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HIGH TOLERANCE IMPEDANCE ELEMENTS
AND METHODS OF MAKING THEM
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2,724,761

FIG. 1

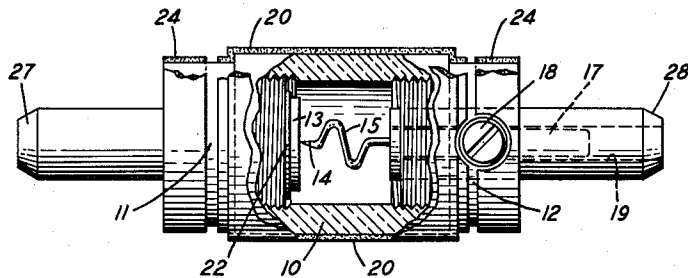


FIG. 2

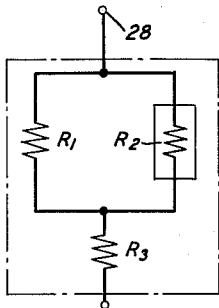


FIG. 3

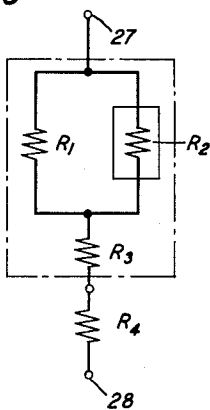


FIG. 4

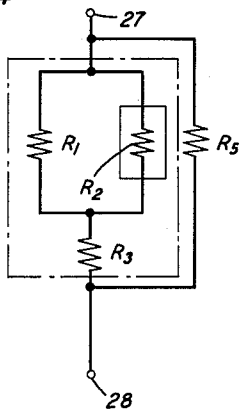
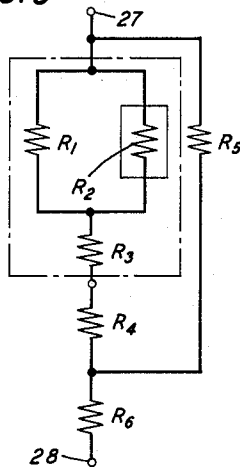


FIG. 5



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HIGH TOLERANCE IMPEDANCE ELEMENTS AND METHODS OF MAKING THEM

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12 Claims. (Cl. 201—63)

This invention relates to high tolerance impedance units and more particularly to high tolerance non-linear conductive units.

An object of this invention is to improve the characteristics of impedance units while simplifying their manufacture. More specifically an object of this invention is to compress the range of impedances of members of a group of impedance units. Another object is to facilitate the production of higher tolerance impedance units without refinements of the manufacturing techniques employed thereon. A further object is to eliminate the need for selection and the waste incident thereto in obtaining impedance units having characteristics within a prescribed restricted range.

Economical manufacturing techniques for many impedance devices and particularly for non-linear conductive units have not been developed to a point where the product has the characteristics as closely controlled as are those characteristics of other forms of impedance devices. In the case of non-linear resistors, their characteristics generally may be less uniform by one or two decimal orders of magnitude for a given degree of manufacturing control than are those of certain forms of fixed resistors. Furthermore, it has been possible to produce these non-linear devices such that the characteristics of individual units of a group are widely dispersed yet the non-linearity of all is in excess of what is necessary for the applications to which they are to be applied. A situation thus arises in the manufacture of these units requiring the production of large numbers of units all directed at a particular characteristic and the selection of only a few acceptable units having corresponding characteristics from the manufactured group. Such techniques are obviously expensive and, therefore, have in the past warranted the practice of rather extensive controls in manufacture.

A feature of this invention resides in achieving the above objects while avoiding the problems set forth by combining in those impedance units having a broad range of characteristics from unit to unit additional impedance elements of fixed value and of a form which can be economically produced to high tolerance whereby the total impedance of each unit more closely approaches that of every other unit.

In one embodiment, this invention is applicable to a type of conductive unit whose resistance varies with voltage applied and which has an equivalent circuit comprising a parallel branch composed of a linear resistance and a resistance which varies with voltage applied in series with a second linear resistance. In such units, the variations of the linear resistances in the equivalent circuit are often rather wide from unit to unit. In accordance with one feature of this invention, these variations are overcome by adding to each unit of the group being manufactured further linear resistances whose magnitudes can be closely controlled thereby bringing the total of the linear resistances present closer to each other and thus compressing the range of over-all impedances of the individual units. The result of such a structural modification is to add to the linear resistances of differing magnitudes inherent in the construction of the non-linear unit other positive linear resistances of fixed magnitude so that the resulting sums of linear resistances are ratios more nearly unity than are the ratios of corresponding linear resistances of differing magnitudes.

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Another feature of this invention resides in normalizing non-linear resistances which have similarly varying though different non-linear resistances by the addition of linear resistances of fixed value to each non-linear resistance of a group.

In the exemplary construction disclosed in detail here, manufactured groups of non-linear conductive devices each comprising a semiconductive wafer of silicon or germanium having an ohmic contact on one surface and a restricted area contact on another surface are each modified in that each unit of a group is provided with one or more high tolerance linear resistances. These added resistances which are integral with the structure of the units are applied so that each unit has substantially the same added resistance as every other unit of the group. These added resistances bring the total impedance of each unit closer percentagewise to that of each other unit of the group. Thus, it is to be understood that this technique is not that of correcting the value of individual units by adding individual values of correcting resistance to each unit but rather is a leveling of the values of all units by the application of identical values of resistance to each unit.

Other objects and features of this invention will be understood from the following detailed description when read in conjunction with the accompanying drawings in which:

Fig. 1 is an elevational view of a point contact non-linear device illustrative of this invention with portions broken away to reveal details of its internal structure;

Fig. 2 is a diagram of the equivalent circuit of a non-linear conductive device of the type shown in Fig. 1 without the addition of elements in accordance with this invention; and

Figs. 3, 4, and 5 are equivalent circuits of various forms of the device of Fig. 1 constructed in accordance with the invention.

Referring now to the drawing, Fig. 1 shows a generally conventional non-linear conductive unit which has an over-all characteristic representable by the equivalent circuit of Fig. 2 under certain operating conditions. The unit comprises a ceramic shell 10, conductive studs 11 and 12 threaded in the opposite ends of the shell, a semiconductive wafer 13 of a material such as germanium or silicon secured in conductive relationship to the stud 11, and a restricted area contact 14 supported in conductive relationship from the stud 12 and engaging the exposed surface of the wafer 13. The restricted area contact is provided by a point on the end of a tungsten or other wire 15 provided with an S-section intermediate its ends to provide axial resiliency and secured in a bore in conductive rod 17. This rod 17 in turn is secured by set screw 18 in the bore 19 of stud 12. In the conventional construction of prior devices, the wafer 13 is secured to the stud 11 by a low resistance ohmic contact such as a solder contact between the brass stud 11 and a rhodium or other plated coating on the back surface of the wafer.

The equivalent circuit of the device constructed as above described includes a shunt resistance of constant value for any given unit, represented as R_1 . In parallel with R_1 is a voltage variable resistance R_2 , the current through which is equal to a constant K multiplied by the voltage across R_2 raised to an exponent n . The values assignable to K and n differ depending upon the operating conditions for the unit including the sense of the applied voltage. The factors determining the value of the quantity n are nearly identical for all similar units constructed by present manufacturing techniques as are those factors determining the value of the constant K for the various units. These latter factors are a function of such things as contact area, semiconductor treatment, and the like. In series with the parallel resistances R_1 and R_2 is a con-

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stant resistance R_3 representing the spreading resistance of the device and being of constant value for any given unit. The value of R_1 and R_3 are functions of contact area and particularly the means of establishing the contact 14 between the point of wire 15 and the wafer 13.

In view of the consistency obtainable with present manufacturing techniques from unit to unit in the constants n and K determining the characteristics of resistor R_2 of the equivalent circuit and the wide variations which occur in the constant resistances R_1 and R_3 from unit to unit, it follows that the variations in the over-all characteristics of conductive units of the sort disclosed in Fig. 1 are principally attributable to the variations occurring in resistances R_1 and R_3 . It is, therefore, eminently advantageous to make more constant the value of the linear resistor elements of each of the conductive units of the group in order to compress the range of impedances which occur from unit to unit in manufacture.

Considering for the moment a simplified mathematical situation offered as an aid to an understanding of this invention, in which A and B are different quantities and C is a constant, it is apparent that the ratio between the two differing quantities can be brought closer to unity by either the addition of the constant C to both or the multiplication of both by the constant C . Applying these principles to resistors wherein the principal objective is consistency from unit to unit and the absolute value of resistance of each unit is subordinate to consistency, the differences between resistances corresponding to A and B can be reduced by the addition of a series resistance of constant value corresponding to C so that

$$\frac{A+C}{B+C}$$

is closer to unity than

$$\frac{A}{B}$$

Further, a nearer approach to each others absolute value as well as a decrease in the ratio of one to the other can be accomplished by combining constant resistance C in parallel with the resistances of differing values, A and B , so that

$$\frac{AC}{A+C}$$

is closer to

$$\frac{BC}{B+C}$$

than A is to B and, as to ratios, so that

$$\frac{\frac{AC}{A+C}}{\frac{BC}{B+C}}$$

is closer to unity than

$$\frac{A}{B}$$

It also follows that further improvement in ratios can be accomplished by combinations of series and parallel constants to resistances which differ in value.

In the present invention, the above considerations have been applied to conductive units having the characteristics disclosed in the equivalent circuit of Fig. 2 wherein consistency from unit to unit is of predominant importance. Non-linear resistor units of the type shown in Fig. 1 can be produced with a relatively high consistency in their non-linear characteristics; however, the linear resistances inherent in their construction which are superimposed on these characteristics have wide variations and therefore cause the over-all characteristics to vary widely from unit to unit. It is possible to economically manufacture

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linear resistances having a uniformly several decimal orders of magnitude higher than those linear resistances inherent in devices constructed for their over-all non-linear conductive characteristics. Further, in many applications of these non-linear conductive units their non-linearity is far in excess of that necessary for their practical utilization and hence certain sacrifices in the degree of non-linearity are acceptable in the interest of uniformity.

Figs. 3, 4, and 5 show equivalent circuits of non-linear conductive units of the type disclosed in Fig. 1 with some of the various combinations of constant resistances which will effect improvements in their uniformity. Units having equivalent circuits such as those shown can be manufactured by mass production techniques with a minimum of modification of the present manufacturing processes employed in the production of point contact, non-linear conductive units. High tolerance linear resistor forms suitable for incorporation in present non-linear conductive units between the terminals 27 and 28 include films and wires employed either singly or in combination. These elements when properly associated with the units can be made effective within certain limited ranges of frequency or can be combined to make the characteristics of each of a group of units more uniform over the entire operating range of the unit.

Considering the unit disclosed in Fig. 1 wherein a button and several film resistors are employed, the films can consist of coatings of colloidal graphite or one of the other common resistor forms which are applied by printing, painting, dipping, electrophoretic and the like processes. One such film 20 is disclosed bridging the ceramic shell 10 and contacting both conductive studs 11 and 12 to provide a shunt resistance R_5 for the equivalent circuit as shown in Fig. 4. This shunt is effective at low frequencies and to a lesser degree at intermediate frequencies; however at high frequencies, of the order of 4000 megacycles, it is practically totally ineffective. The film 20 can be made an effective high frequency parallel resistance by so locating the unit relative to the electric vector that the film 20 is parallel therewith, or is normal thereto when the film is sufficiently thick to provide some resistance to the energy along that vector.

Series resistance R_4 as represented in the circuit of Fig. 3 is provided in the disclosed embodiment by two resistor forms. A mass 22 of linear resistive material provides low frequency and some intermediate frequency resistance when positioned intermediate the conductive stud 11 and the semiconductive wafer 13. This mass is in the form of a button 22 of carbon or metallic material which may be either undiluted or diluted with non-conducting material as is well known in the art. The button can be conductively associated with stud 11 and wafer 13 by applying suitable electrodes such as silver paint to its major surfaces and then soldering to those surfaces. The button 22, however, as shown is ineffective as a series resistance at high frequencies due to the capacitive coupling between the stud 11 and wafer 13; hence, an additional high frequency series resistance has been provided in the form of conductive films 24 of a nature similar to film 20. These films 24 are applied to the external surface of the conductive studs and are effective only at higher frequencies where skin effect causes the major conduction to be along the stud surfaces. Although in the specific device disclosed the coatings 24 have been applied to both ends of the unit, this is not necessary in effecting the purpose of this invention; however, it has been found that for certain operations the most desirable orientation for a series film resistance is with the stud bearing the film intermediate the non-linear junction and the signal source. Since the structure disclosed is often arranged for mounting so that either stud is adjacent the signal source, the coating of resistive films on both studs assures that a high frequency series resistance is located in its more effective position.

The combination of series and parallel resistances effec-

tive at both low and high frequencies and of constant value from unit to unit is effected as in the circuit of Fig. 5 by applying all of the resistances illustrated in the structure of Fig. 1 to the non-linear resistor units. In this circuit the added resistors correspond to the elements of the structure of Fig. 1 as follows: R₅ is parallel film 20, R₄ is series button 22, and R₆ is series film 24. It is to be understood, however, that these and other forms of resistances can be applied singly or in other combinations.

While any of the above-described additions amount to degrading, as non-linear devices, all of the units of a group, in order to obtain very nearly identical impedances, as pointed out above, the non-linearity of units of this nature is in excess of that necessary for many of their applications. Hence, the resultant products, from a commercial standpoint, are far superior to those known heretofore in that they have satisfactory non-linear characteristics, a high degree of uniformity as to their impedances, can be produced with a few simple and inexpensive additional operations applied to generally conventional units, require considerably less rigorous testing, and eliminate a substantial amount of waste.

No specific values of resistance have been suggested in the present disclosure since characteristics of the units to which these tolerance narrowing techniques are applicable vary widely as do the acceptable balances in loss of non-linearity against uniformity in units of a group. Such considerations are obvious to one skilled in the art in view of the teachings offered here. It is also obvious that the techniques disclosed are applicable to other forms of impedance units in effecting a narrowing of wide tolerance devices by the addition of narrow tolerance elements thereto and particularly to other conductive elements of both the linear and non-linear type. Numerous other arrangements may be devised by those skilled in the art without departing from the spirit and scope of the invention.

What is claimed is:

1. A high tolerance impedance unit comprising a unitary structure including a pair of terminals, a non-linear resistive element between said terminals having an equivalent circuit comprising the combination of a parallel linear and non-linear resistor in series with a linear resistor, and an integral high tolerance resistor of fixed value in series with said equivalent circuit and between said terminals.

2. A high tolerance impedance unit comprising a unitary structure including a pair of terminals, a non-linear resistive element between said terminals having an equivalent circuit comprising the combination of a parallel linear and non-linear resistor in series with a linear resistor, and an integral high tolerance resistor of fixed value connected in parallel across said equivalent circuit and between said terminals.

3. A high tolerance impedance unit comprising a unitary structure including a pair of terminals, a non-linear resistive element between said terminals having an equivalent circuit comprising the combination of a parallel linear and non-linear resistor in series with a linear resistor, an integral high tolerance resistor of fixed value in parallel with said equivalent circuit and connected between said terminals, and an integral high tolerance series resistor of fixed value between said terminals.

4. A non-linear resistive unit comprising a unitary structure including a housing, a pair of terminals on said housing, a non-linear resistor intermediate said terminals and within said housing, and an integral linear resistive unit having a high tolerance intermediate said terminals.

5. A non-linear resistor unit comprising a unitary structure including a pair of conductive studs, a hollow insulating member extending between said studs, a semiconductive body, an ohmic contact between said body and one of said studs, a limited area contact connected to the other stud and engaging said body, and a resistive

coating on one of said conductive studs to form a linear resistance unit having a high tolerance.

6. A non-linear resistor unit comprising a hollow insulating member, a conductive stud in each of the opposite ends of said member, a semiconductive body within said member electrically associated with one of said studs through a linear contact, an electrical connection from said other stud to said body having a non-linear resistive characteristic, and a resistive coating on said insulating member and connected electrically with each of said studs to form a linear resistance unit having a high tolerance.

7. A non-linear resistor unit comprising a hollow insulating member, a conductive stud supported on each end of said member, a linear resistor button secured to one of said studs with an ohmic contact, a semiconductive body secured to said button with a linear contact, and an electrical connection from said other stud to said body having a non-linear resistive characteristic.

8. A non-linear resistor unit comprising a hollow insulating member, a conductive stud supported on each end of said member, a linear resistor button secured to one of said studs with an ohmic contact, a semiconductive body secured to said button with a linear contact, an electrical connection from said other stud to said body having a non-linear resistive characteristic, and a conductive coating on said insulating member and connected electrically with each of said studs.

9. A non-linear resistor unit comprising a hollow insulating member, a conductive stud supported on each end of said member, a linear resistor button secured to one of said studs with an ohmic contact, a semiconductive body secured to said button with a linear contact, an electrical connection from said other stud to said body having a non-linear resistive characteristic, a conductive coating on said insulating member and connected electrically with each of said studs, and a resistive coating on one of said conductive studs.

10. An electrical translator comprising a unitary structure including a housing, a pair of terminals supported in insulated relationship on said housing, a semiconductive body within said housing electrically connected to one of said terminals, a pointed wire contact electrically connected to the other of said terminals and having its point engaging the surface of said body, and a linear resistor integral with said structure and intermediate said terminals.

11. An electrical translator comprising a unitary structure including a housing, a pair of terminals supported in insulated relationship on said housing, a semiconductive body within said housing electrically connected to one of said terminals, a pointed wire contact electrically connected to the other of said terminals and having its point engaging the surface of said body, a linear film resistor connected between said terminals and electrically in parallel with said body and said wire contact.

12. An electrical translator comprising a unitary structure including a housing, a pair of terminals supported in insulated relationship on said housing, a semiconductive body within said housing electrically connected to one of said terminals, a pointed wire contact electrically connected to the other of said terminals and having its point engaging the surface of said body, and a film of resistance material on one of said terminals having a linear resistive characteristic.

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