not necessarily employed—the decimal system yielding the advantage of being more easily set up to a given resistance value. The present system also requires a more simple switching element than is used with conventional resistance boxes.

A potentiometer incorporating the features of this invention permits the attainment of values with relatively few resistance elements, which values would normally require a great plurality of resistors. In essence the potentiometer incorporating the principles of the invention provides an equivalent potentiometer of great length and, in fact, the potentiometer length may be termed indefinite since the resistance may be doubled readily by the provision of an additional stage. Doubling the value of previous resistances in a chain of resistor elements together with the addition of a switch member is effective to provide in the usual case a continuous range of resistance in the potentiometer.

Apparatus in accordance with the present invention includes resistance boxes-potentiometer combinations, motor driven potentiometers and skip distance devices, as well as the resistance boxes and potentiometers to which specific reference has been made. Utility is found for these networks in the fields of application common to resistance boxes and potentiometers; however, definite advantages, as noted hereinbefore and as noted hereinafter, are attributed to the apparatus of this invention. For example, a potentiometer incorporating the features of this invention is not only fully equivalent in application to the well known Kelvin-Varley circuit but exhibits a particular advantage in that loading at the output end has substantially no effect on the reliability of the reading—in distinct contrast to the Kelvin-Varley circuit. This obtains since the equivalent resistances for the various settings are easily calculated from the load resistance and the reading of the control settings when utilizing a potentiometer of the present invention, whereas most equivalent resistances are calculated only with the greatest difficulty in the Kelvin-Varley circuit.

Such features render the devices in accordance with the present invention useful in meter applications, Wheatstone bridges, circuits requiring variable grounds such as a quadrant quartz fiber electrometer, or a power

supply, and in fact in areas where a potentiometer is required to possess good reproducibility, substantially indefinitely large resolvability, and even in circuits where the potentiometer is loaded.

In resistance-box applications, the switch member associated with the resistance device of a stage incorporates means for including or excluding the resistance device of that stage from the circuit of the instrument while yet providing for the application of power to a succeeding stage through the switch members. In addition in potentiometer application the switch members provide for the positioning of the conventional potentiometer of the resistance device in a desired position relative to other resistance devices of the circuit of the apparatus. In addition, a simplified setting arrangement is achieved in apparatus in accordance with the invention by the relationship of the resistance devices and the switch members.

The invention will be more fully understood by reference to the following detailed description and accompanying drawings wherein:

FIGURE 1 is a circuit diagram of an arrangement embodying the invention and particularly illustrating a resistance box circuit;

FIGURE 2 is a schematic view of a panel illustrating an array of switches useful in conjunction with a circuit such as that of FIGURE 1;

FIGURE 3 is a circuit diagram similar to that of FIGURE 1 but particularly illustrating a combination resistance box and potentiometer circuit;

FIGURE 4 is a modification illustrating the invention in connection with a D.C. voltage meter application;

FIGURE 5 is a circuit diagram of an arrangement embodying another modification of the invention and particularly illustrating a potentiometer arrangement which is susceptible to the addition of resistance in accordance with fixed rules to provide a potentiometer of substantially indefinite length;

FIGURE 6 is a schematic view illustrating the equivalent circuit of FIGURE 5 with the switch settings as shown in FIGURE 5;

FIGURE 7 is a schematic view of a panel arrangement useful in connection with the circuit of FIGURE 5 for the setting of the switches;

FIGURE 8 illustrates a motor driven potentiometer circuit arrangement in accordance with the principles of the invention;

FIGURES 8A and 8B are schematic illustrations of equivalent circuits in accordance with two switch settings of the circuit of FIGURE 8, the equivalent resistor circuits being broken by dot-dash lines and emphasizing the potentiometer contact positions;

FIGURE 8C is a perspective view of one type of movable element useful in making and breaking contacts in the motor-driven structure of FIGURE 8;

FIGURE 9 is a circuit diagram illustrating a skip distance potentiometer;

FIGURE 10 is a schematic view illustrating the equivalent circuit of FIGURE 9;

FIGURE 11 is a circuit diagram similar to that of FIGURE 9 but incorporating an additional distance in a skip distance potentiometer; and

FIGURE 12 is a schematic view of the equivalent electric circuit of FIGURE 11, the specific values being eliminated.

In the description of the drawings which follows similar designations have been used wherever practicable to identify similar parts having similar functions.

In FIGURE 1, which is a circuit diagram of a resistance box having terminals designated RB, L–1 may be considered the input power line connection and L–2 the out-

put power line connection. Between the terminals RB there are provided a plurality of stages of the resistance box, the stages being indicated at **11**, **21**, **31**, **41**, **51**, **61** and **71**.

Each stage comprises a switch member and a resistance device. As shown in FIGURE 1 each resistance device is a single resistor element denominated by the resistor value. The switch means comprised of a plurality of switch members are connected between the resistance box terminals RB. Each switch member includes a pair of electrically insulated power contacts, P–1, P–2 and through one of which, in any position of the device, power is applied to the particular switch through an arm B of the movable member of the switch. As shown the switch may be a double pole-double throw lever arrangement; in FIGURE 1 all movable members are illustrated in dotted lines, in other figures some movable members are not shown to aid clarity in the drawing. Each switch also includes a pair of resistance device contacts electrically connected together and designated R–1 and R–2, and through which contacts power is applied to the resistor element of the stage.

A third pair of contacts designated S–1 and S–2 are suitably termed switch contacts and power in an appropriate position on the switch is applied through these contacts from one stage to a power contact of a succeeding stage rightwardly as shown in FIGURE 1.

As will be particularly noted from FIGURE 1 the resistance having a value of 30 ohms is connected between the resistance device contacts R–1, R–2 and the power contact P–1 of stage 21 and the contacts S–1, S–2 of stage **11** are directly connected to the power contact P–2 of stage **21**, such connection being provided by the conductor L–3.

As illustrated in FIGURE 1 the switch is of a lever type and the contacts will be of the jaw type (not shown) to receive the blade B of the lever. Further, the switch as illustrated is a double throw switch and accordingly when moved to either position is effectively locked. However, it is to be noted that other types of switch structures may be employed as will be apparent, the particular feature of the switch being the contact arrangement and the arrangement of contacts between stages.

For convenience the switches of the stages have been successively designated W–1, W–2, W–3, W–4, W–5, W–6 and W–7, the resistor elements being designated by their form and value.

The resistance box of FIGURE 1 is predicated upon a decimal system of resistance values and affords a particular advantage in the simplicity of setup of the switches to attain a particular resistance. Further, a minimum number of switches and resistances are utilized to attain a large range of resistance values.

Reference is now made to FIGURE 2 wherein there is indicated a panel designated by the numeral **12** and which panel is marked with a series of resistance values similar to those of FIGURE 1. Further, the resistance box terminals are indicated at the right side of the figure as are their connections to the power line. The switches are designated in accordance with FIGURE 1; in addition, however, there is provided at the left hand side letters A and N.

Referring again briefly to FIGURE 1, it will be apparent that with all the switches in the upper position, which is the A position of FIGURE 2, all of the resistances are in circuit. Similarly, it will be noted that by simply throwing the switch of stage **11**, that is W–1, to the lower or N position (FIGURE 2), all of the resistances are by-passed.

The rule for setting up the resistance box may be stated to be: counting from the left, A commands to connect the first resistance in circuit; N commands to leave it out. Then proceeding to switches on the right, A leaves each previous command unchanged; N changes the previous command.

The following shows several settings of the resistance box:

31

	30	20	10	5	3	1	1
A	x		x	x	x	x	
N		x					x

70

A	x	x	x	x	x	x	x
N							

26

A							
N	x	x	x	x	x	x	x

27

A							x
N	x	x	x	x	x	x	

23

A				x			x
N	x	x	x		x	x	

47

A	x			x			x
N		x	x		x	x	

This may be exemplified by noting that if the switch of stage **11** is thrown to the N position while all others remain in the A position, all others, together with the resistance of stage **11**, are out of circuit. However, if the switch of stage **21** is also thrown to an N position, then the resistance of stage **21** and all the succeeding switches in the A position are such that the succeeding resistances are in circuit.

Consequently it may also be stated that if the number of switches counting from the left in the N position is even, that latter N switch and all succeeding switches in the A position are in circuit; but a next succeeding switch in an N position, that is, a switch in an odd numbered position on the N side, would place itself and all succeeding switches on the A side out of circuit.

In FIGURE 3, utilizing a circuit very similar to that shown in connection with FIGURE 1, the stages are designated by the numerals **13**, **23**, **33**, **43** and **53**. The specific resistance values in this instance are different and as designated on the drawing in addition the stage **53** has a resistance device, which is a potentiometer having the terminal P–T, the other potentiometer terminals of the combination being attached to the P–1 and P–2 terminals of stage **13**, one of which is coincident with a resistance box terminal designated RB and also P–T. This potentiometer may be said to be of substantially indefinite length, since its electrical length may be increased by simply adding a suitable resistance and a switch. The resistance device of stage **53** is simply a basic standard potentiometer type, but it is to be noted is added as the lowest resistance of the box.

To provide the potentiometer for any particular setting it is only necessary to determine the resistance as described above for the resistance box. The circuit then provides that following in series after this set resistance, will be the potentiometer of stage **53**, after which, also in series, will appear the remaining resistance in the box. Thus the switches provided in connection with FIGURE 3 will provide a continuous range of resistance values

from zero to 1200 and will permit the slide of the basic potentiometer to be positioned at any point within the 1200 ohm span. It is to be noted that the circuit arrangement of FIGURE 3 differs from FIGURE 1 only in the addition of one lead L–4, and the basic potentiometer of stage **53**. This circuit will be better understood when explanation is made in conjunction with FIGURES 5, 6 and 7.

In FIGURE 4 a D.C. voltmeter arrangement is illustrated, an important feature of the circuit being that for any voltage reading greater than 0.1 volt a full scale deflection may be obtained.

The meter is designated at V and is suitably a 20,000 ohms per volt meter requiring 50 microamperes for full scale deflection, the resistance of the meter being 2,000 ohms and 0.1 volt providing for the full scale deflection.

Between the right hand terminal T of the meter and the terminal S–1 there is provided a rheostat having a total resistance of 2,000 ohms and adapted to drop 0.1 volt when a current of 50 micro-amperes is flowing. The circuit arangement of the box is similar to that described hereinbefore except for specific values of resistance indicated on the drawing, the voltage drop with a 50 micro-ampere flow being indicated on each resistor. Thus it will be apparent that the volt meter may read from zero to 22.3 volts and that the reading may be to three places or better by an appropriate selection of the rheostat or the potentiometer designated at **14** generally. The 22.3 volts is composed of the voltage drops across all resistors plus the voltage drop in the meter when the maximum current of 50 micro-amperes is flowing

$$(10+5+3+2+1+.5+.3+.2+.1+.1+.1)$$

With the addition of only 4 more resistances and 4 switches the meter would be extended to better than 200 volts. In general, the addition of 4 resistances and 4 switches increases the range of resistance by a factor of ten.

In FIGURE 5 the circuit arrangement is that whereby one standard potentiometer, together with a plurality of fixed resistances and an equal number of switches, provides an equivalent potentiometer of great length; in fact, the potentiometer may be made indefinitely long as its resistance can always be doubled by simply adding one switch and one fixed resistance.

The circuit of FIGURE 5 differs from the preceding circuits in that the standard potentiometer of 100,000 ohms having the terminal PT is directly in series with a fixed resistance of 100,000 ohms. Each of the remaining fixed resistances has a value double that of the preceding resistance, reading from left to right in FIGURE 5.

As will be apparent the contacts R–1, R–2, S–1, S–2, P–1 and P–2 of each switch are similar in arrangement and function to the contacts of FIGURES 1, 3 and 4. However, by the modification noted and by appropriate selection of switches in either the up or downward position (FIGURE 5), the position of the potentiometer having the contact PT, relative to the other resistances, may be widely varied. FIGURE 5 exemplifies this, the potentiometer being shown between the terminal L–1, L–2 in an equivalent resistor circuit where each resistance has a value of 100 kilohms. If the switches in FIG. 5 are closed in the direction of the arrows, the potentiometer contact slider being connected to terminal PT is positioned between the 12th and 14th of the equivalent resistance circuit of FIG. 5 as shown in FIGURE 6. It will be immediately apparent also that if all of the switches of FIGURE 5 were placed in the upper position, the potentiometer resistance devices would assume an initial position adjacent the power line contact L–1.

The circuit of FIGURE 5 is thus equivalent to 16 different resistances each of 100,000 ohms resistance, and the potentiometer may be located at any of the positions in the resistance line by simply appropriately maneuvering the switches.

FIGURE 7 exemplifies this, FIGURE 7 being a schematic view of a panel arrangement wherein the potentiometer control is designated at PT and the switches are designated at F, G, H and I.

The columns of numerals designated SW.SET are for providing switch settings, the numeral 1 of the switch setting column, with relation to FIGURE 5, designating an upward position of the switch, while the numeral 2 designates a downward position of the switch. Thus for the first setting 1111 is the equivalent resistance circuit which shows 16 resistances of 100,000 ohms each in linear array with the potentiometer in the first position. However, the equivalent circuit shown in FIGURE 6 would be attained with the setting 2121, which is as the switches are depicted in FIGURE 5. It is thus to be noted that an equivalent potentiometer of substantially indefinite length may be attained by the use of the circuit described and that the potentiometer will have a continuous range.

FIGURE 8 illustrates an application of a circuit similar to that of FIGURE 6 but motor driven. In FIGURE 8 the numeral **100** designates a motor driving a shaft **101** and carrying a high speed gear **102** and a potentiometer **103**, the contacts of which are designated as **104**, **105** and **106**.

The potentiometer **103** is a one-turn continuous rotation potentiometer and is assumed to have a value of 100 kilohms. Extending parallel with the shaft **101** is a driven shaft **107** carrying a gear **108** which meshes with the gear **102** to provide the driven shaft **107** at a speed $\frac{1}{16}$ of that of the shaft **101**. Shaft **107** mounts a plurality of cams C–1, C–2, C–3, C–4, C–5. These cams as depicted are positioned to determine the setting of the switches W–**20**, **21**, **22**, **23**, **24** of the stages **16**, **26**, **36**, **46**, **56**, respectively.

FIGURE 8C shows one possible movable element for use in the circuit of FIGURE 8, the letter M designating metal for electrical conduction and I designating insulating material to provide for the required insulation of the contacts. The movable element as shown is spring biased to a downward position normally.

The values of resistances are illustrated on the drawing and are similar to those shown in FIGURE 5, the primary difference being that the continuous rotation potentiometer has its own switch W–**20** independent of the switch of the fixed resistance of 100 kilohms, which switch is designated at W–**21**.

The switch W–**20** of stage **16** has its resistance device contacts and its switch contacts connected, respectively, to the contacts **105**, **104** of the continuous rotation potentiometer **103** through leads L–5, L–6, respectively. Lead L–7, which is the slide lead, extends from the contact **106** to the terminal TS, the power line terminals being designated at L–1, L–2.

In the position shown in FIGURE 8 the cams are so provided that the equivalent circuit of FIGURE 8*a* is obtained. Further, the single turn potentiometer **103** may be assumed to be in its second turn of 16 revolutions. The circuit may be readily traced starting at L–1 and proceeding through switches W–**24**, W–**23**, W–**22**, W–**21** through the resistance of 100 kilohms and to switch W–**20**, then through the single turn potentiometer **103** and back through switches W–**20**, W–**21** to 200 kilohm resistance switch W–**22** to 400 kilohm resistance switch W–**23** to 800 kilohm resistor switch W–**24** and to terminal L–**2**.

When the motor and its associated shaft and potentiometer have made 8 full turns the cams will be in their diametrically opposite positions to those shown in FIGURE 8. Then switch W–**20**, switch W–**21** and switch W–**22** will be in the same positions as they are shown in FIGURE 8; but switches W–23 and W–**24** will be in the reverse position to that of FIGURE 8. This position would put the basic potentiometer in its tenth turn. The

equivalent circuit for the last of 16 turns is shown in FIGURE 8B.

Thus, it is to be clearly noted that the arrangement of invention is particularly suitable for motor driven applications, such as are found useful in conjunction with analogue computers, for example.

FIGURES 9–12, inclusive, indicate applications of circuits in accordance with the invention to skip distance potentiometers, FIGURE 10 being the equivalent circuit for the arrangement shown in FIGURE 9, and FIGURE 12 being the equivalent circuit for the arrangement shown in FIGURE 11.

As will be clearly noted from FIGURE 9, with the switch W–30 in an upward position the potentiometer may cover the range from zero to 100 kilohms. If the switch were provided in a downward position the potentiometer would cover the range of 200 to 300 kilohms. Thus a fixed resistance in the 100 to 200 range exists, as is clearly indicated by FIGURE 10.

By adding a resistance which is twice that of the fixed resistance of FIGURE 9 and by providing an additional switch, as in FIGURE 11, the circuit of FIGURE 12 is obtained in contrast to the equivalent circuit of FIGURE 10. It will be noted that skip distance resistances exist between 100 and 200 kilohms and between 300 and 400 and between 500 and 600.

It is further to be noted and is deemed apparent from the foregoing that if an additional resistance were to be added to FIGURE 11, and if this additional resistance has 8 times the resistance of the basic potentiometer, that is 800 kilohms, then a 1½ megohm total resistance is achieved with every other 100,000 ohms comprising a skip distance or a fixed resistance.

Various patterns of skip distances may be provided by suitably alternating the switch positions in accordance with the foregoing teachings. It will be appreciated then that by the addition of a resistance element and a switch to the circuits specifically illustrated various patterns of skip distances may be provided and that such arrangements are useful where a sudden change of potential is desirable—as in a signaling device or a control system.

In the devices illustrated it is to be noted that one resistance device of each circuit connects between a resistance device contact and a switch contact of the switch member of the stage usually termed the first stage and that the switch selection means is adapted to connect either power contact with a switch contact or with a resistance device contact. In succeeding stages the fixed resistance element constituting the resistance device is connected between a resistance device contact of its stage and a power contact of a preceding stage. The other power contact of the preceding stage is electrically connected with a switch contact of a succeeding stage, the switch selection means serving to connect electrically the power contacts and other contacts selectively as described to provide alternate electrical paths between terminals through the power contacts.

Input and output terminals of the potentiometer network are connected either with power contacts of one stage or with a switch contact and a power contact. In the case of a potentiometer the movable contact cooperates with the input terminal usually as in other potentiometer arrangements. The basic potentiometer is often connected in series with a resistance device in the first stage.

It will further now be apparent that depending on the equivalent circuit desired a relationship exists between the resistance values in both potentiometer and resistance box circuits. As already noted a continuous range of resistance is obtainable in a resistance box from zero upwardly by doubling the preceding resistance through the addition of the required fixed resistance and a switch (FIGURE 5). This same effect is also obtained (FIGURE 1) by employing a decimal system and adding less than the sum of previous resistances.

The skip distance device is obtained if one adds more than the sum of the previous resistances (FIGURES 9 and 11).

It will be understood that this invention is susceptible to modification in order to adapt it to different usages and conditions and accordingly, it is desired to comprehend such modifications within this invention as may fall within the scope of the appended claims.

What is claimed is:

1. In combination, in a resistance circuit network, two terminal means, a circuit including switch means comprising a switch member having a pair of electrically insulated power contacts, a pair of resistance device contacts electrically permanently connected together and a pair of switch contacts electrically permanently connected together, said power contacts, resistance device contacts and switch contacts being electrically insulated from each other, a resistance element electrically permanently connected with one end to said resistance device contacts, a switching means including ganged first and second movable contact means respectively connected to said pair of power contacts, said first movable contact capable of selectively engaging one of said switch contacts and one of said resistance device contacts, while simultaneously said second movable contact is capable of selectively engaging the other one of said resistance device contacts and the other one of said switch contacts, and means including the other end of said resistance element and one of said switch contacts for electrically interconnecting said two power contacts and said two terminal means, respectively.

2. In combination, in a resistance circuit network, two terminal means, a circuit including switch means comprising a switch member having a pair of electrically insulated power contacts, a pair of resistance device contacts permanently electrically connected together and a pair of switch contacts also permanently electrically connected together, said power contacts, resistance device contacts and switch contacts being electrically insulated from each other, a resistance device including a potentiometer permanently electrically connected between one of said resistance device contacts and one of said switch contacts, selection means including ganged first and second movable contact means respectively connected to said pair of power contacts, said first movable contact being capable of selectively engaging one of said switch contacts and one of said resistance device contacts, while simultaneously said second movable contact is capable of selectively engaging the other one of said resistance device contacts and the other one of said switch contacts, and means including said power contacts and one of said switch contacts for electrically interconnecting said two power terminals and said two terminal means, respectively.

3. In combination, a resistance circuit network comprising: a pair of terminals and switch means adapted for being connected between said terminals, said switch means comprising a first and a second switch member, said first switch member having a pair of electrically insulated power contacts and said second switch member having a pair of insulated power contacts, each of said first and second switch members having a pair of resistance device contacts electrically permanently connected together and a pair of switch contacts also electrically permanently connected together, a first resistor electrically connected between one of said resistance device contacts and one of said switch contacts of said first switch member, selection means for selectively electrically connecting simultaneously said power contacts of said first switch member with a switch contact and with a resistance device contact of the said first switch member, a power contact of the first switch member being permanently connected electrically with a switch contact of the second switch member, a second resistor being permanently electrically connected between the other power contact of

said first switch member and a resistance device contact of said second switch member, means electrically connecting the said power contact of said second switch member with one of said terminals, selection means for selectively electrically connecting the latter said power contact with a switch contact and with a resistance device contact of said second switch member, and means for electrically connecting the other of said pair of terminals with one of said switch contacts of said first switch member and to provide alternate electrical paths from one of said terminals to the other one of said terminals.

4. In combination, a resistance circuit network comprising, a pair of terminals and switch means adapted for being connected between said terminals, said switch means comprising first and second switch members, said first switch member having a pair of electrically insulated power contacts and said second switch member having a pair of power contacts, each of said first and second switch members having a pair of resistance device contacts, each pair being electrically permanently connected together and a pair of switch contacts electrically permanently connected together, a first resistor electrically connected between one of said resistance device contacts of said first switch member and a power contact of said second member, selection means for said first and second member each including ganged first and second movable contact means respectively connected to said pair of power contacts, said first movable contact capable of selectively engaging one of said switch contacts and one of said resistance device contacts, while simultaneously said second movable contact is capable of selectively engaging the other one of said resistance device contacts and the other one of said switch contacts, one of said power contacts of said first switch member being connected electrically with one of said terminals, a second resistor permanently electrically connected to a resistance device contact of said second switch member, means electrically connecting the other one of said power contacts of said second switch member with one of said switch contacts of said first member and means for electrically connecting the other of said pair of terminals with a switch contact of said second switch member and the other end of said second resistor.

5. In combination, a resistance network comprising, a pair of terminals and switch means adapted for being connected between said terminals, said switch means comprising first and second switch members, said first switch member having a pair of electrically insulated power contacts and said second switch member having a pair of insulated power contacts, each of said first and second switch members having a pair of resistance device contacts permanently electrically connected together and a pair of switch contacts also permanently electrically connected together, a resistance device electrically permanently connected between one of said resistance device contacts and one of said switch contacts of said first switch member, selection means in said first and second switch member, each selection means including ganged first and second movable contact means respectively connected to said pair of power contacts, said first movable contact capable of selectively engaging one of said switch contacts and one of said resistance device contacts, while simultaneously said second movable contact is capable of selectively engaging the other one of said resistance device contacts and the other one of said switch contacts, a first power contact of the first switch member connected electrically permanently with a switch contact of the second switch member, a second resistance device electrically connected between the other power contact of said first switch member and a resistance device contact of said second switch member, and means electrically connecting the said pair of power contacts of said second switch member respectively to said pair of terminals.

6. In combination, in a resistance network device, a pair of terminals and switch means electrically connected between the said terminals, said switch means comprising a plurality of switch members, each said switch member including a pair of electrically insulated power contacts, a pair of switch contacts electrically permanently connected together and a pair of resistance device contacts electrically permanently connected together, a resistance device electrically connected between a resistance device contact of each switch member and a power contact of an adjacent preceding switch member, means electrically connecting the other said power contact of the latter said switch member with a switch contact of its succeeding switch, first switch means for connecting one of said power contacts of each switch member selectively to one resistance device contact and to one switch contact thereof, second switch means ganged with said first switch means for respectively connecting the other of said power contacts to the other switch contact and the other resistance device contact of said switch member, means electrically connecting one of said terminals to a power contact of a last one of the switch members, and means for electrically connecting the other one of said terminals to a switch contact of a first switch member having no preceding switch member to provide for completing alternate electrical circuits between said terminals upon operation of said selection means.

7. A measuring instrument as claimed in claim 6 and in which instrument the resistance devices are each a single resistance element and the resistance values are arranged in a decimal system.

8. A potentiometer device, in combination: a plurality of stages each comprising a resistance device and an associated switch member, a first one of which stages includes a potentiometer with a sliding terminal, said other stages having single resistance elements; an input terminal and an output terminal; each of said switch members having a pair of electrically insulated power contacts, a pair of switch contacts electrically permanently connected together and a pair of resistance device contacts also electrically permanently connected together, switch selection means in each switch member including ganged first and second movable contact means respectively connected to said pair of power contacts, said first movable contact capable of selectively engaging one of said switch contacts and one of said resistance device contacts, while simultaneously said second movable contact is capable of selectively engaging the other one of said resistance device contacts and the other one of said switch contacts; means electrically connecting said input terminal with a power contact of the last one of said stages, means electrically connecting said output terminal with the other power contact of said last one of said stages, a said resistance device of each intermediate and said last stage being electrically connected between a resistance device contact of its stage and a power contact of an adjacent preceding switch member, the first said stage having the resistance device including the potentiometer thereof electrically connected between a resistance device contact of its own stage and a switch contact of its own stage.

9. A potentiometer comprising, in combination, a plurality of stages each comprising a resistance device and a switch member and a first one of which stages includes a potentiometer, said other stages each having a single resistance element; a sliding terminal pertaining to said potentiometer; an input and output terminal of said instrument, each of said switch members having a pair of electrically insulated power contacts, a pair of switch contacts electrically permanently connected together and a pair of resistance device contacts also electrically permanently connected together, switch selection means including ganged first and second movable contact means respectively connected to said pair of power contacts, said first movable contact capable of selectively engaging one of said switch contacts and one of said resistance device contacts, while simultaneously said second mov-

able contact is capable of selectively engaging the other one of said resistance device contacts and the other one of said switch contacts; means electrically connecting said input terminal with a power contact of the last one of said stages, a said resistance device of each intermediate stage and said last stage being electrically connected between a resistance device contact of its stage and a power contact of an adjacent preceding switch member, the first said stage having the resistance device thereof including the said potentiometer of the stage electrically connected between a resistance device contact of its own stage and a switch contact of its own stage, and means electrically connecting the said output terminal electrically with any of the second of the power contacts of said last stage and one of the switch contacts of said first stage.

10. A resistance device network combination, an input and an output terminal; a plurality of stages each comprising a resistor and a switch member, each of said switch members having a pair of electrically insulated power contacts, a pair of switch contacts electrically permanently connected together and a pair of resistance device contacts electrically permanently connected together, switch selection means including ganged first and second movable contact means respectively connected to said pair of power contacts, said first movable contact capable of selectively engaging one of said switch contacts and one of said resistance device contacts, while simultaneously said second movable contact is capable of selectively engaging the other one of said resistance device contacts and the other one of said switch contacts; means electrically connecting said input terminal with a power contact of the last one of said stages; and means electrically connecting said output terminal with a switch contact of the first one of said stages, a said resistance device of each intermediate stage and said last stage being electrically connected between a resistance device contact of its stage and a power contact of an adjacent preceding switch member, the first one of said stages having a resistance device thereof electrically connected between a resistance device contact of its own stage and a switch contact of its own stage.

11. In a potentiometer device, the combination comprising a plurality of stages each comprising a single fixed resistor and a swtich member and wherein a first one of which stages includes a potentiometer, a terminal of said potentiometer and an input and an output terminal of said instrument; each of said switch members having a pair of electrically insulated power contacts, a pair of switch contacts electrically permanently connected together and a pair of resistance device contacts electrically permanently connected together, switch selection means including ganged first and second movable contact means respectively connected to said pair of power contacts, said first movable contact capable of selectively engaging one of said switch contacts and one of said resistance device contacts, while simultaneously said second movable contact is capable of selectively engaging the other one of said resistance device contacts and the other one of said switch contacts; means electrically connecting said input terminal with a power contact of a last one of said stages, a said resistor of each intermediate stage and said last stage being electrically connected between a resistance device contact of its stage and a power contact of an adjacent preceding switch member, the first said stage having the resistor thereof including the said potentiometer of the stage electrically connected between a resistance device contact of its own stage and a switch contact of its own stage, the fixed resistor of each stage from the first to the last having a resistance value substantially double that of the fixed resistor of a preceding stage, and means electrically connecting the said output terminal with the second of the power contacts of said last stage.

12. In a potentiometer the combination comprising a plurality of stages each comprising a resistance device and a switch member and a first one of which stages includes a potentiometer, each of said stages having a single fixed resistance element, a terminal of said potentiometer and an input and an output terminal of said instrument, each of said switch members having a pair of electrically insulated power contacts, a pair of switch contacts electrically permanently connected together and a pair of resistance device contacts electrically permanently connected together, switch selection means for each member including ganged first and second movable contact means respectively connected to said pair of power contacts, said first movable contact capable of selectively engaging one of said switch contacts and one of said resistance device contacts, while simultaneously said second movable contact is capable of selectively engaging the other one of said resistance device contacts and the other one of said switch contacts, means electrically connecting said input terminal with a power contact of a last one of said stages, a said resistance device of each intermediate stage and said last stage being electrically connected between a resistance device contact of its stage and a power contact of an adjacent preceding switch member, the first said stage having the resistance device thereof including the said potentiometer of the stage electrically connected between a resistance device contact of its own stage and a switch contact of its own stage, the fixed resistance element of any single stage between the first and last and including the last stage having a resistance value which is at least substantially equal to the sum of the resistances of the preceding stages including the total potentiometer resistance, and means electrically connecting the said output terminal with the second of the power contacts of said last stage.

13. In combination, an adjustable resistance network: a plurality of stages each of which comprises a switch member and a resistance device element, each said switch member having a pair of electrically insulated power contacts, a pair of electrically connected resistance device contacts and a pair of electrically connected switch contacts, said pairs of contacts being electrically insulated from each other, an input terminal and an output terminal for the plurality of stages, a first of said stages having the resistance element thereof electrically connected between a resistance device contact and a switch contact of its stage, said resistance elements of the other stages being electrically connected between a resistance device contact of its own stage and a power contact of a preceding stage, the other power contact of each preceding stage being connected electrically with a switch contact of a succeeding stage, selection means in each stage including ganged first and second movable contact means respectively connected to said pair of power contacts, said first movable contact capable of selectively engaging one of said switch contacts and one of said resistance device contacts, while simultaneously said second movable contact is capable of selectively engaging the other one of said resistance device contacts and the other one of said switch contacts, said input terminal being electrically connected with a power contact of the last stage, and a potentiometer electrically interconnecting a switch contact of the switch member of the first stage and said output terminal.

14. In combination, in a motor driven potentiometer, a conventional one turn continuous rotation potentiometer, means for driving said potentiometer in rotation, a plurality of stages, a first of said stages comprising a first switch member and said conventional potentiometer, each of the other stages comprising a resistance element and a switch member in electrical connection, each said switch member having a pair of electrically insulated power contacts, a pair of resistance device contacts in electrical connection and a pair of switch contacts in electrical connection, switch contacts and electrical resistance device contacts of each stage being insulated electrically from each other pair of the stage, said first one of said stages having said conventional potentiometer electrically connected between a switch contact and a resistance device contact of

the switch member of the stage, the said resistance elements of the succeeding stages being electrically connected between a power contact of a preceding stage and a resistance device contact of its stage, a switch contact of each of a succeeding stage being connected electrically with the other power contact of a preceding stage, selection means in each stage for electrically connecting a power contact of the stage with a switch contact and with a resistance device contact of the stage, a plurality of cams, one for each said selection means for engaging said selection means individually, means for driving said cams in fixed relation to said conventional potentiometer, a slide terminal of said potentiometer and an input and output

terminal of said stages, one of said latter terminals having electrical connection with a power contact of said last stage and the other of said terminals having electrical connection with the other power contact of the last stage.

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