

June 1, 1954

L. A. ROSENTHAL
LOGARITHMIC POTENTIOMETER

2,680,177

Filed Nov. 15, 1951

3 Sheets-Sheet 1

Fig. 1-

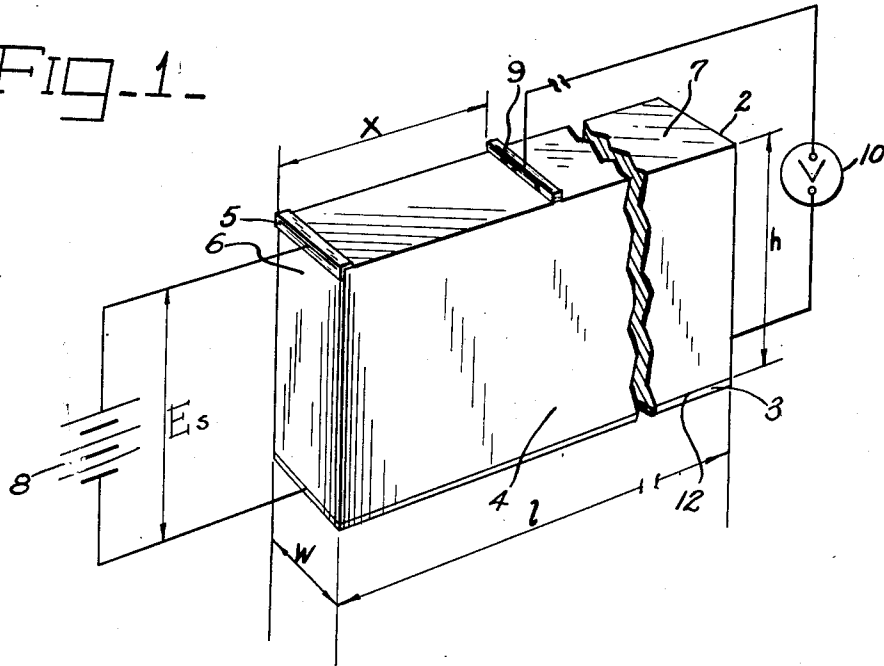
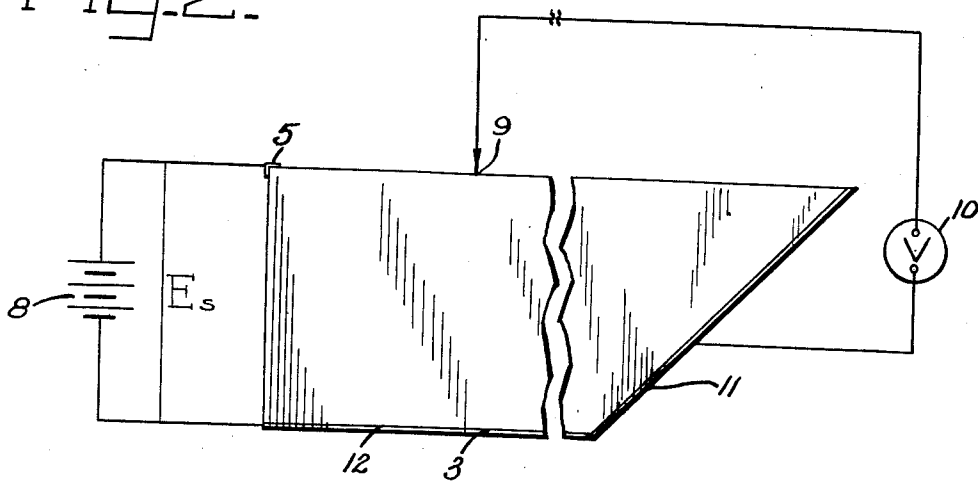


Fig. 2-



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Fig. 3.

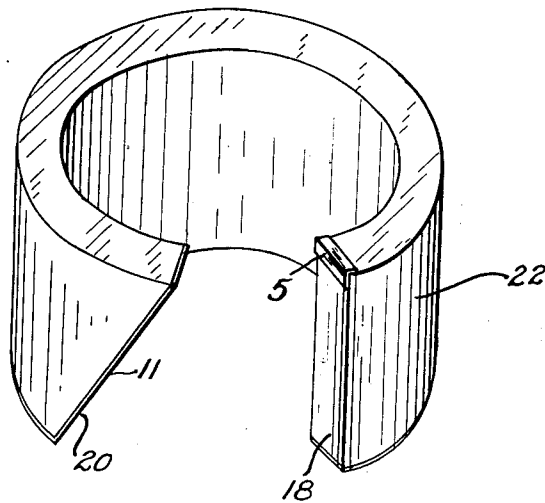
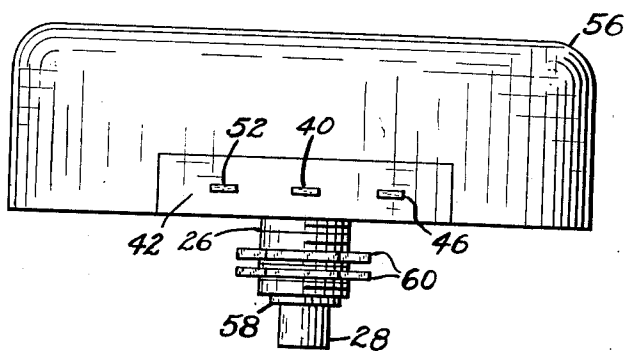


Fig. 4.



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Fig. 5.

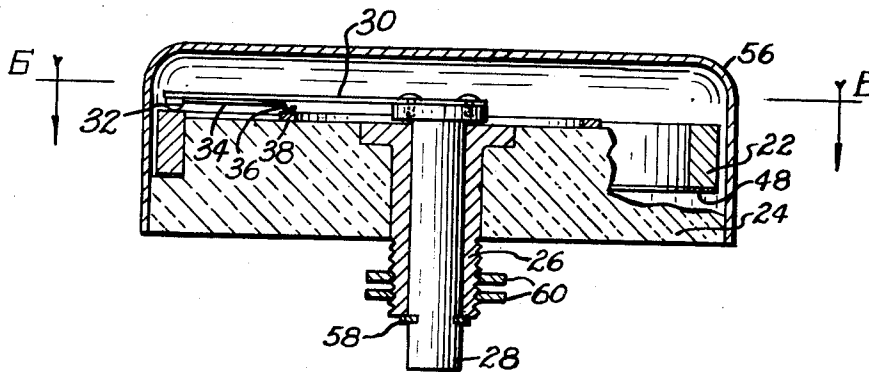
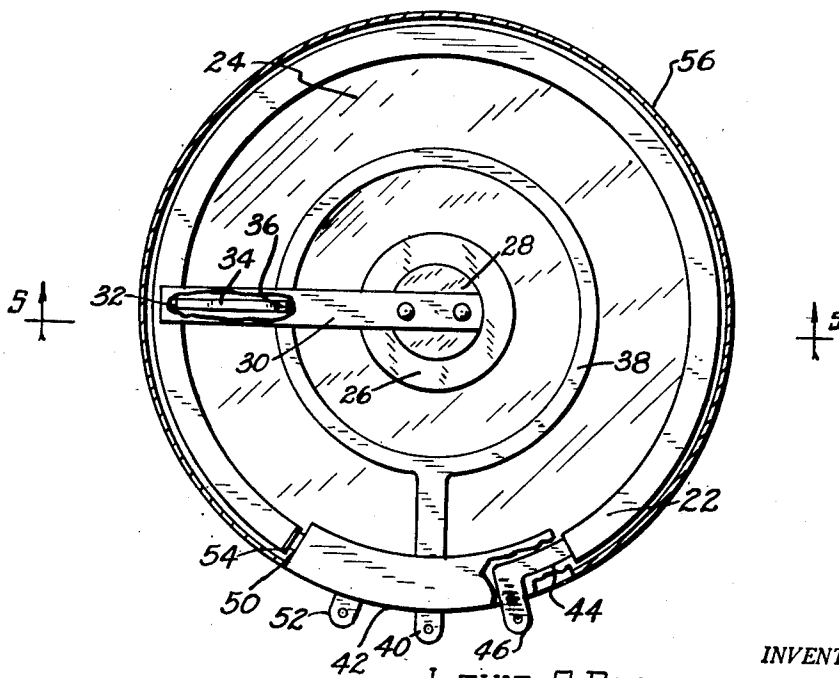


Fig. 6.



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LOGARITHMIC POTENTIOMETER

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12 Claims. (Cl. 201-60)

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This invention relates to logarithmic potentiometers and particularly the type utilizing composition resistance elements.

A need has long existed for a rugged logarithmic potentiometer which is low in cost, sufficiently accurate for precision applications and suitable for high frequency use. Commercially available logarithmic potentiometers generally consist of resistance wire wound on a tapered card or the step potentiometer (step ladder network) in which a switching mechanism varies the output in a stepwise fashion by changing the location of a movable arm from section to section of a network. Both prior systems have poor resolution, are not continuous and have poor high frequency response at higher attenuations.

There is disclosed in this application an improved apparatus utilizing a slab of a composition resistance material in a novel arrangement which permits the production of low cost precision logarithmic potentiometers which are suitable for high frequency applications.

Accordingly, it is an object of this invention to provide an apparatus having a logarithmic variation of voltage output with a linear variation of the position of a movable contact.

It is another object of this invention to provide a relatively low cost and rugged precision logarithmic voltage divider.

It is an additional object of this invention to provide a wide range logarithmic potentiometer.

A further object of this invention is to provide a logarithmic potentiometer capable of carrying relatively large currents.

It is still another object of this invention to provide a logarithmic voltage divider suitable for high frequency applications.

These and other objects, features and advantages will be made more apparent by reference to the following description and the accompanying drawings in which the same symbols refer to the same things.

Figure 1 presents in a combined isometric and schematic drawing a simple version of a logarithmic potentiometer utilizing a slab of conductive material.

Figure 2 shows, in elevation, a preferred embodiment of the potentiometer element of this invention.

Figure 3 shows isometrically, an embodiment of the potentiometer of this invention in a form suitable for an angular type potentiometer.

Figure 4 shows, in elevation, an assembled potentiometer incorporating the element shown in Figure 3.

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Figure 5 is a sectional view of the potentiometer shown in Figure 4.

Figure 6 shows, in cross-section, a plan view of the potentiometer of Figure 4.

In Figure 1 there is shown a slab 2 of resistive material having a highly conductive layer 3 over face 12 and a strip of similar highly conductive material 5 along the intersection of face 6 and face 7. A source of potential 8 is connected between strip 5 and layer 3. Movement of the probe 9, a distance x along face 7 would result in a logarithmic variation of output voltage E as indicated by meter 10 connected between probe 9 and layer 3.

If this slab has the dimensions h , w , and l the voltage E will vary with x , the position along probe surface 7, according to the equation:

$$E = E_s e^{-ax}$$

where E_s is the applied voltage and x is in centimeters and $a = \pi/2h$, where h is the height of the strip in cm.

The two dimensional solution of La Place's equation shows that for an infinitely long slab the potential distribution over face 4 of the slab is of the form

$$E = E_s e^{-ax} \sin ay$$

where y is the distance in centimeters above face 4. An infinitely long slab would not allow any reflections since all voltages propagated down the slab are attenuated. Along the top edge of the slab the factor $\sin ay$ becomes $\sin \pi/2$ or 1. The thickness w of the slab will determine the power dissipation qualities (of the potentiometer) and the impedance level of a potentiometer made from a given conductive plastic.

I have found that in practice the theoretical values indicated above are not attained and only about the first forty percent of the simple slab-shaped element is usable with any degree of accuracy.

It is believed that since the slab is not infinitely long, the voltage E_s applied between contacts 3 and 5 propagates a wave which is not zero when it reaches the right hand edge, a reflected wave being introduced. The reflected wave produces a voltage which decreases in logarithmic manner from right to left. Accordingly, the output voltage is the sum of at least two exponential voltages.

I have found that by providing a tapered portion 11, the face of which is coated with highly conducting material (shown in Figure 2), the propagated wave is dissipated much as an ocean wave on a beach. Since practically all reflected waves are eliminated only the propagated wave

is significant and the desired logarithmic variation of voltage with linear change of the contact position is obtained. A greater useful attenuation is attainable since the right hand side is at true zero potential.

The particular taper angle is not critical and an angle of 45° has been found satisfactory.

The element shown in Figure 3 is intended for use in an angular potentiometer. A material of appropriate specific resistivity is molded in the form of a cylinder. Two cuts, along faces 18 and 20, are made to remove an angular section. It is apparent that a more complex mold could be utilized which will directly mold the taper portion and thus eliminate the cutting operation. The equipotential surface may be created by such means as spraying the element with metal, electroplating, and coating with conductive lacquer. Terminals may be attached by the use of metal inserts or by soldering to sprayed metal areas.

The embodiment of this invention in an angular potentiometer is shown in Figures 4, 5 and 6. The resistance element 22, such as is shown in Figure 3 is attached to insulating plastic base 24. A brass bushing 26 is integrally molded to the base 24. The shaft 28 supports an insulating arm 30 which carries moving contact 32, which is made of carbon, a connecting wire 34 between contact 32 and a beryllium copper spring contact 36 which rides against copper pickup ring 38. A strap 40 forms an integral part of the ring element and serves as a terminal thus eliminating connections and provides a desirable short path for high frequency applications. An insulating strip 42 is provided to support the terminals. A connection 44 is provided between terminal 46 and sprayed metal equipotential face 48. Similarly an electrical connection 50 is provided between terminal 52 and contact face 54. A protective cover 56 is provided. This cover may be transparent and it has been found desirable to cement it to the insulating base to seal out dirt and moisture. Wire clip 58 locks shaft 28 into bushing 26. Nuts 60 are used to mount the unit onto a panel board.

The following example clearly shows the advantage derived from the practice of the preferred embodiment of this invention wherein a tapered portion is provided.

A potentiometer was made by molding a ring from a composition material containing about 5% carbon black and a phenolic resin which exhibited a specific resistivity of 1130 ohm-centimeters when molded.

The ring was 2 inches in outside diameter, 1 1/8 inches in inside diameter and 1/2 inch high. The ring was cut through in planes parallel to its axis and radius at two points about 5/8 inch apart leaving a ring segment subtending about 320° of arc. A conductive equipotential surface was formed on one of the ring shaped flat faces and on one of the cut faces by means of an air drying silver lacquer. Terminals were applied to the equipotential surface and to the uncoated flat surface adjacent to the uncoated cut surface.

The unit was constructed substantially as described above.

Moving the contact through 108° of arc (which represents 34% of the available track) provided an attenuation of 30 decibels. The variation of this attenuation with angular displacement of the contact followed the desired logarithmic relationship with an accuracy of about 1%. It was found that if an accuracy of 5% were tolerable the useful track covered 153° of rotation (equiva-

lent to 48% of the total available track) with a corresponding increase to 38 db of attenuation.

The ring was dismounted from the potentiometer and a segment was removed from one end to provide a 45° tapered portion similar to the one shown in the element of Figure 3.

The resulting cut surface was painted with silver lacquer so as to form a continuous equipotential surface with the flat surface and the potentiometer was reassembled.

The variable contact of the modified potentiometer was rotated through an angle of 180° (56% of the available total) with an attenuation of 45 decibels without deviation from a logarithmic relationship of more than 1% at any point.

Through 250° of rotation (78% of the available track) an attenuation of 60 decibels was obtained with an adherence to function within 5%.

This experiment clearly shows the importance of the tapered portion.

It is apparent that the shaped resistance element may be made in many diverse ways; for example, it may be machined from a large block, cast in a mold or molded under pressure. The choice of material would depend on the desired characteristics, there being many suitable materials commercially available.

It is clear that a very material advantage of the potentiometer elements described herein lies in possessing material thickness with consequent ruggedness. Accordingly, it is preferred that elements made in accordance with this invention be at least one-sixteenth inch in thickness preferably at least one-eighth inch in thickness. It would be expected that a relatively thick ring shaped structure of material would show noticeable deviations from theory. I have found that the thickness of a ring shaped element of this invention may be as great as four-tenths of its outside radius without serious departure from the desired function. For the purposes of the invention it is preferred that for small sizes of potentiometers, say 1.5 to 4 inches in diameter, the thickness of the ring be held to 0.03 to 0.4 times the outside radius of the ring. For larger potentiometers a thickness of 1/4 to 1/2 inch will generally be appropriate.

If a ring shaped element is made thicker than about 0.4 times its outside radius modified logarithmic relationships between angular rotation and output potential result. These may be useful in certain specific applications.

While there has been described what are at present considered the preferred embodiments of this invention, it will be obvious to those skilled in the art that various changes and modifications may be made herein without departing from the invention.

I claim:

1. Apparatus for obtaining an electrical signal which varies in a logarithmic manner with a linearly varying adjustment comprising a three dimensional block of resistive material having a first contact making face, a second face having a first portion essentially parallel to said first face and having a second portion tapered so as to meet said first face, a highly conductive coating on said second face including said tapered portion, a movable contact for establishing electrical connection to said contact making face, means for moving said contact, means for applying a potential between a fixed location at the end of said contact making face opposite said tapered end and spaced from said highly conductive coating, and means to connect an output circuit be-

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tween said movable contact and said highly conductive coating.

2. The apparatus of claim 1 wherein the thickness of said block is at least one-sixteenth of an inch.

3. A resistance element for inclusion in a logarithmic potentiometer device having a contact making face and a highly conductive layer spaced from said contact making face, said layer having a first portion substantially parallel to said contact making face and a second portion at an angle to said contact making face.

4. The element of claim 3 in the form of a hollow cylinder wherein said contact making face is perpendicular to the axis of revolution.

5. A logarithmic potentiometer comprising an insulating plastic base, a resistance element in the form of a hollow cylinder having a contact making face and a conductive equipotential surface parallel to said face, means to fixedly contact said equipotential surface and one end of said contact making surface, a rotatable shaft adapted to position a movable contact at points along said contact making surface, a terminal, means to electrically connect said movable contact with said terminal.

6. The element of claim 5 wherein the thickness of said resistance element is within the range 0.03 to 0.4 of the outside radius of said cylinder.

7. The apparatus of claim 5 wherein the radius of the outside of said resistance element is less than two inches and is not more than 32 times its thickness.

8. A logarithmic potentiometer comprising an insulating plastic base, a resistance element in the form of a hollow cylinder having a contact making face and a parallel conductive equipotential surface, means to fixedly contact said equipotential surface and one end of said contact making surface, a rotatable shaft adapted to position a movable contact at points along said contact making surface, an electrical connection from said first movable contact to a second movable contact, a highly conductive surface in con-

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tact with said second movable contact, and a terminal in electrical connection with said highly conductive surface.

9. The potentiometer of claim 8 wherein the outside radius of said hollow cylindrical element is between 2.5 and 32 times the thickness of the wall of said hollow cylindrical element, said radius being not greater than two inches.

10. Apparatus for obtaining an electric signal which varies in a logarithmic manner with a linearly varying adjustment comprising a section of a hollow cylindrical element composed of a uniform resistive material having a first and a second face essentially at right angles to the axis of revolution, a third face angularly disposed so as to join said first face at an obtuse angle, a fourth face essentially at right angles to said first and second faces, said first and third faces being coated with a highly conductive material, means for electrically contacting a said second face, means for radially adjusting said contact, means for applying a potential between the juncture of said second and fourth faces and said highly conductive material and means to connect an output circuit between said highly conductive material and said contact.

11. The potentiometer of claim 10 wherein the outside radius of said hollow cylindrical element is less than two inches and is between 2.5 to 32 times the thickness of the wall of said hollow cylindrical element.

12. The apparatus of claim 10 wherein said hollow cylinder has an outside radius of over 2 inches and a wall thickness greater than 0.2 inch.

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