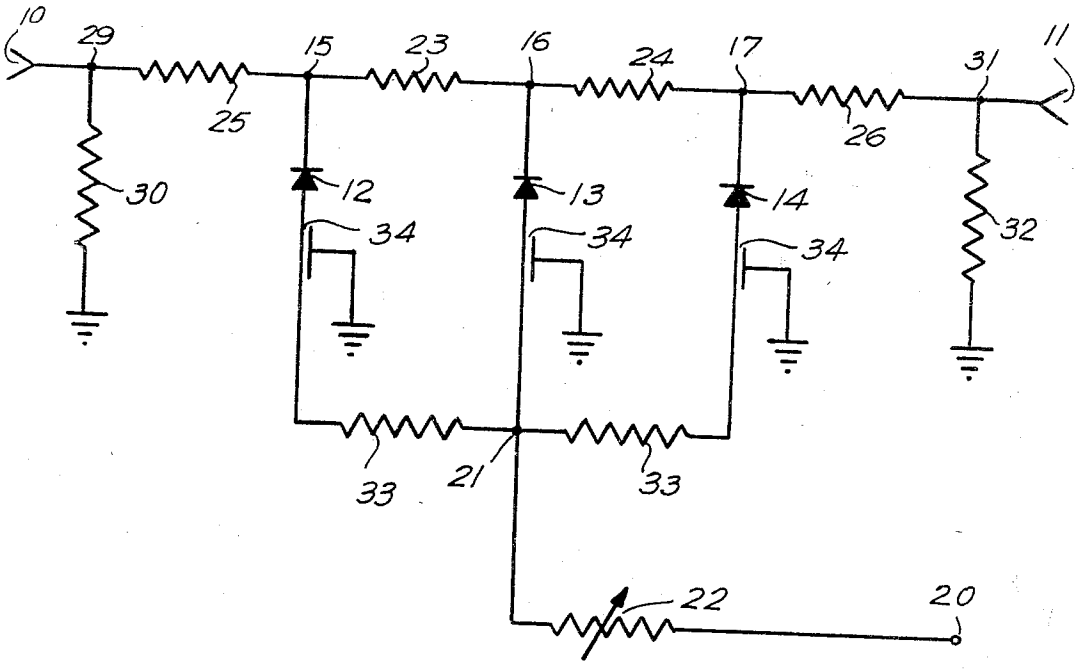
June 13, 1967

A. FRISCH ETAL

3,325,754

RESISTOR-DIODE ATTENUATOR

Filed May 13, 1964



INVENTORS:
ARNOLD FRISCH
LAWRENCE H. WEISS
MORRIS ENGELSON

BY

ATTORNEY

United States Patent Office 3,325,754 Patented June 13, 1967

3,325,754

RESISTOR-DIODE ATTENUATOR

Arnold Frisch, Brooklyn, Lawrence H. Weiss, Forest Hills, and Morris Engelson, Brooklyn, N.Y., assignors, by mesne assignments, to Tektronix, Inc., Beaverton, Oreg., a corporation of Oregon

Filed May 13, 1964, Ser. No. 367,153
3 Claims. (Cl. 333—81)

This invention relates to power adjustment means of the type often referred to as "attenuators," and more particularly to an attenuator for selectively adjusting the amount of power supplied to a load from a source of alternating current power.

One of the most common types of attenuators is a potentiometer.

A potentiometer is a resistor having an adjustable tap, i.e., a resistor having two ends, and a fixed value of resistance as measured between these ends, and a third terminal whose position is adjustable to any point between these ends. If a source of power is connected across the fixed terminals and a load is placed between either fixed terminal and the tap, then the potentiometer may be said to act as an attenuator. This is because the voltage, or alternately, the power, available at the load is smaller (or at most equal to) that supplied by the source.

Theoretically a potentiometer is a pure resistance. However, in actuality the various electrical connections involved in a potentiometer, including the elements of the sliding terminal, offer a certain amount of capacitive and inductive impedance. Such impedance can be ignored when the potentiometer is being employed with a source of direct current or with an alternating current source of relatively low frequency. However, since the effect of these impedances increases with the frequency of the voltage applied to the potentiometer, when a potentiometer-attenuator is employed with a high frequency source of power, e.g., a radio frequency source, the effects of these impedances become considerable and cannot be ignored. As a consequence, the usefulness of potentiometer-attenuaors is limited to installations involving relatively low frequencies. Another disadvantage of a potentiometer, as an attenuator in A.C. installations, is the fact that the impedance which it presents does not remain constant, but rather varies with the frequency of the source and the setting of the attenuator. This leads to a further disadvantage, which is that the attenuation produced by a potentiometer varies with the frequency of the source.

Types of attenuators other than potentiometers are, of course, well known. There are purely mechanical attenuators, but these tend to be bulky and expensive. In addition, there are electrically controlled attenuators, but these may not be continuously variable, may not exhibit constant impedance, and have limited bandwidth.

It is an object of the present invention to provide an attenuator, the input impedance of which does not vary with the frequency of the power source, or with the attenuation setting.

It is another object of the invention to provide an attenuator wherein the attenuation produced at any particular setting is subsantially independent of frequency.

It is a further object of the invention to provide such an attenuator having no moving parts, the degree of attenuation produced by the attenuator being electrically controlled.

It is still another object of the invention to provide an

attenuator which is compact, inexpensive to manufacture, and thoroughly practical throughout a large range of frequencies.

To achieve these objects, the present invention provides an attenuator comprising plural resistors series connected between a source of alternating current power and a load, and plural variable resistance means connected to the junctions between the resistors.

When current flowing through one of the series-connected resistors from the source reaches a junction, it divides; a portion of the current flows toward the variable resistance means and the remainder flows toward the load. Obviously, the amount of current which flows toward the variable resistance means depends upon the selected resistance of the means. A feature of the invention is the employment of an electrically controlled variable resistance means, such as a diode, the resistance value of which depends upon the value of D.C. voltage supplied to it. Means are provided for permitting continuous variation of the D.C. voltage supplied to the variable resistance means in order to vary the amount of power supplied to the load.

An extremely important feature of the invention is the provision of resistors in parallel with the input and output sides of the attenuator for reducing the input and output voltage standing wave ratios of the attenuator and making them as close to unity as possible.

Other objects and advantages of the invention will be apparent from the following description in which reference is made to the accompanying drawing.

The drawing is a schematic diagram of an attenuator constructed in accordance with the present invention.

The attenuator is shown connected between two terminals **10** and **11**. The terminal **10** is connected to a source of alternating current power, and the terminal **11** is connected to a load to be supplied by the source via the attenuator. The source and load are not shown.

The attenuator chosen to illustrate the present invention employs three diodes **12**, **13**, and **14** which serve as variable resistance means. However, it is to be understood that any number of diodes may be used. The diodes **12–14** are connected, respectively, to three junctions **15**, **16**, and **17**, the junctions being connected in series with one another and with the terminals **10** and **11**. The diodes which are arranged to pass current in the direction of the junctions, are connected in parallel with one another and with the load connected to terminal **11**. Biasing voltage is supplied to the diodes from a D.C. source **20**. The anodes of all the diodes **12–14** are connected to a common junction **21**, and arranged in series between the D.C. source **20** and the junction **21** is a potentiometer **22** capable of continuously varying the value of biasing voltage supplied to the diodes.

The endmost diodes **12** and **14** are isolated from the center diode **13** by resistors **23** and **24**, respectively, the former being located between the junctions **15** and **16**, and the latter being located between the junctions **16** and **17**. Furthermore, the diode **12** is isolated from the source terminal **10** by a resistor **25** connected between terminal **10** and junction **15**, and the diode **14** is isolated from the load terminal **11** by a resistor **26** connected between terminal **11** and junction **17**. The four isolating resistors **23–26** are therefore connected in series between the terminals **10** and **11**, and are preferably equal to one another in value. Connected to a junction **29**, between resistor **25** and terminal **10**, in parallel with resistor **25** is a "padding" resistor

30, and connected to a junction 31, between resistor 26 and terminal 11, in parallel with resistor 26 is another padding resistor 32. The purpose of the padding resistor is to reduce the input and output voltage standing wave ratios (VSWR) of the attenuator and bring these ratios as close to unity as possible. This function will be described in more detail below.

Connected in series between the junction 21 and the anode of each of the endmost diodes 12 and 14 is a balancing resistor 33. The resistor 33 insures that the current flowing to the endmost diodes from the D.C. source 20 equals the current flowing to the center diode 13. Arranged between the anode of each diode and ground is a by-pass capacitor 34. The by-pass capacitors prevent radio frequency leakage from the attenuator through the D.C. power supply leads. They also provide a low impedance radio frequency return at the diode anodes, and they decouple the diode sections from one another thus increasing the maximum value of attenuation attainable.

The operation of the attenuator is as follows:

If minimum attenuation of the power level between input terminal 10 and output terminal 11 is desired, i.e., if maximum power is to appear at terminal 11, the potentiometer 22 is adjusted to introduce its largest possible resistance into the circuit. As a result, there is almost no D.C. voltage drop across the diodes 12–14 and consequently, the diodes act substantially as open circuits, i.e., they offer extremely high resistance to the flow of A.C. current from the source connected to terminal 10. This is due to the well known characteristic curve of a diode which indicates that at low voltages, the current through a diode remains substantially constant throughout variation of voltage. Since $\Delta V = \Delta I \cdot R$, where ΔV is change in voltage drop across the diode, ΔI is current flowing through the diode, and R is the resistance offered by the diode, it is clear that if ΔV is large but ΔI remains very small, R must be very large.

Current from the A.C. source, entering the attenuator through terminal 10 divides when it reaches the junction 29; a portion of the current flows through padding resistor 30 and the remainder flows through the first isolating resistor 25. Upon reaching the junction 15, the current flowing through resistor 25 tends to divide so that a portion flows toward diode 12 and the remainder flows through resistor 23. However, under the circumstances mentioned above, the resistance of diode 12 is so large that substantially all of the current flows through resistor 23. Similarly, at junctions 16 and 17, substantially no current flows toward the diodes 13 and 14, respectively. Hence, nearly all the current which flows through resistor 25 reaches terminal 31. At this point the current divides between padding resistor 32 and the load connected to terminal 11.

If maximum attenuation is desired, i.e., minimum power at terminal 11, the potentiometer 22 is adjusted to introduce minimum resistance into the circuit, whereby a high current flows to the diodes 12–14. As a result, the resistance of the diodes is very small and they act practically as open circuits. This is again due to the diode characteristic which indicates that at high currents, the voltage drop across a diode remains substantially constant. Thus, in the expression given above, if ΔV approaches zero, and ΔI is large, R must approach zero.

When the portion of the current from terminal 10, which flows through the resistor 25, reaches the junction 15, under the circumstances just described almost all of the current will flow toward the diode 12, since its resistance is very small. The small portion of the current flowing through the resistor 23 is again divided at junction 16 in such a way that most of it flows toward diode 13. It will be appreciated, therefore, that almost no A.C. current reaches the terminal 11.

Obviously, if the potentiometer 22 is adjusted to an intermediate resistance value, the current reaching each junction 15–17 will divide in proportion to the resistance value of the diode connected to that junction and the resistor 23, 24, or 26 immediately following the junction. Thus, since the potentiometer 22 permits continuous variation of the current flowing to the diodes and hence the resistance of the diodes, the arrangement as a whole permits continuous variation of the attenuation produced by the attenuator.

In order to clearly describe the function of the padding resistors 30 and 32, it will be helpful to assign illustrative values to the resistors 23–26, 30, and 32. It is to be understood, however, that these values are presented for the sake of explanation and are not intended to limit this disclosure in any way. Assume that each resistor 23–26 has a value of 220 ohms, and that resistors 30 and 32 each has a value of 56 ohms. Assume also that the attenuator is designed to have a characteristic impedance of 50 ohms.

If resistors 30 and 32 were not present, the input impedance of the attenuator under the conditions of minimum attenuation would be essentially the sum of the resistance values of the resistors 23–26, since almost all of the current from terminal 10 would flow through all the resistors. On the other hand, under conditions of maximum attenuation, the input impedance of the attenuator would be essentially the value of the first resistor 25, since almost no current flows through the other resistors. Clearly, therefore, it would be impossible for the attenuator to have an input impedance, and for similar reasons an output impedance, which remains close to the characteristic impedance of the attenuator at both maximum and minimum attenuation. This is undesirable because under these circumstances, the input and output voltage standing wave ratio (VSWR) will not be close to unity. VSWR may be defined as the ratio of the maximum to minimum voltage existing in an arbitrarily long lossless transmission line of characteristic impedance Z_0 connected to a load of impedance Z.

Provision of the padding resistors 30 and 32 reduces the input and output VSWR of the attenuator to a value close to one. Using the value given above, it will be seen that at minimum attenuation, the minimum value of input impedance is 52.6 ohms. This value is calculated as follows:

$$Z_{max} \approx \frac{4(220)(56)}{4(220)+56} = 52.6 \text{ ohms}$$

The input VSWR is therefore: 52.6/50 (characteristic impedance) = 1.056. At maximum attenuation, the minimum value of input impedance is 48.3 ohms. This value is calculated as follows:

$$Z_{min} \approx \frac{220(56)}{220+56} = 48.3 \text{ ohms}$$

The input VSWR is therefore: 50/48.3 = 1.035. Similar calculations can be made to determine the output VSWR of the attenuator, and these would be identical to the input VSWR values. It will be seen, therefore, that the present invention provides an attenuator having an input and an output VSWR very close to unity, and certainly far lower than the VSWR of 1.5 to 2 which can ordinarily be tolerated in components of this type.

The invention has been shown and described in preferred form only and by way of example, and many variations may be made in the embodiment described which will still be comprised within the spirit of the invention. It is understood, therefore, that the invention is not limited to any specific form or embodiment except insofar as such limitations appear in the appended claims.

What is claimed is:

1. An attenuator adapted to be connected between a source of alternating current power and a load for the purpose of adjusting the amount of power supplied to the load, comprising an electric circuit between the source and load, said circuit including a plurality of series connected junctions, plural voltage variable resistance means each having a first and a second terminal and each having said first terminal connected to one of said junctions,

means for supplying a selected D.C. voltage to said second terminal of said variable resistance means said means for supplying a selected D.C. voltage having a point of ground reference potential in common with said source of alternating current power and said load, an isolating resistor between each of said junctions and between the endmost junctions and said source and load, and padding resistors connected from junctions between the endmost of said isolating resistors and said A.C. source and load to said point of ground potential.

2. An attenuator as defined in claim 1 where each of said variable resistance means is a diode.

3. An attenuator as described in claim 2 including at least three of said diodes, the anodes of said diodes being connected to a common junction, and a balance resistor between each of said endmost diodes and said common junction.

References Cited

UNITED STATES PATENTS

2,003,428	6/1935	Cowan	323—66
2,775,659	12/1956	Nelson	330—200
2,854,643	9/1958	Wigan et al.	333—81
3,153,189	10/1964	Sweeney	323—66
3,188,554	6/1965	Reid	323—74
3,202,940	8/1965	Dietrich	323—52

OTHER REFERENCES

Johnson: Transmission Lines and Networks, McGraw-Hill, New York, copyright 1950, pages 286–289 relied on.

HERMAN KARL SAALBACH, *Primary Examiner.*

R. F. HUNT, *Assistant Examiner.*