

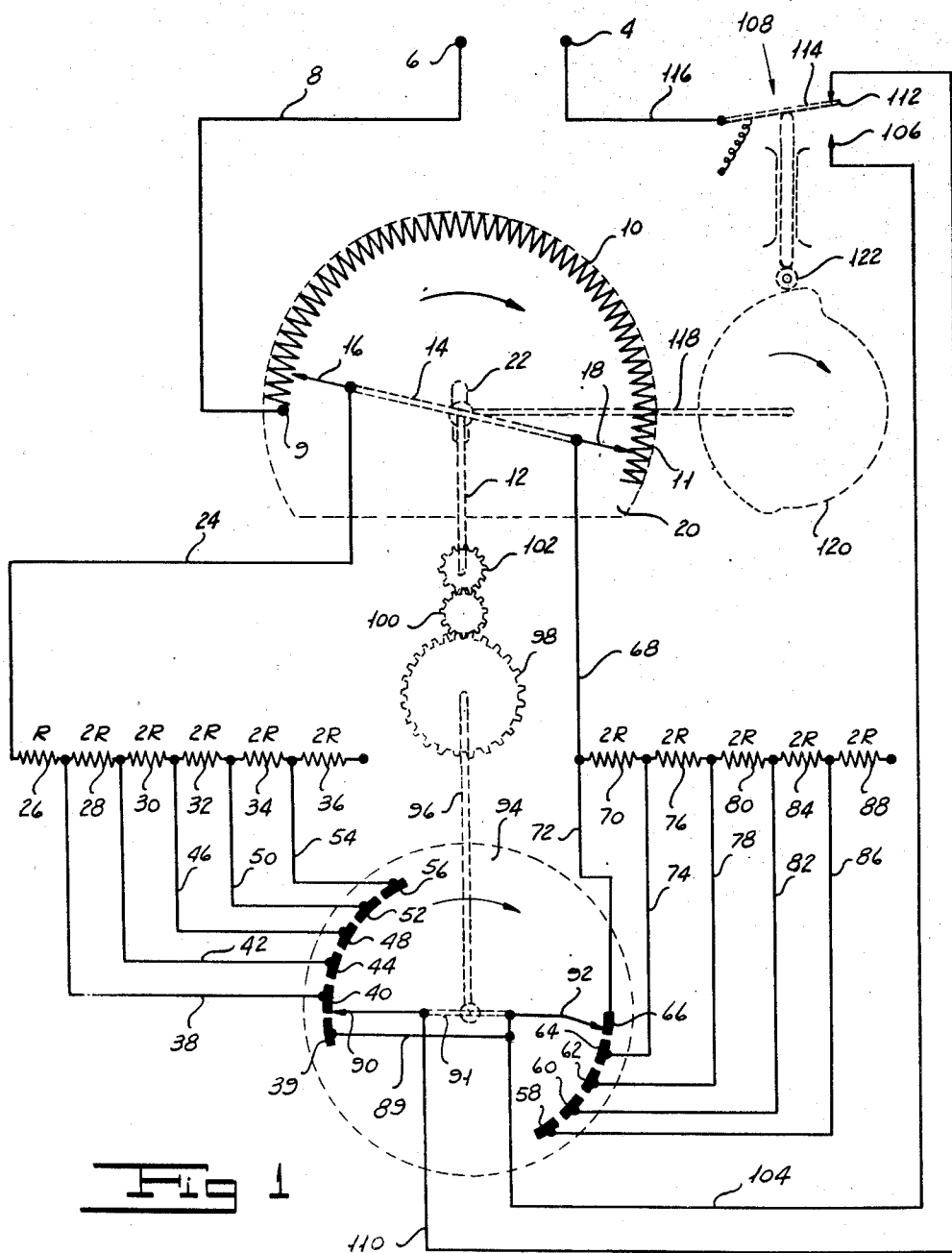
July 17, 1951

C. F. SCHAEFER
VARIABLE RESISTOR

2,561,140

Filed July 30, 1949

2 Sheets-Sheet 1



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2 Sheets-Sheet 2

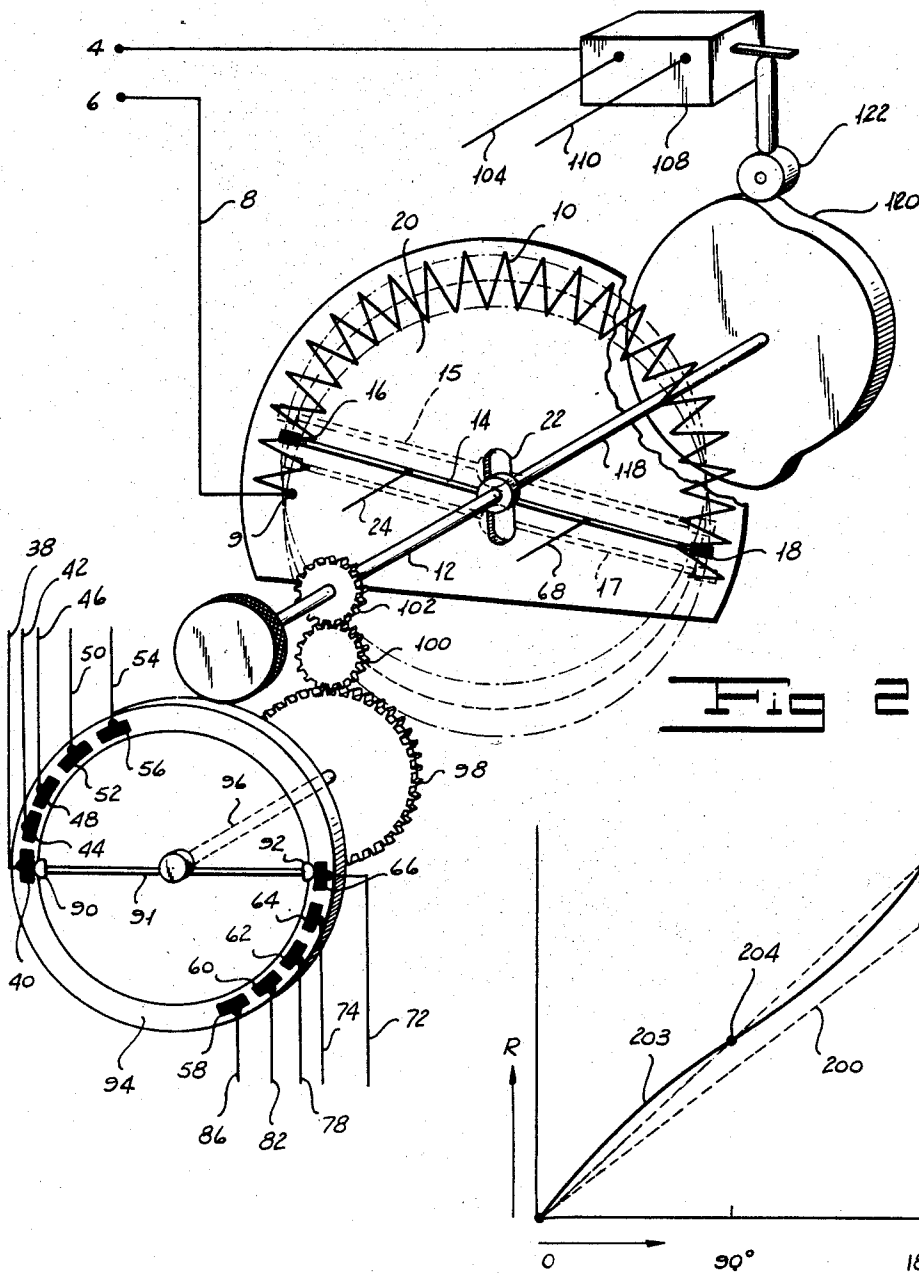
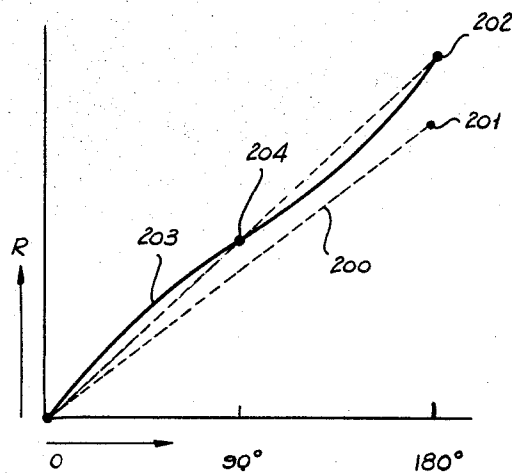


FIG 3



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VARIABLE RESISTOR

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My invention relates to variable resistors and more particularly to a variable resistor enabling me to adjust a resistance with improved accuracy. Most variable resistors comprise a resistance element such as a winding of a resistance wire of a nickel chrome alloy or the like upon an insulating base or core together with a brush movable over the resistance element. The length of the resistance element between a terminal and the brush determines the particular resistance for the setting. It has been very difficult in practice to produce a variable resistor having linearity throughout and a desired overall resistance. It is possible to adjust fixed resistors to give the desired overall resistance within very narrow limits. The resistance element, however, varies from point to point so that the resistance will not necessarily vary as a linear function of the movement of the brush over the resistance element. In many applications such as phase shifters and electronic computing instruments it is extremely desirable to have a variable resistor which will have not only the desired overall resistance but in which the resistance can be varied with greater accuracy to produce a linear function.

One object of my invention is to provide a variable resistor having the desired overall resistance within narrow limits and which will have greater improved linearity, so that a predetermined movement of the variable brush will produce a corresponding change in resistance within narrow limits.

Other and further objects of my invention will appear from the following description:

In general, my invention contemplates the division of the desired overall resistance of a variable resistor into a plurality of increments of fixed resistors, each of which may be adjusted to have a desired resistance within close limits. A variable resistor having overall resistance equal to one-half of the increments is provided with a pair of brushes spaced 180° apart. The brushes are moved in synchronism with a switch apparatus adapted to switch the fixed resistors cumulatively in series with the rheostat element in timed relation, so that I need only to accept non-linearity of a small fraction of the overall resistance and thus enable me to achieve a variable resistor having a resistance variable over a wide range with a high degree of accuracy.

In the accompanying drawings which form part of the instant specification and which are to be read in conjunction therewith, and in which like reference numerals are used to indicate like parts in the various views:

Figure 1 is a diagrammatic view showing a resistor containing one embodiment of my invention.

Figure 2 is a perspective schematic view show-

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ing the construction of the resistor shown in Figure 1.

Figure 3 is a graph of resistance plotted against degrees of rotation of the variable brush showing how an adjustment in the resistance of the resistor with which the brush cooperates is made.

Referring now to the drawings, a pair of terminals 4 and 6 are provided across which the resistance is measured. A conductor 8 connects the terminal 6 to an arcuate resistor 10 of a conventional rheostat construction which may be formed of any suitable resistance element wound to give the best linearity that can be achieved with a resistor of this construction. The arc of the resistance element 10 may be about 200°. A central shaft 12 supports an insulating arm 14 upon which are mounted a pair of brushes 16 and 18 which are positioned 180° apart. The resistance element 10 is mounted on a suitable insulating base 20 which is provided with a slot 22 permitting displacement of the resistance winding 10 with respect to the brushes, so that the brushes may include more or less of the resistance element between their points of contact for purposes of adjustment, as will be pointed out hereinafter more fully. The value of the resistance included between the brushes 16 and 18 is a predetermined value, say R. The brush 16 is connected by a conductor 24 to a plurality of resistance elements 26, 28, 30, 32, 34, 36 and the like, which are connected in series. The value of the resistance of resistance element 26 is R. That is exactly the same as the value of the resistance of the resistor 10 which is included between the brushes 16 and 18. The value of the subsequent resistors 28, 30, 32 and 34 are carefully calibrated to be 2R. The end of resistor 26 is connected by conductor 38 to a switch sector 40. The end of resistors 28 and 30 in series is connected by a conductor 42 to a switch sector 44. The end of resistors 26, 28 and 30 in series is connected by a conductor 46 to a switch sector 48. The end of resistors 26, 28, 30, and 32 in series is connected by conductor 50 to a switch sector 52. Similarly the end of resistor 34 which is in series with resistors 32, 30, 28, and 26 is connected by conductor 54 to a switch sector 56. A symmetrically disposed group of switch sectors 58, 60, 62, 64, and 66 are provided to correspond with switch sectors 50, 52, 48, 44, and 40. Brush 18 is connected by a conductor 68 to the end of resistor 70 which is also connected by a conductor 72 to the switch sector 66. The other end of resistor 70, the value of the resistance of which is 2R, is connected by conductor 74 to the switch sector 64. Another resistor 76 of the value 2R is connected in series with resistor 70 and its end is connected by conductor 78 to the switch sector 62.

Another resistor 80 having a resistance value of 2R is connected in series with resistors 70 and 76 and its end is connected by conductor 82 to the switch sector 60. A further resistor 84 is connected in series with the resistors 80, 76, and 70, and its end is connected by a conductor 86 to the switch sector 58. There may be as many additional resistors, such as resistor 88, similarly connected to additional sectors as desired. There are a pair of brushes 90 and 92 spaced 180° apart so that when brush 90 just makes contact with sector 40 moving in a clockwise direction, brush 92 will be at the lower portion of sector 66. Brush 92 will make contact with sector 64 before contact of brush 90 is broken with sector 40. The sectors are mounted upon a base member 94. In order to avoid a critical adjustment of the zero point an additional sector 39 is connected by conductor 89 to the brush 92. In this way, if the zero point varies from point 9 or if the microswitch 108 lags in its action zero resistance will be registered either by brush 16 or by brush 18. The brushes 90 and 92 are carried by insulating arm 91 adapted to be rotated by a shaft 96. The shaft 96 is connected to a gear 98 which meshes with a gear 100. The gear 100 meshes with a gear 102 which is secured to a shaft 12. The arrangement is such that when the brush 16 rotates 180° the reduction gearing will rotate the brush 92 to make contact with sector 64 and upon rotation of an additional 180° the brush 90 will make contact with sector 44. In other words, a 360° rotation of the arm 14 will move the arm 91 which carries brushes 90 and 92 from a point upon a sector 40 to a corresponding point upon adjacent sector 44. Similarly a rotation of 360° of the arm 14 will move the brush 92 from a point on sector 66 to a corresponding point upon sector 64. The sectors 56 and 40 are out of phase an equivalent of 180° of movement of arm 14.

The brush 92 is connected by conductor 104 to contact point 106 of a snap switch indicated generally by the reference numeral 108. The brush 90 is connected by a conductor 110 to contact point 112 of the snap switch 108. The movable switch member 114 which is adapted to make alternate contact with contact points 106 and 112 is connected by conductor 116 to the variable resistor terminal 4. A shaft 118 is connected for rotation with the arm 14 of the rheostat element of the resistor. A cam 120 is secured to and carried by shaft 118 for rotation therewith. The cam is shaped to coact with a follower 122 adapted to actuate the switch 114, such that every 180° of rotation of the arm 14 will throw the switch alternately to make contact with the other of the contact points. For example, in the position shown the switch arm 114 has just been thrown to make contact with contact point 112. In operation, let us assume that the parts are in position for a zero resistance. This will occur when brush 18 is at the point 9. In this position the switch arm 114 should be in contact with the contact point 106. In practice an exact relationship between the position of brushes 16 and 18 and the point of operation of switch 108 is difficult to control. The switch arm 114 may, therefore, be in contact with contact point 112, but zero resistance will still be recorded due to the interconnection of brush 92 and segment 39 by the conductor 89. The arrangement is such that the correct resistance will be included between terminals 6 and 4 as the switch operates at any time that

both brushes 16 and 18 are in contact with the resistance winding between point 9 and the end of the winding. For example, if there were 200° of winding, the nominal operating point might be set when one of the brushes was 10° from point 9 with a tolerance of plus or minus 10°. The conductors will have a small but fixed resistance so that this constant is always additive to the resistance of my variable resistor. With the parts in the position described, the resistance across posts 4 and 6 is measured as follows: From post 6 through conductor 8 through brush 18 through conductor 68 through conductor 72 to sector 66 through brush 92 through conductor 104 to contact point 106 through switch arm 114 to the post 4. When brush 18 is at point 9 on the resistance winding 10, brush 16 will be 180° therefrom or at point 11. The path from post 6 through conductor 8 through the resistor 10 to the brush 16 through the conductor 24 through the resistor 26 through the conductor 38 to the sector 40 and thence to brush 90 and conductor 110 to contact post 112 is open since the synchronization of the parts is such that when brush 18 is at point 9 brush 16 will be at point 11 and the switch arm 114 will be in contact with post 106, as just pointed out. Let us now trace the operation of my resistor. As the arm 14 of the rheostat element thereof is rotated in a clockwise direction, as indicated by the arrow in Figure 1, the resistance across the posts 4 and 6 will gradually increase until it reaches a predetermined value of R which occurs when the brush 18 reaches a point, say point 11, on the resistance winding 10. When this occurs the brush 16 will have reached the point 9 and the cam 102 will operate the switch arm 114 so that it will make contact with contact post 112. The resistance across the posts 4 and 6 will then be measured from post 6 through conductor 8 through brush 16 through conductor 24 through the resistor 26, the value of which will be observed is R, exactly equal to the arcuate segment of the resistance winding 10 traversed by the brush 18 up until the instant the cam was operated. Continuing the path through which the resistance is measured, we have the conductor 38, the sector 40, the brush 90, the conductor 110, the contact post 112, the switch arm 114, the conductor 116 and finally post 4. It will be observed that in this position the other resistance path from post 6 through the rheostat resistor 10, brush 18, conductor 68, conductor 72, sector 66, brush 92, conductor 104 to post 106 is open. As the rotation continues a resistance proportional to the rotation will be included in the resistance path in series with the resistor 26. When the brush 16 reaches the point 11 this resistance will be exactly 2R and at this instant the brush 18 will be in contact with the point 9 and the cam will operate the switch arm 114, so that it will contact contact point 106. The rotation of the arm 14 is transmitted by shaft 12 to the gear 102 which will idle the gear 100 in a counterclockwise direction and the gear 98 in a clockwise direction. The gear ratios are such that just prior to the throwing of the switch arm 114 to bring it into contact with contact point 106 the brush 92 will have moved to make contact with sector 64. The resistance path then will be from terminal post 6 through conductor 8 through brush 18 through conductor 68 through resistor 70 through conductor 74 through sector 64 through brush 92, through conductor 104 to contact point 106 through switch arm 114, con-

ductor 116 and post 4. It will be observed that the resistor 70 is $2R$ which is the precise equivalent of the resistor 26 plus the added resistance introduced by the traversal of the brush 16 over the arcuate resistor 10. Continued rotation will increase the resistance in increments of R proportional to the rotation of the arm 14. Every 180° at a point when the resistance traversed equals R a switching will occur substituting at that instant a fixed resistance whose value increases the former fixed resistance by the value of the resistance just added. The process may continue to any desired resistance as expressed in multiples of R . In the resistor illustrated in Figure 1, $10R$ is the maximum resistance which can be obtained with the sectors shown. Additional sectors and additional resistors similar to 36 and 88 may be added as desired. It will be clear that when the arm 14 is turned in a counterclockwise direction the resistance is decreased in a manner similar to that described above, and fixed resistors are cut out of the resistance path in multiples of R for every 180° of counterclockwise rotation of the arm 14 of the rheostat element of my resistor.

It will be readily appreciated by those skilled in the art that it is extremely important that the overall resistance of the arcuate resistance element 10 which is swept by a brush to the point at which the switch takes place, that is, the value of the resistance embraced between brushes 16 and 18 must be exactly equal to R . Since it is extremely difficult to make a resistance element exactly linear, and since the brushes must be maintained at a position 180° from each other in order not to disturb the phase relationship in the switching, there must be means for calibrating the value of the resistance embraced between the brushes to equal the value R . I do this in a simple and convenient manner.

Referring now to Figure 2, it will be observed that the base member 20 is provided with a slot 22 so that it may be adjusted to give a relative motion between the arm 14 and the geometric center of the circle along the locus of which the resistance 10 is positioned. The resistor 10 furthermore is wound so that it has a definite width of an appreciable area to the end that if the base 20 is moved so that its center is eccentric from the axis of rotation of the shaft 12 which carries the arm 14, the brushes 16 and 18 will still make contact with the resistance wire. If the base member 20 is moved downwardly the arm 14 and the brushes 16 and 18 will occupy the position indicated by the dotted lines 15. If the base is moved upwardly the arm 14 will occupy the dotted position indicated by the reference numeral 17. It will be seen, therefore, that the relative movement of the base 20 will include a longer or shorter arc of the arcuate resistor between the brushes 16 and 18 depending on the direction of movement of the base. If the base is moved downwardly the arcuate segment will be less than a semicircle. If the base is moved upwardly the arcuate segment embraced by the brushes will be more than a semicircle.

Referring now to Figure 3, let us assume that the resistor 10 is substantially linear. The resistance across the rheostat element only will vary as shown by the dotted line 200. The curve 203 shows that as the brush moves from the point 9 around clockwise the resistance will increase in proportion to the angle of rotation. The point 201 which represents the 180° point of rotation is the value of the resistance embraced by the

180° sweep. If this value of R is less than the desired value which is located at point 202 on the curve 203, it will be necessary to move the base member 20 upwardly so that a sweep of 180° of the brush will include more than 180° of the arcuate resistor 10 in an amount sufficient to bring the overall resistance to the value indicated by the point 202. Since the center of rotation of the brush is now eccentric to the locus of the arcuate resistor, the resistance will vary as a sine curve shown by the curve 203 of Figure 3. Since the sine of 90° is one, the resistance at point 204, the 90° point, will be exactly correct. One of the brushes is made to coincide with point 9 during the adjustment, so that the zero degree point will always be correct. The amount of the adjustment is made so that the 180° point will coincide with point 202 to give a correct resistance value at this point. Accordingly, the resistance will have a correct value at the zero point, the 90° point, and the 180° point. The slight variation in resistance at intermediate angles is small since the sine of the angle of displacement of the base with respect to the center of rotation of the brushes is usually quite small. The overall error will in all cases be small and much better than that of any known variable resistor. A variable resistor having a linearity of winding within .1% and together with an overall resistance of 1%, is considered excellent. If a variable resistor of this construction were used as a resistance element 10, the error in values between zero and R would be no better than that obtained by a variable resistor. Between values of R and $2R$ the error is one-half, between values of $2R$ and $3R$ the errors are reduced to one-third, and at values between $7R$ and $8R$ the errors are reduced to one-eighth. If an extremely accurate variable resistor is required the units of R may be reduced to a small fraction of the overall resistance involved and an extremely high average accuracy will be obtained by means of my construction, as can readily be appreciated. Furthermore, since only one variable resistor is required, this can be constructed to careful tolerances and the accuracy of the entire system will be greatly improved.

It will be seen that I have accomplished the objects of my invention. I have provided a variable resistor having a desired overall resistance within narrow limits and which has greater linearity so that a predetermined movement of a variable brush will produce a corresponding change in resistance within narrow limits. I have provided a simple and expeditious means for adjusting the overall resistance of the variable resistor without sacrificing accuracy percentage-wise with respect to the whole assembly.

It will be understood that certain features and sub-combinations are of utility and may be employed without reference to other features and sub-combinations. This is contemplated by and is within the scope of my claims. It is further obvious that various changes may be made in details within the scope of my claims without departing from the spirit of my invention. It is, therefore, to be understood that my invention is not to be limited to the specific details shown and described.

Having thus described my invention, what I claim is:

1. A variable resistor having two terminals across which resistance is varied, including in combination a rheostat having a resistance element, a brush, means for traversing said brush

successively in effective contact with said resistance element, a group of fixed resistors, means for connecting the fixed resistors successively in cumulative series, means for operating said connecting means in phase with the traversing movement of said brush, means for connecting said brush to one end of the group of said fixed resistors, means for connecting one variable resistor terminal to one end of the rheostat resistance element, a switch for successively connecting the other variable resistor terminal to the other end of the group of series connected resistors, and means for operating said switch in phase with the traversing movement of said brush.

2. A variable resistor having two terminals across which resistance is varied, including in combination a rheostat having a resistance element, a pair of brushes, means for traversing said brushes successively in effective contact with said resistance element, a pair of groups of fixed resistors, means for connecting the fixed resistors of respective groups successively in cumulative series, means for operating said connecting means in phase with the traversing movement of said brushes, means for connecting one of said brushes to one end of a group of fixed resistors, means for connecting the other of said brushes to one end of the other group of fixed resistors, means for connecting one variable resistor terminal to one end of the rheostat resistance element, a switch for alternately connecting the other variable resistor terminal to the other end of one group of series connected fixed resistors, and means for operating said switch in phase with the traversing movement of said brushes.

3. A variable resistor as in claim 2, in which said brushes are positioned 180° apart and the value of the resistance element between said brushes is R , the value of the first fixed resistor of one group of fixed resistors is R , and the value of successive fixed resistors of that group is $2R$, the value of the first fixed resistor of the other group of fixed resistors is zero and the value of each of the other fixed resistors of the second group is $2R$.

4. A variable resistor as in claim 2, in which said brushes are positioned on an insulating arm and spaced substantially 180° from each other, and the means for traversing said brushes successively in contact with the resistance element includes means for rotating said arm.

5. A variable resistor as in claim 2, in which said means for connecting said fixed resistors successively in cumulative series includes a plurality of conductors each connected to two adjacent resistors at an inter-resistor point, and a brush for successively contacting said conductors.

6. A variable resistor as in claim 2, in which said means for connecting said fixed resistors successively in cumulative series includes a plurality of conductors each connected to two adjacent resistors at an inter-resistor point, a brush for successively contacting said conductors, and said means for operating said brush comprises means movable as a function of the movement of the rheostat brushes.

7. A variable resistor as in claim 2, in which said means for operating said switch comprises a cam and means for rotating said cam as a function of the traversing movement of said rheostat brushes.

8. A variable resistor as in claim 2, in which said brushes are positioned 180° from each other and means for varying the resistance of said rheo-

stat resistance element which is included between said brushes.

9. A variable resistor as in claim 2, in which the resistance element of said rheostat is disposed along the locus of a circle and said brushes are mounted upon a rotatable arm having its center of rotation normally substantially concentric with the locus of the resistance element, and means for displacing the center of rotation of said brush bearing arm from the center of the locus of said resistance element.

10. A variable resistor as in claim 2, in which said switch comprises a quick acting switch whereby to reduce the time interval during which the circuit is interrupted in the shifting of the connection of the variable resistor terminal from the end of one group of series connected fixed resistors to the end of the other group of series connected fixed resistors.

11. A variable resistor as in claim 2, in which said means for connecting the fixed resistors of one group successively in cumulative series is operated in fixed phase relation to the operation of the means for connecting the other group of fixed resistors successively in cumulative series.

12. In a variable resistor, a rheostat having a resistance element, a pair of movable brushes adapted successively to traverse said resistance element to vary the resistance between a brush and one end of the resistance element, a pair of groups of a plurality of fixed resistors each resistor having a predetermined resistance value, switching means adapted alternately to connect the fixed resistors of respective groups successively in cumulative series with the rheostat resistance element at predetermined points of a brush travel over the rheostat element.

13. A variable resistor having two terminals across which resistance is varied, including in combination a rheostat having a resistance element, a pair of brushes, means for traversing said brushes successively in effective contact with said resistance element, a pair of groups of fixed resistors, means for connecting the fixed resistors of respective groups successively in cumulative series, means for operating said connecting means in phase with the traversing movement of said brushes, means for connecting one of said brushes to one end of a group of fixed resistors, means for connecting the other of said brushes to one end of the other group of fixed resistors, means for connecting one variable resistor terminal to one end of the rheostat resistance element, a switch for alternately connecting the other variable resistor terminal to the other end of one group of series connected fixed resistors, means for operating said switch in phase with the traversing movement of said brushes, said means for connecting the fixed resistors of respective groups in cumulative series including a pair of brushes and a plurality of segments, and means for interconnecting the zero segments to give a zero resistance with either brush.

CARL F. SCHAEFER.

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