

Jan. 4, 1938.

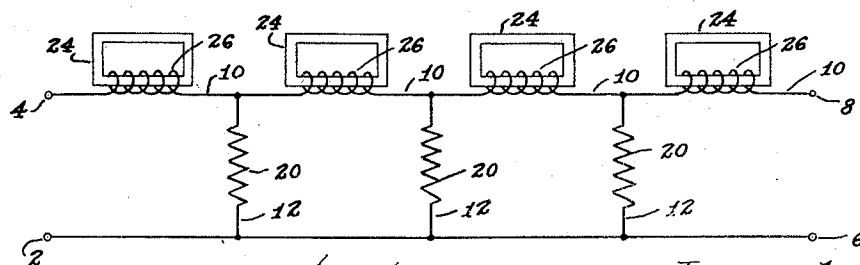
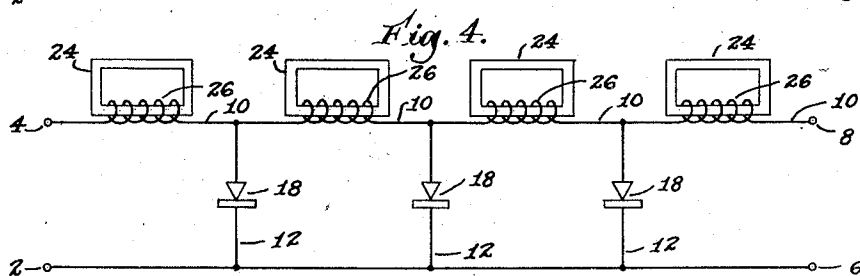
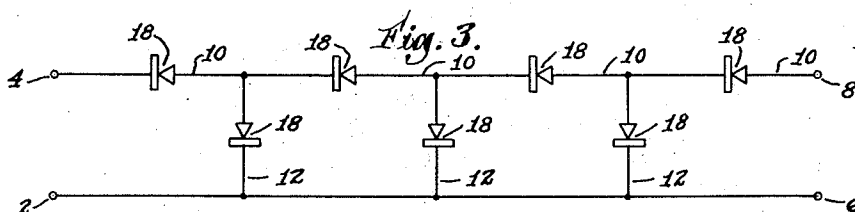
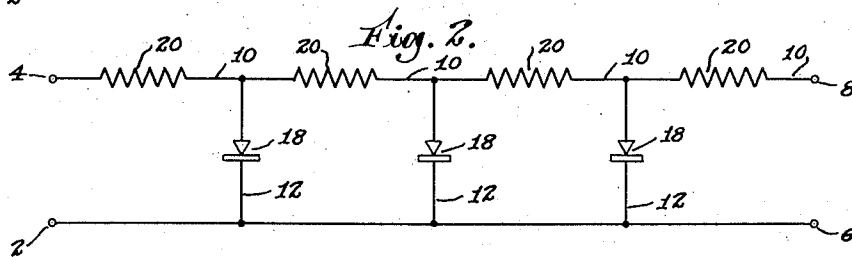
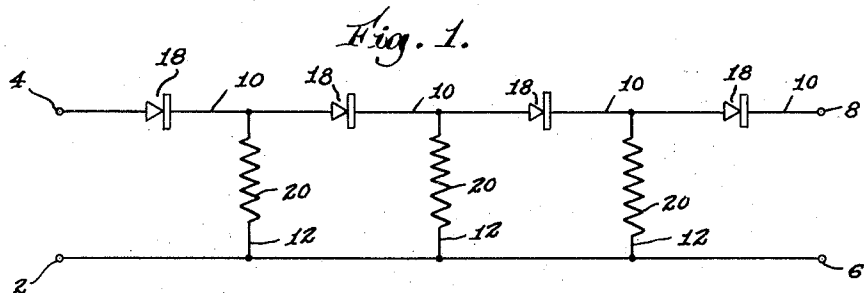
W. N. TUTTLE

2,104,336

ELECTRIC SYSTEM

Filed July 30, 1932

3 Sheets-Sheet 1



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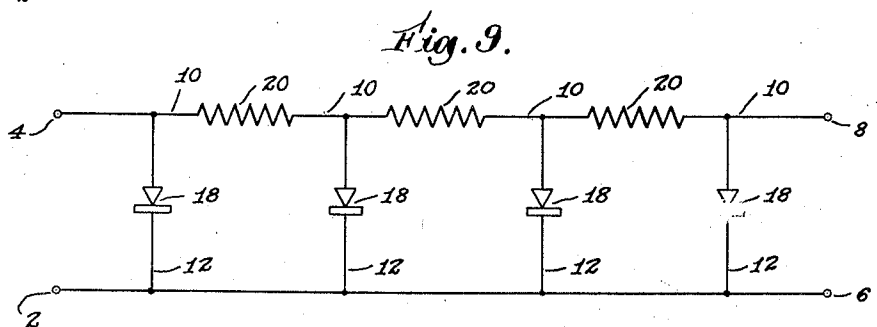
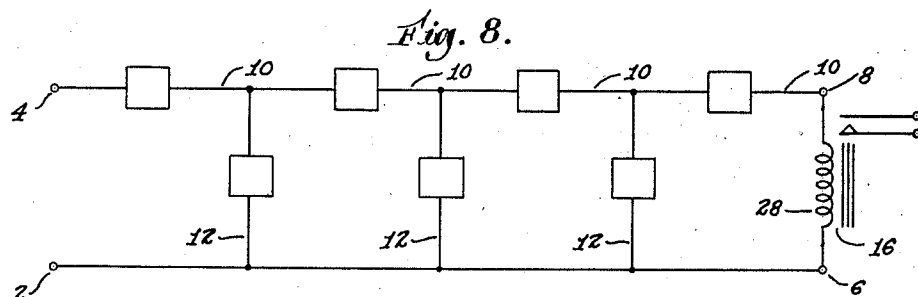
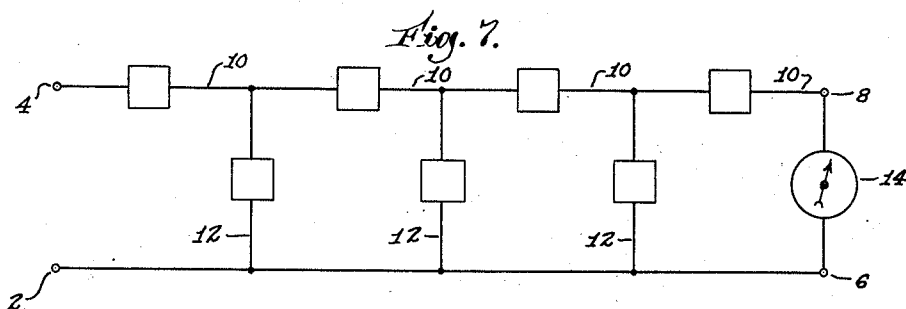
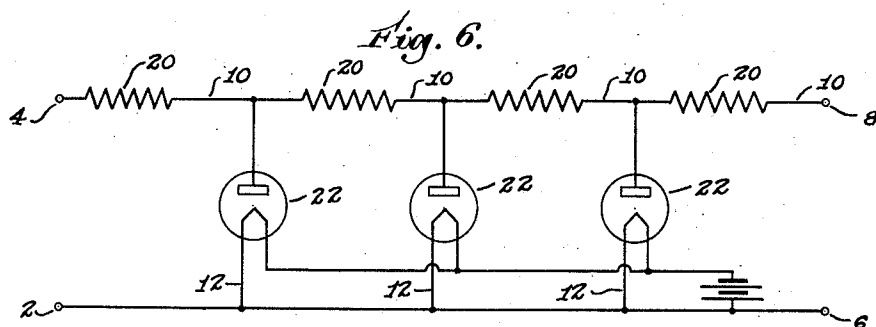
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ELECTRIC SYSTEM

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3 Sheets-Sheet 2



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ELECTRIC SYSTEM

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3 Sheets-Sheet 3

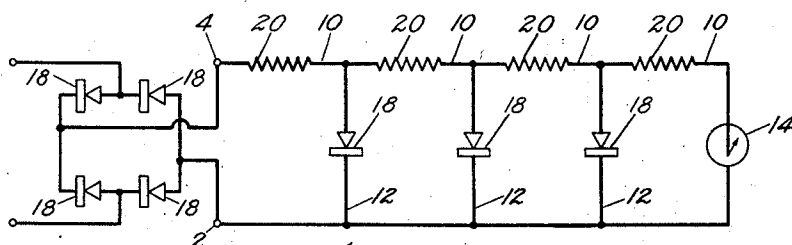


Fig. 10.

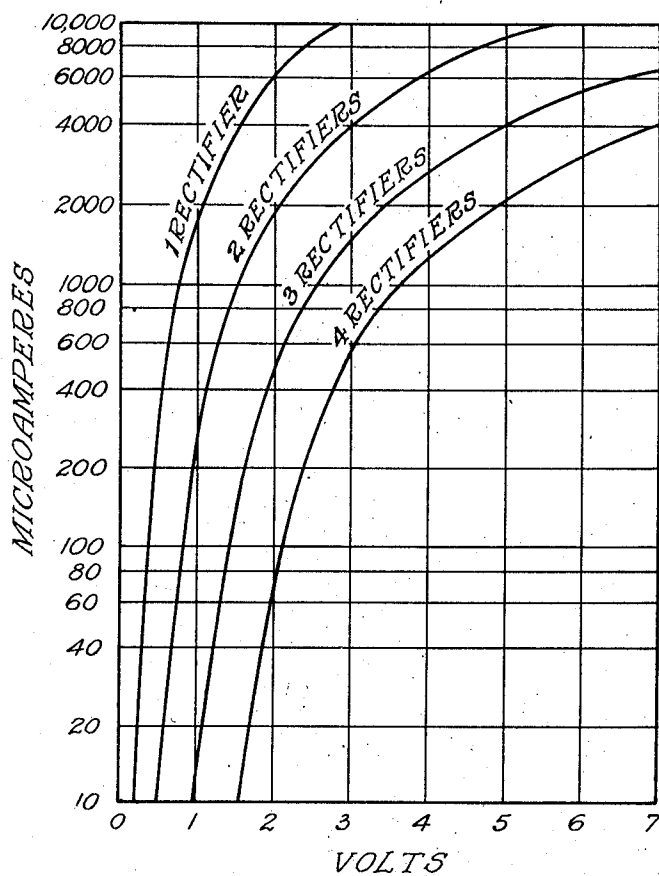


Fig. 11.

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ELECTRIC SYSTEM

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21 Claims. (Cl. 178—44)

The present invention relates to electric systems, and more particularly to electric networks, especially of the ladder type. From a more specific aspect, the invention relates to electric systems embodying such networks. From a still more limited point of view, the invention relates to electric instruments that may comprise such networks, such as electric meters, electric relays and the like.

An object of the invention is to provide a new and improved electric network that shall be simple to construct, cheap to manufacture, and efficient in operation.

A further object is to provide a new and improved electric instrument embodying such network.

Other and further objects will be explained hereinafter, and will be particularly pointed out in the appended claims.

The invention will now be explained in connection with the accompanying drawings, in which Fig. 1 is a diagrammatic view of a ladder-type network embodying the present invention; Figs. 2 to 10 are similar views of modifications and Fig. 11 is a view showing explanatory curves.

The invention comprises a suitable, ladder-type network having an input connection, represented by input terminals 2, 4 and an output connection, represented by output terminals 6, 8. The network may have any desired number of sections,—three being illustrated,—each having a series arm 10 and a shunt arm 12. The individual sections may be of the form illustrated in Figs. 1 to 8 or that illustrated in Fig. 9. In Fig. 7, there is shown connected to the output terminals 6, 8, a suitable indicating meter 14. In Fig. 8, the instrument similarly connected with the output circuit is a relay 16; and it will be understood that other instruments may also be so connected.

The terminals 2, 4 of the input connection may be connected with any source of voltage, current, power, etc. that it is desired to measure in the meter 14 of Fig. 7, it being understood that the meter may be of any desired type, such as the usual moving-coil type of direct-current instruments, or any alternating-current instrument, such as of the thermionic, the thermocouple, the hot-wire-ammeter or the copper-oxide-rectifier types. The input connections for the relay 16 and other instruments may be made, as will be understood, by persons skilled in the art.

In Fig. 1, each of the set of series arms is shown provided with a copper-oxide rectifier 18, and each of the set of shunt arms is shown provided with a resistance 20. In the case of the resist-

ance 20, of course, Ohm's law applies; that is, the current is proportional to the voltage. Circuit elements for which this is true, such as these resistances 20, will, for brevity, be hereinafter referred to in the specification and claims as linear elements. By the same token, the copper-oxide rectifiers 18 are non-linear elements. Both linear and non-linear elements, obviously, may be resistive, as in the case of the copper-oxide rectifiers 18, the resistances 20, and the diode rectifiers 22, Fig. 6; inductive, as illustrated by the saturable cores 24 in inductive windings 26 of Figs. 4 and 5; capacitive; or a combination of the same. As is also obvious, therefore, the present invention is applicable for use with both direct and alternating current.

In Fig. 1, then, the set of series arms 10 are provided with non-linear rectifier elements 18, and the set of shunt arms with linear resistances 20. This arrangement, however, may be reversed as in Fig. 2, where the resistances 20 are shown disposed in the series arms 10 and the rectifiers 18 in the shunt arms 12.

It is possible, however, to have non-linear rectifiers 18 in both sets of arms, as illustrated in Fig. 3, the elements in adjacent arms 10 and 12 of each mesh of the network being connected in opposite sense, as illustrated in Fig. 3; and to combine inductive with non-inductive elements in the various series and branch arms, as in Figs. 4 and 5. Only a few of the many possibilities are illustrated in the drawings, but these few are sufficient to illustrate the principle of the invention, which will now be explained.

In the case of a rectifier, as is well known, conduction of current takes place more readily in one direction than in the other. The resistance of a perfect rectifier would change from zero to infinity as the applied voltage is reversed. In rectifiers obtainable in practice, however, the resistance changes continuously and more or less gradually as the applied voltage approaches zero and reverses in direction. For larger values of voltage, on the other hand, there may be a very high or practically infinite ratio between the resistances in the two directions.

It is evident, therefore, that over a certain range of voltages of one polarity a rectifier is a circuit element whose resistance decreases with increasing voltage. For a range of voltages of the opposite polarity, the opposite characteristic is obtained and the resistance of the element increases with increasing voltage.

Referring, first, to Fig. 3, the series rectifiers are connected in such sense that high resistance 55

is offered to large currents and low resistance to low currents or negative currents. The shunt rectifiers are connected in the opposite sense so that low resistance is offered to high currents and high resistance to low or negative currents.

Low currents, therefore, flow readily through the series rectifiers (and through the output meter 14 or the relay coil 28 of Figs. 7 and 8) and are not appreciably shunted off by the shunt rectifiers.

High currents, on the other hand, can not easily flow through the first series rectifier, and most of this high current flows through the first shunt rectifier. Only a small fraction of the original voltage is thus impressed on the second series rectifier. When this process is repeated in the several sections of the network, a negligibly small voltage is impressed on the output circuit.

The network of Fig. 3 thus passes low currents and suppresses high currents to a very large degree.

The rectifiers 18 of Fig. 3 may, of course, be all reversed in sense, the series and the shunt rectifiers pointing in the opposite direction to the directions shown. The network will then pass high currents and substantially suppress the low currents, because the low voltages or currents will be passed by the series rectifiers 18 and choked back by the parallel-connected rectifiers 18.

The operation of the other systems illustrated is based upon similar principles. For example, if the network has series resistances 20, which are linear, and parallel-connected rectifiers, as in Fig. 2, then if a high voltage is applied to the input terminals 2, 4 of the circuit, the parallel, or shunt, copper-oxide rectifiers 18 would have low resistance compared with the series linear resistances 20. For low voltages or currents, the parallel, copper-oxide rectifiers 18 have a high resistance as compared with the series resistances 20; therefore, there is very little shunting effect.

In the network of Fig. 2, the resistance of the first and last resistors 20 may be half that of the second and third, which latter may be equal. This may be desirable in view of the impedance of the apparatus connected at the input or output terminals.

Fig. 6 is of the same nature as Fig. 2, except that the non-linear rectifiers 18 have been replaced by diodes 22 which, depending on an electron stream for the conduction of current, are likewise non-linear. Though the magnetic-core devices 24, 26 of Figs. 4 and 5, as ordinarily used in other applications, are purposely designed so as to be as nearly linear as possible, they are, in accordance with the present invention, designed so as to be markedly non-linear.

A chain of series resistances 20 and copper-oxide rectifiers 18 may be employed to produce a logarithmic voltmeter, as in Fig. 7. It is found that, over a very wide, useful range, say from about 0.01 volt to more than 30 volts, a curve plotted with numerical values of the output current as the ordinate, and with the logarithm of the input voltage as the abscissa, closely approximates a straight line. By varying the number and the kind of the rectifier elements, the approximation to the straight line may be improved. On the other hand, the range over which the logarithmic relation holds may, by this expedient, become decreased.

In ordinary electric meters, the deflection of the pointer is proportional to the current through the moving coil of the meter. This results in a

scale on which currents near the zero point can not be read with as high percentage accuracy as at the other end of the scale. The range of currents or voltages which can be satisfactorily measured on a single-scale instrument is consequently very much limited.

In the logarithmic meter of the present invention, on the other hand, the resulting scale is such that readings may be made with the same percentage accuracy over the entire range.

In Fig. 1, where the series and the shunt elements are interchanged with respect to Fig. 2, the system, as before stated, discriminates against low voltages and favors the high voltages. This opens possibilities for the use of a relay 16, as before-mentioned, operated at a certain critical voltage or current.

If the relay 16 is employed in connection with the system of Fig. 1, it will, of course, be operated by direct current because, even though the source be alternating current, the rectifiers 18 will rectify it. If saturable-core devices such as are illustrated at 24, 26 be employed, however, the network will then be of the alternating-current type, and the relay 16 may then be operated by alternating current. The novel relay of the present invention is therefore adapted for both alternating and direct currents.

The operation of the relay may, perhaps, be better understood from the following. In connection with Fig. 11 the upper curve represents the first section of the chain of Fig. 1, with the abscissa representing numerical values of the voltage applied to the input terminals 2, 4, and the ordinate representing logarithmic values of the output current. The second curve similarly represents the first two sections, representing the performance of a network embodying only the said two sections, comprising two series rectifiers 18 and one shunt resistance 20, the meter 14 taking the place of the second shunt resistance 20. It will be noted that the second curve is substantially parallel to the first-named curve. Additional curves plotted in the same way, by adding additional sections to the network are found to be of similar nature, but moved over bodily to the right. In each case, the current rises abruptly and then bends over gradually to the right. For example, in the particular arrangement where three sections were employed, comprising four series rectifiers 18 and three shunt resistances 20, the current is found to rise abruptly at a voltage value of about 1.5 volts; while, in the case of a single section, the current began to rise abruptly at approximately .2 of a volt. A much smaller percentage change in voltage is therefore required to produce a large change in current in the case of the three-section network than in the case of a single section.

In connection with ordinary relays, designed to operate at a certain value or current, a spring is commonly adjusted delicately so as to operate at the particular value desired. Due to such factors as bearing friction, the relay may respond at any current within a certain limited range of values, say between 17 and 20 milliamperes. If, therefore, the voltage at the terminals of the relay is between 1.7 or 2.0 volts, the relay may or may not operate. According to the present invention, on the other hand, the fact that the current rises very abruptly, beginning at 1.5 volts, in the example given above, results in the current through the relay passing very rapidly through the region of doubtful operation, for a

few hundredths of a volt variation in the voltage applied.

A very effective alternating-current meter may be provided, as illustrated in Fig. 10, by connecting two opposite input terminals of a Wheatstone-bridge arrangement, having rectifiers in each arm, to the source of alternating current, and connecting the other two opposite terminals to the input terminals 2, 4 of Fig. 2, the meter 14 being connected with the terminals 6, 8 as in Fig. 7. The two arms of the Wheatstone bridge adjacent to the input terminals thereof should be oppositely disposed with respect to the input current, as is well understood in the art.

Further modifications may obviously be made by persons skilled in the art, and all such are considered to fall within the spirit and scope of the invention, as defined in the appended claims.

What is claimed is:

1. An electrical network of the ladder type having a plurality of sections and input and output terminals to operate on direct voltage of specified polarity applied to the input terminals comprising resistive series arms and resistive shunt arms, a plurality of the shunt arms each having a rectifier, the rectifiers being connected in such a sense as to make the direct voltage at the output terminals vary less than in proportion to the direct voltage at the input terminals.

2. An electrical network of the ladder type having a plurality of sections and input and output terminals to operate on direct voltage of specified polarity applied to the input terminals comprising resistive series arms and resistive shunt arms, a plurality of the series arms and a plurality of the shunt arms having a rectifier connected in such a sense as to make the direct voltage at the output terminals vary less than in proportion to the direct voltage at the input terminals.

3. A passive electrical network having an input and an output and comprising a plurality of sections, each section containing one or more substantially non-linear impedances of such value as to make the voltage at the output terminals vary over an appreciable range substantially in proportion to the logarithm of the voltage at the input terminals.

4. An electrical network of the ladder type having an input and an output and comprising a plurality of sections each having a series arm and a shunt arm, at least one of the arms being substantially non-linear in such a sense as to make the voltage at the output terminals vary over an appreciable range substantially in proportion to the logarithm of the voltage at the input terminals.

5. An electrical network of the ladder type having an input and an output and comprising a plurality of sections each having a series arm and a shunt arm, the series arms being substantially linearly resistive and one or more of the shunt arms being non-linearly resistive to make the voltage at the output terminals vary over an appreciable range substantially in proportion to the logarithm of the voltage at the input terminals.

6. An electrical network having an input and an output and comprising a plurality of sections, each section containing one or more substantially non-linear impedances of such value as to cause the section to offer greater attenuation to large voltages than to small voltages and to cause the network as a whole to make the voltage at the output vary over an appreciable range

substantially in proportion to the logarithm of the voltage at the input.

7. An electrical network having an input and an output and comprising a plurality of sections, each section containing one or more non-linear impedances varying with voltage in such a sense as to cause each section to offer greater attenuation to large voltages than to small voltages, and proportioned so that the maximum variation in impedance in the different sections occurs at different values of the voltage at the input.

8. An electrical network of the ladder type having an input and an output and comprising a plurality of sections each having a series arm and a shunt arm, each section containing a substantially non-linear impedance in the series arm and a substantially linear impedance in the shunt arm, the non-linear impedances varying with voltage in such a sense as to cause each section to offer greater attenuation to large voltages than to small voltages, and proportioned so that the maximum variation in impedance in the different sections occurs at different values of the voltage at the input.

9. An electrical network of the ladder type having an input and an output and comprising a plurality of sections each having a series arm and a shunt arm, each section containing a substantially non-linear impedance in the series arm and a substantially linear impedance in the shunt arm, the impedances being of such value as to cause each section to offer greater attenuation to large voltages than to small voltages and to cause the network as a whole to make the voltage at the output vary over an appreciable range substantially in proportion to the logarithm of the voltage at the input.

10. An electrical network of the ladder type having an input and an output and comprising a plurality of sections each having a series arm and a shunt arm, each section containing a substantially linear impedance in the series arm and a substantially non-linear impedance in the shunt arm, the non-linear impedances varying with voltage in such a sense as to cause each section to offer greater attenuation to large voltages than to small voltages, and proportioned so that the maximum variation in impedance in the different sections occurs at different values of the voltage at the input.

11. An electrical network of the ladder type having an input and an output and comprising a plurality of sections each having a series arm and a shunt arm, each section containing a substantially linear impedance in the series arm and a substantially non-linear impedance in the shunt arm, the impedances being of such value as to cause each section to offer greater attenuation to large voltages than to small voltages and to cause the network as a whole to make the voltage at the output vary over an appreciable range substantially in proportion to the logarithm of the voltage at the input.

12. An electrical network of the ladder type having an input and an output and comprising a plurality of sections each having a series arm and a shunt arm, the impedances of the series and shunt arms all being substantially non-linear, the non-linear impedances varying with voltage in such a sense as to cause each section to offer greater attenuation to large voltages than to small voltages, and proportioned so that the maximum variation in impedance in the different sections occurs at different values of the voltage at the input.

13. An electrical network of the ladder type having an input and an output and comprising a plurality of sections each having a series arm and a shunt arm, the impedances of the series and shunt arms all being non-linear, the impedances being of such value as to cause each section to offer greater attenuation to large voltages than to small voltages and to cause the network as a whole to make the voltage at the output vary over an appreciable range substantially in proportion to the logarithm of the voltage at the input.

14. An electrical network having an input and an output and comprising a plurality of sections, each section containing one or more impedances including a copper-oxide rectifier, the rectifier impedances varying with voltage in such a sense as to cause each section to offer greater attenuation to large voltages than to small voltages, and proportioned so that the maximum variation in impedance in the different sections occurs at different values of the voltage at the input.

15. An electrical network having an input and an output and comprising a plurality of sections, each section containing one or more impedances including a copper-oxide rectifier, the impedances being of such value as to cause each section to offer a greater attenuation to large voltages than to small voltages and to cause the network as a whole to make the voltage at the output vary over an appreciable range substantially in proportion to the logarithm of the voltage at the input.

16. An electrical network having an input and an output and comprising a plurality of sections, each section containing one or more substantially non-linear impedances varying with voltage in such a sense as to cause each section to offer greater attenuation to large voltages than to small voltages, and proportioned so that the maximum variation in impedance in the different sections occurs at different values of the voltage at the input.

17. An electrical network having an input and an output and comprising a plurality of sections, each section containing one or more substantially non-linear impedances of such value as to cause the section to offer greater attenuation to large voltages than to small voltages of a specified polarity and to cause the network as a whole to make the voltage at the output vary over an appreciable range substantially in proportion to the logarithm of the voltage at the input.

18. An electrical network having an input and an output and comprising one shunt arm and a

series arm on each side of the shunt arm, each arm having an impedance, the impedance of the shunt arm being substantially linear, the impedance of each of the series arms being substantially non-linear and varying with voltage in such a sense as to cause the network to offer greater attenuation to large voltages than to small voltages, and proportioned so that the maximum variation in impedance of the two series arms occurs at different values of the voltage at the input.

19. An electrical network having an input and an output and comprising one shunt arm and a series arm on each side of the shunt arm, each arm having an impedance, the impedance of the shunt arm being substantially linear, the impedance of each of the series arms being substantially non-linear, the impedances being of such value as to cause the maximum variation of the substantially non-linear impedances to occur at different values of input voltage and to cause the network as a whole to make the voltage at the output vary over an appreciable range substantially in proportion to the logarithm of the voltage at the input.

20. An electrical network having an input and an output and comprising one series arm and a shunt arm on each side of the series arm, each arm having an impedance, the impedance of the series arm being substantially linear, the impedance of each of the shunt arms being substantially non-linear and varying with voltage in such a sense as to cause the network to offer greater attenuation to large voltages than to small voltages, and proportioned so that the maximum variation in impedance of the two shunt arms occurs at different values of the voltage at the input.

21. An electrical network having an input and an output and comprising one series arm and a shunt arm on each side of the series arm, each arm having an impedance, the impedance of the series arm being substantially linear, the impedance of each of the shunt arms being substantially non-linear, the impedances being of such value as to cause the maximum variation of the substantially non-linear impedances to occur at different values of input voltage and to cause the network as a whole to make the voltage at the output vary over an appreciable range substantially in proportion to the logarithm of the voltage at the input.

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