

[54] UNITARY RESISTOR AND SHUNT  
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[52] U.S. Cl. .... **338/49**  
[51] Int. Cl. .... **H01c 13/00**  
[58] Field of Search ..... 338/49, 13, 20, 21,  
338/31, 65, 68, 73, 74, 92

[56] **References Cited**  
**UNITED STATES PATENTS**  
2,935,712 5/1960 Oppenheim et al. .... 338/20

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[57] **ABSTRACT**  
A unitary resistor film and shunt and a method of producing same for use as a resistor element per se or as the resistance element of a linear, nonlinear or characterized potentiometer. A conductive material is screened and fired onto the resistor film at a location that is spaced inwardly of end portions of the resistor in such a manner that a negligible amount of diffusion occurs between the conductive and resistive film material to thereby reduce the resistivity of the resistor film, e.g., ten fold without incurring any change in its original size, temperature coefficient of resistivity or stability.

**7 Claims, 3 Drawing Figures**

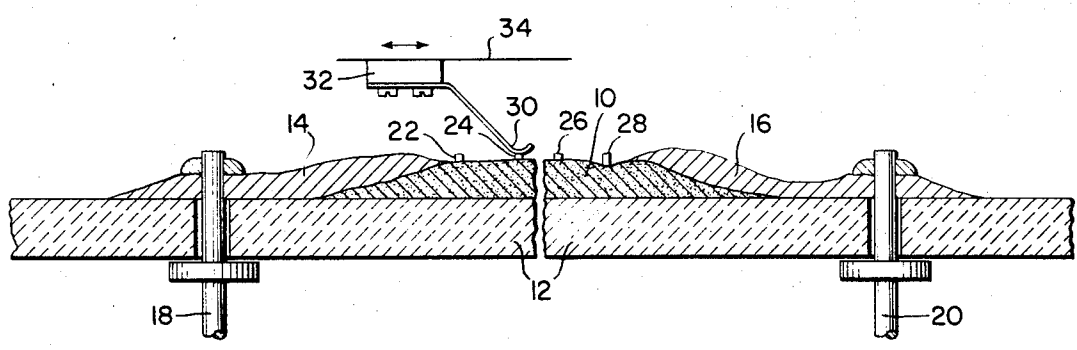


FIG. 1

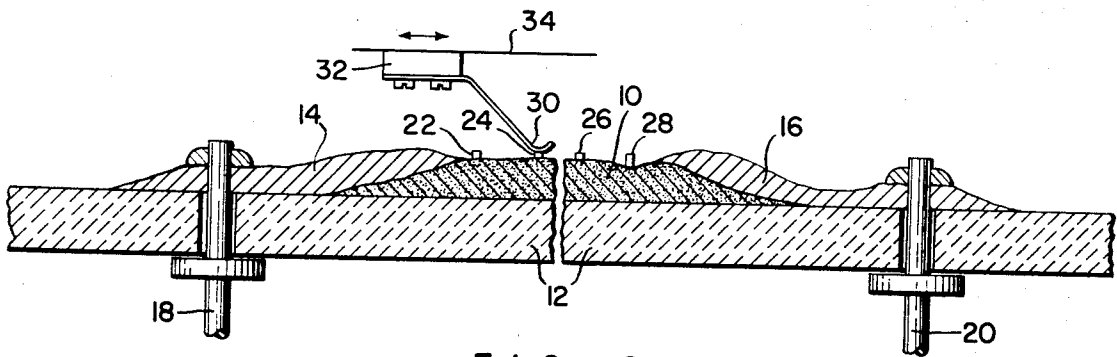


FIG. 2

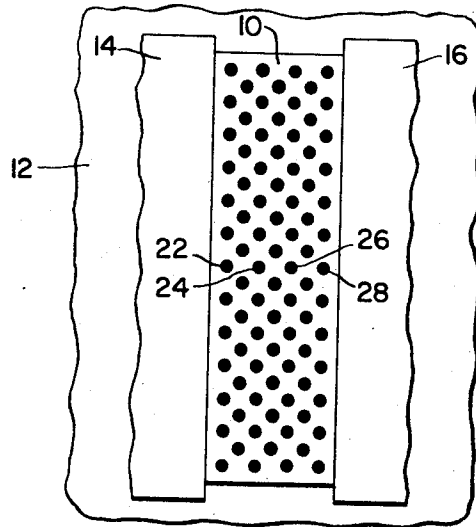
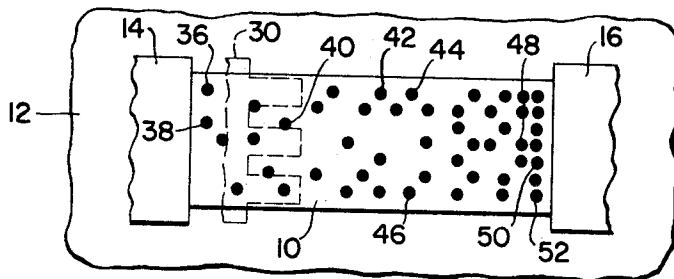


FIG. 3



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## UNITARY RESISTOR AND SHUNT

It is an object of the present invention to provide a unique resistor film and shunt and the method by which this unit can be manufactured.

More specifically, it is another object of the invention to provide a resistor film distributed shunt for an electrical circuit that employs conductor material fired on a resistor film in a characteristic manner.

It is still another object of the present invention to provide a distributed shunt of the aforementioned type for a resistor film that requires less space than conventional shunts since it eliminates the requirement for an external resistance and allows all of its shunting action to take place within a single resistor.

Another object of the invention is to provide a resistor film such as, e.g., that which is disclosed in my copending patent application with characteristically spaced apart conductive material fired thereon and thereby provides a method by which the resistivity of the resistor described in the aforementioned referred to application can be lowered without incurring any change in the temperature coefficient of resistivity and its stability.

Another object of the present invention is to provide a unique distributed shunt of the aforementioned type having an array of polka-dots printed on a resistor film and which may have open portions passing there-through between the rows of dots which form the array and thereby be able to create an extremely light weight resistor.

More specifically it is another object of the present invention to provide the aforementioned resistor with a number of small spots of disc shape conductive material that are spaced from one another in a characteristic pattern.

Another object of the invention is to screen conductive ink spots onto the aforementioned resistor so that they can be jointly fired with the resistor at the same time and at the same temperature as that described for the two terminal conductors set forth in my copending application.

It is another object of the present invention to provide a means of reducing the size of presently available characterized resistor film or wire wound variable resistors by providing a modified form of the aforementioned distributed shunt in which a desired diminishing concentration of disc shaped conductors are formed along the length of the resistor.

A better understanding of the invention may be had from the following detailed description when read in connection with the accompanying drawing in which:

FIG. 1 is a cross-sectional view taken through the resistor film and through the unique array of conductive dots which are fired on this resistor.

FIG. 2 is a detailed plan view of a preferred form of the thick film resistor distributed shunt showing how conductors formed in a polka-dot pattern are printed on the thick film resistors shown in FIG. 1 and

FIG. 3 shows how a variable resistor can be formed by the addition of arrays of conductive dots of increasing density between one end of the resistor and another.

FIG. 1 shows a resistor film 10 that has been selected from any one of a number resistor ink mixes for firing onto a non-electrically conductive substrate 12 at 1,000° C. The material that is employed for the sub-

strate is an aluminum oxide that is preferably 96 percent pure. One example of a positive coefficient of resistivity resistor ink that can be used to make part of the mix for resistor 10 is 40 percent by weight ruthenium, 20 percent by weight ruthenium oxide, RuO<sub>2</sub>, and the remainder 40 percent by weight formed from glass frit. An example of a negative coefficient of resistivity resistor ink that can be used to make the remaining part of the desired mix for resistor 10 is comprised of substantially 40 percent by weight of RuO<sub>2</sub>, 20 percent by weight of Ru and 40 percent by weight of glass frit.

FIG. 1 also shows a pair of conductors 14, 16 fired onto associated opposite ends of the resistor 10 for connecting the resistor to terminals 18, 20.

FIGS. 1 and 2 show disc shaped conductors, e.g., 22, 24, 26 and 28 which protrude from the upper surface of the resistor 10.

These conductors are preferably made of the same material as the terminal conductors set forth in my copending application. It should be understood that although the resistor 10 is made into a distributed shunt by the firing on of the polka-dots in the preferred fashion shown in FIG. 2 other forms of conductors such as strips, squares, etc. could be used for this purpose.

The polka-dot arrangement is considered the preferable form because they insure the most uniform distribution of the conductor material over the resistor.

It should be understood that the resistor 10 is first fired at 1,000° C onto the electrically non-conductive substrate 12. The conductive discs, for example 22, 24, 26, and 28, and the other remaining conductive discs shown in a polka-dot fashion in FIG. 2 are thereafter jointly fired along with the terminals conductors 14, 16 and the resistor 10 at 550° C.

The aforementioned unique firing method allows the conductive discs, for example 22, 24, 26, and 28, to be fired onto the resistor 10 with an negligible amount of diffusion taking place between these conductive disc and their associated resistor 10. The polka-dot pattern has the advantage over the other aforementioned conductors, in that any small amount of diffusion that occurs between a conductive disc 22, 24, 26, or 28 and the resistor 10 will always be uniform.

It is to be understood that the addition of the conductive discs such as the conductors 22-28 shown in FIG. 1 and 2 to the outer surface of the resistor 10 provides a way of keeping its size, such as its width and length of an abnormally small dimension. These conductors, e.g., 22-28 also retain the basic parameters such as temperature coefficient of resistivity and the stability of resistor 10 substantially constant and at the same time provide a method to decrease by as much as ten the resistivity of the resistor 10.

If it is desired to use the resistor 10 and its associated disc shaped conductive dots, e.g., 22, 24, 26 28 etc. as a resistance distributed shunt in a miniaturized printed circuit the array of conductive discs formed thereon can be covered by means of a flexible material such as a flexible silicone polymer and a second hard outer covering such as glyptal 1201B paint in the same manner as the resistor and the terminal conductors are covered in my copending application. This encapsulating structure will protect the resistor 10 from ambient air, water vapor, water and hydrogen sulfide (H<sub>2</sub>S) and ambient temperature that may vary from the standard reference level of 25° C ± 50° C so that no more than ±0.1% change in value of the resistor can occur.

In another application it may be desirable, as is shown in FIG. 1, to employ the resistor 10 and its associated disc shaped conductive dots as a shunted slide wire, along which a metallic wiper 30 and a support number 32 for same can be moved in the direction of the arrows along the surface 32. The wiper 30 can be of a multiple contacting type in which some of contacts formed by wiper 30 in contact with some of the conductive dots 22, 24, 26, or 28 etc. as it is moved along the top surface of resistor 10. This will be so because the multiple fingers arrangement of this wiper 30 will allow it to always contact some of the dots in a row of dots as it travels across the dots 22-28 on the resistor 10 because of the polka-dot pattern of these dots. The distance between each row of dots is 0.020 inches, the distance between each dot in any row is 0.030 inches and the diameter of the each conductive dot is 0.020 inches. It can therefore be seen that contacts formed by the wipers 30 are of sufficient width that some one or more of them will always be in contact with at least one half of one of the dots of each row along which it is brought into contact.

The height of the dots, e.g., 22-28 above the surface of the resistor 10 is 0.00035 inches.

One thumb rule method of calculating the amount of resistance which is afforded by a resistor having equally distributed conductive dots, can be derived as follows:

$$R \text{ with dots} = R \text{ no dots} \left[ \frac{(A - \Delta A)}{(A + \Delta A)} \right] K$$

wherein  $\Delta A$  is equal to the total area of deposited evenly distributed dots.

$A$  is equal to the total area of the resistor before the dots are fired thereon and  $K$  is a factor which for the distribution shown in FIG. 2 is equal to 2.

From the aforementioned it can be seen that the conductive dots, such as dots 22-28, provide a precise way of causing electrical fields to move in a arcuate fashion between adjacent pairs of dots and thereby affect an internal shunting action.

FIG. 3 shows a resistor 10 mounted on a substrate 12 and having its end portions connected to terminals 18-22 by means of conductive materials 14, 16 in the same manner as that shown in FIG. 1. FIG. 3 differs from FIG. 1 and 2 in the manner in which the dots shown in FIG. 3 are positioned on the resistor 10. For example, the dots 36, 38, 40 that are located near the left-end of the resistor are widely spaced apart from one another. The conductive dots 42, 44, 46 mid-way between the ends of the resistor are spaced closer to their adjacent dots than the adjacent dots with which dots 36, 38, 40 are associated and the spacing of the conductor dots 48, 50, 52 are spaced in a still more closely related dense fashion with their adjacent dots that they are associated than any other preceding group of dots.

With the aforementioned construction shown in FIG. 3 it can be seen that a much greater degree of shunting of the aforementioned electrical field will take place between the dots near conductor 16 than those near conductor 12.

It can also be seen that as the multipoint contacting wiper 30, previously described under the description of FIG. 1, is moved along the resistor 10 in a left to right direction that a characterized decreasing resistance will be encountered. It should be understood that other different arrays and shapes of conductive material can be employed for those shown in FIG. 3 in order to provide

either a characteristic resistor per se or an adjustable resistor for a circuit that is employed as a slidewire along which a wiper 30 can be moved.

From the aforementioned description it can be seen that a resistor film has been provided which has conductive dots fired onto its outer surface so that a distributed shunt is provided within the resistor so that the resistivity of the resistor can be reduced by as much as a factor of ten without changing its size and without changing its basic parameters such as its temperature coefficient resistivity and stability.

Although not shown in the drawing it should be understood that apertures can be formed in the resistor 10 between the conductive dots, e.g., 22-28 when an extremely light weight resistor is desired.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. A unitary resistor film and shunt for an electrical circuit comprising, a resistor film, conductive material forming an outer surface portion of said resistor film that is in spaced apart relationship with its ends and wherein the conductive material provides a path through which an electrical field can be shunted as said field is transmitted through said resistor and wherein the conductive material is comprised of a plurality of conductors that are of a disc shaped configuration.

2. A unitary resistor film and shunt for an electrical circuit comprising, a resistor film, conductive material forming an outer surface portion of said resistor film that is in spaced apart relationship with its ends and wherein the conductive material provides a path through which an electrical field can be shunted as said field is transmitted through said resistor and wherein the conductive material is positioned to form an array of polka-dots.

3. The unitary resistor and shunt defined in claim 1 wherein said conductor being positioned in rows which are 0.020 inches apart from one another, are spaced at 0.030 inches from one another along each of the aforementioned rows and wherein the diameter of each disc shaped conductor is 0.020 inches.

4. A unitary resistor film and shunt for an electrical circuit comprising, a resistor film, conductive material forming an outer surface portion of said resistor film that is in spaced apart relationship with its ends and wherein the conductive material provides a path through which an electrical field can be shunted as said field is transmitted through said resistor and wherein the conductive material is positioned to form a plurality of uniform shaped spaced apart conductors and the number per unit area of said conductors between one portion of the resistor and another are positioned in a gradually diminishing pattern to enable the resistor to possess gradually decreasing resistance along the part of the resistor that extends between said two portions.

5. A unitary resistor film and shunt for an electrical circuit comprising, a resistor film, conductive material forming an outer surface portion of said resistor film that is in spaced apart relationship with its ends and wherein the conductive material provides a path through which an electrical field can be shunted as said field is transmitted through said resistor and wherein the conductive material is positioned to form a plurality of spaced apart conductors that are positioned in a prescribed varying dense relationship with one another between two portions of the resistor to en-

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able said resistor to possess a characterized variable non-linear resistance characteristic along said resistor part that extends between its said two portions.

6. A unitary resistor film and shunt for an electrical circuit comprising, a resistor film, conductive material forming an outer surface portion of said resistor film that is in spaced apart relationship with its ends and wherein the conductive material provides a path through which an electrical field can be shunted as said field is transmitted through said resistor and wherein the conductive material is positioned to form a plurality of spaced apart conductors on the outer surface of said resistor and wherein each conductor is comprised of 70

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percent by weight of silver powder, substantially 10 percent by weight of lead boro silicate glass and the remainder decanol alcohol.

7. The thick film resistor and shunt defined in claim 6 and wherein the resistor is comprised of a positive coefficient of resistivity resistor ink that possesses substantially 20 percent by weight of RuO<sub>2</sub>, 40 percent by weight of Ru and 40 percent by weight of glass frit, and a negative temperature coefficient of resistivity ink that possesses substantially 40 percent by weight of RuO<sub>2</sub>, 20 percent by weight of Ru and 40 percent by weight of glass frit.

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