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CIRCUIT WITH EXTENDED LOGARITHMIC CHARACTERISTIC

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Fig. 1

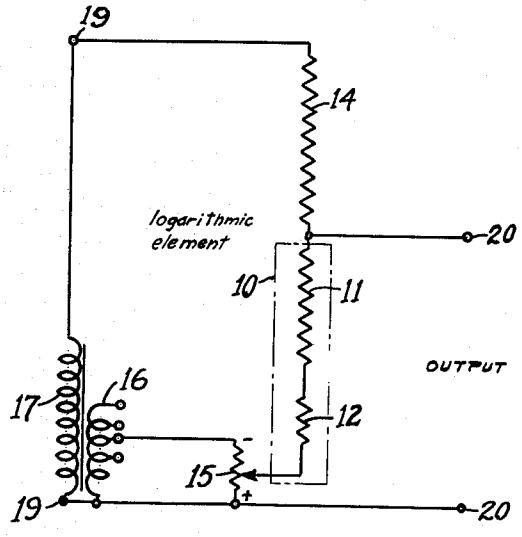


Fig. 2

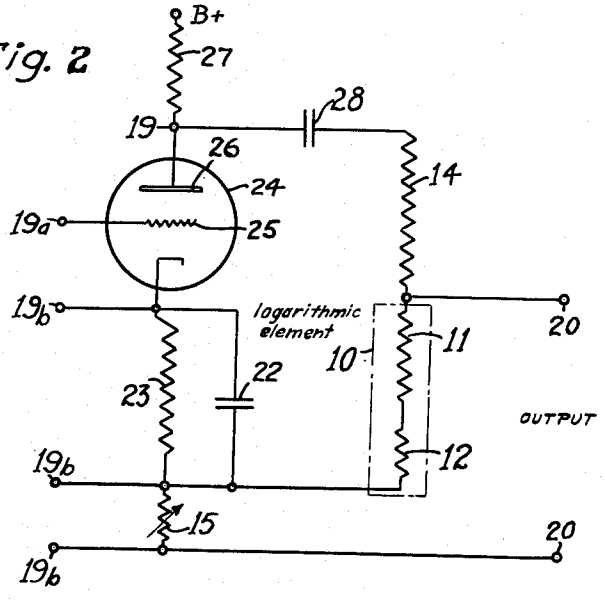
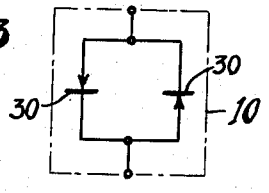


Fig. 3



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CIRCUIT WITH EXTENDED LOGARITHMIC CHARACTERISTIC

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10 Claims. (Cl. 250—27)

The invention relates to a circuit including an element in the circuit with a logarithmic characteristic in which the logarithmic range is substantially increased. The logarithmic characteristic is one in which the output voltage or current of a circuit is directly proportional to the logarithmic of the input voltage (or current) over the logarithmic range. Such elements have a resistance which varies inversely with current which is the logarithmic characteristic. Many crystals and other materials have this characteristic over a certain portion of its applied voltage range; however, the germanium crystal has a logarithmic range which is greater than that of the other known logarithmic elements. The germanium crystal has a logarithmic range of approximately forty-five decibels and the invention provides a circuit by which the logarithmic range is substantially extended such as to seventy-five decibels. If desired the circuit may be such as or may be adjusted to deviate somewhat from the logarithmic characteristic to compensate for the circuit or device connected with the output terminals of the logarithmic circuit.

It is an object of the invention to construct a logarithmic circuit including an element having a logarithmic characteristic in which the range of the logarithmic characteristic is extended.

Another object of the invention is to construct a logarithmic circuit with a logarithmic range which is substantially extended by an out of phase voltage being applied to the circuit, such as across an ohmic resistor, properly related to the inherent ohmic resistance of the logarithmic element.

Another object of the invention is to construct a simple logarithmic circuit with an extended logarithmic range including the cathode bias resistor of a vocuum tube as means for introducing an out of phase voltage into the circuit.

A still further object is to construct a logarithmic circuit which may extend the logarithmic range thereof and/or insert a desired variation from the logarithmic characteristic in the range above the normal range of the logarithmic characteristic and which may extend into the normal range if desired.

Other objects of the invention will be more apparent from the following description when taken in connection with the accompanying drawings illustrating two embodiments of the invention in which:

Figure 1 shows a diagrammatic logarithmic circuit utilizing a transformer to apply an out of phase voltage to the circuit;

Figure 2 shows a diagrammatic logarithmic circuit utilizing a cathode bias resistor of an electron tube to introduce an out-of-phase voltage into the circuit; and

Figure 3 shows two rectifier units having a logarithmic characteristic connected in parallel to form a logarithmic element.

Many crystals and artificial ceramic materials have a logarithmic characteristic in that uniform or linear variations in the voltage input will result in logarithmic variations in voltage output. A similar circuit may be used

for voltage-current logarithmic conversions with an extended range. Such elements are also known as varistors. With the circuit herein, the logarithmic range of a germanium crystal known as the IN 34 has been nearly doubled from forty-five decibels to seventy-five decibels by an extension of the range on the high voltage side thereof.

The circuit includes a logarithmic element **10** which is diagrammatically shown as a resistance or impedance **11** having a pure or unmodified logarithmic characteristic and connected in series therewith an inherent resistance **12** of fixed ohmic value. Logarithmic elements have inherently this dual logarithmic and ohmic characteristic. One or more logarithmic elements may be connected in series or parallel depending upon the voltage or current output or input desired.

The circuit includes a first resistor **14** having a value of resistance as will be discussed more fully hereinafter. For the IN 34 germanium element the resistance may be roughly of ten thousand ohms and a resistance of one hundred thousand ohms has been used satisfactorily for a single and two logarithmic elements. Means is connected in series with the logarithmic element and the input to insert an out of phase voltage into the output circuit portion corresponding in value or related in value with the voltage response of the inherent ohmic resistance characteristic of the logarithmic element. This preferably is accomplished by a second resistor **15** connected in series with the logarithmic element **10** and has a value of ohmic resistance related to that of the internal ohmic resistance of the logarithmic element as will appear hereinafter. Preferably to the second resistor is a potentiometer, so that it may roughly approximate the ohmic value of the internal ohmic resistance of the logarithmic element and may be adjusted when connected to insert into the circuit at least a portion thereof which is of a value of ohmic resistance properly related to that inherently in the logarithmic element. The potentiometer for the second resistor is preferred because the fixed ohmic resistance inherent in a logarithmic element is different in each logarithmic element and the variable resistor enables adjustment to be made for whatever value of ohmic resistance occurs and also to enable the output voltage to vary from the logarithmic characteristic either above or below as may be desired from a consideration of the load connected with the output terminals.

An out of phase voltage is applied across the second resistor or potentiometer from any suitable source that shown in Figure 1 being from a secondary winding **16** of a transformer whose primary winding **17** is connected across the circuit and preferably across the input terminals **19** of the circuit, a turns ratio being approximately determined by the proportion E secondary is to E primary as the inherent resistance is to the sum of the inherent resistance and that of the first resistor. A ratio of about one thousand to one supplies the necessary out of phase voltage. A different and higher turns ratio will be used if the transformer is connected across circuit elements providing a lower primary voltage. The secondary winding of the transformer may be connected in series with the logarithmic element in place of the potentiometer if the desired value of voltage can be ascertained or if the number of turns can be varied by taps to adjust the same; however, the potentiometer is the simpler and more practical arrangement.

The first resistor **14**, the logarithmic element **10** and the second resistor or potentiometer **15** are connected together in series and the input terminals **19** are across this series circuit. The series arrangement preferred and particularly illustrated, is with the first resistor connected to the high voltage side of the logarithmic element and the second resistor or potentiometer connected with the other or low voltage side of the logarithmic element.

The second resistor may be connected between the first resistor and the logarithmic element but it is essential that the second resistor be connected with the logarithmic element in order that the output terminals **20** be connected across the logarithmic element and the means for inserting an out of phase voltage which is shown as the second resistor or potentiometer.

In the circuit of Figure 2, the second resistor or potentiometer **15** is a part of the cathode resistor **23** of a vacuum tube **24**, shown as a triode. This second resistor has an approximate ohmic value properly related to the logarithmic and tube circuit as will appear and is adjustable to an ohmic value determined practically by testing the logarithmic characteristic of the output. A by-pass condenser **22** is many times used with a cathode resistor and if so used, it must be connected so as not to by-pass any part of the second resistor or potentiometer.

The vacuum tube **24** includes a grid **25** having an input terminal **19***a* connected therewith and the other input terminal **19***b* which conveniently is at the lower or low potential end of the second resistor. The vacuum tube includes a plate or anode **26** having a load resistor **27** connected therewith adapted to be connected with a source of plate potential. The first ohmic resistor **14** is connected with the plate at an input terminal **19** and through a blocking condenser **28**. The first resistor, the logarithmic element, and the second resistor are connected in series as described hereinbefore. For a circuit including a vacuum tube one of the input terminals **19***a* is the connection with the grid and the other may be at any point **19***a* with the cathode resistor. Output terminals **20** are provided across the logarithmic element **10** and the second resistor **15**.

The voltage variations across the cathode resistor, and hence the second resistor **15**, is in out of phase relation with the plate voltage of the tube and therefore applies an out of phase voltage in series with the logarithmic element in the same manner as an out of phase voltage is applied across the second resistor or potentiometer utilizing a transformer of the circuit of Figure 1. The vacuum tube comprises means connected across or to the input terminals of the circuit and controlled by the input and inserting an out of phase voltage in series with the logarithmic element. The value of the second resistor **15** can be approximately determined by the ratio of the product of the load resistance **27** (*a*) and the inherent ohmic resistance (*b*) of the logarithmic element divided by the resistance (*c*) of the first resistor **14**, that is, $(a)\times(b)$ divided by (*c*). In other words the second resistor will approximately differ from the inherent ohmic resistance of the logarithmic element in the same ratio that the vacuum tube load resistance differs from the resistance of the first resistor.

The means for inserting an out of phase voltage in series with the logarithmic element in both circuits inserts a voltage corresponding with, or equal in magnitude to the voltage within the circuit occasioned by the inherent fixed ohmic resistance of the logarithmic element. In all of the circuits illustrated the second resistance or the inserted out of phase voltage may be adjusted to vary the output voltage somewhat from a true logarithmic response either above or below the same if such variation should be desirable because of the circuit or device connected with the output terminals **20**. The term logarithmic range or extended logarithmic range as used herein means a true logarithmic response or such desired deviation therefrom and from the normal response of a logarithmic element alone. In the circuits described the out of phase voltage is derived from means connected across the input terminals of the logarithmic circuit, the means in Figure 1 being a primary winding of a transformer and in Figure 2, a vacuum tube which may serve a double function namely to supply an out of phase voltage for the logarithmic circuit and an input voltage amplifier.

If the logarithmic element used is one of the germanium rectifiers, such as the IN 34, the logarithmic element **10** may include at least two such rectifiers **30** connected in parallel with each other and connected in reverse relation as shown in Figure 3, in order that the logarithmic operation may occur on both halves of the A. C. input wave, if A. C. input is used.

The first resistor may have a minimum resistive value roughly determined as five times the resistance of the logarithmic element at the lowest value of the current through the element. For example when extending the range to seventy-five decibels the resistance of the IN 34 logarithmic element is about two thousand ohms which means the first resistor may have a minimum resistance of ten thousand ohms. For logarithmic elements having lower resistances the first resistor may have a resistance less than ten thousand ohms, likewise, for a lower operating range for the IN 34 element where the resistance is lower, the first resistor also may be less than ten thousand ohms.

This invention provides an improvement in a circuit with extended logarithmic characteristic. It is understood that various modifications in structure, as well as changes in mode of operation, assembly, and manner of use, may and often do occur to those skilled in the art, especially after benefiting from the teachings of an invention. This disclosure illustrates the preferred means of embodying the invention in useful form.

What is claimed is:

1. A logarithmic circuit having an extended logarithmic range comprising a circuit including input terminals to which the input voltage is applied an element having a logarithmic characteristic and operated at its logarithmic characteristic over a portion of an applied voltage range and having an inherent ohmic resistive characteristic which causes deviation from the logarithmic characteristic at higher applied voltages, a first resistor having a resistance which is substantially constant with change in current and having a resistance value of at least five times the resistance of the logarithmic element at its lowest operating current value, means connected between the input terminals to generate an out-of-phase voltage with respect to the input voltage including means connected in series with the logarithmic element to which the out-of-phase voltage is applied, the cut-of-phase voltage corresponding to the voltage response of the inherent resistive characteristic of the logarithmic element, the first resistor and the logarithmic element and the out-of-phase voltage means being connected between the input terminals in series, and a set of output terminals including therebetween the out-of-phase voltage means and the logarithmic element.

2. A logarithmic circuit having an extended logarithmic range as in claim 1 in which the means to which the out-of-phase voltage is applied is a second resistor having an ohmic value of resistance which applies an out-of-phase voltage at least approximately corresponding to the voltage response of the inherent resistance of the logarithmic element.

3. A logarithmic circuit having an extended logarithmic range comprising a circuit having input terminals to which an input voltage is applied, an element having a logarithmic characteristic and operated at its logarithmic characteristic over a portion of an applied voltage range and having an inherent ohmic resistive characteristic which causes deviation from the logarithmic characteristic at higher applied voltages, a first resistor having a resistatnce which is substantially constant with change in current and having a resistance value of at least five times the resistance of the logarithmic element at its lowest operating current value, means connected in the circuit including therebetween at least the first resistor and generating an out-of-phase voltage with respect to the input voltage and including means connected in series with the logarithmic element to which the out-of-phase voltage is applied corresponding to the voltage response

of the inherent resistive characteristic of the logarithmic element, the first resistor and the logarithmic element and the means to which the out-of-phase voltage is applied being connected between the input terminals in series, and a set of output terminals including therebetween the means to which the out-of-phase voltage is applied and the logarithmic element.

4. A logarithmic circuit having an extended logarithmic range as in claim 3 in which the means to which the out-of-phase voltage is applied is a second resistor having an ohmic value of resistance which applies an out-of-phase voltage to the circuit at least approximately corresponding to the voltage response of the inherent resistance of the logarithmic element.

5. A logarithmic circuit having an extended logarithmic range to which an input voltage is applied comprising a circuit including input terminals to which the input voltage is applied, an element having a logarithmic characteristic and operated at its lorgarithmic characteristic over a portion of an applied voltage range and having an inherent ohmic resistance, which causes deviation from the logarithmic characteristic at higher applied voltages, a first resistor having a resistance which is substantially constant with change in current and having a resistance of at least five times the resistance of the logarithmic element at its lowest operating current value a potentiometer connected with the logarithmic element and having a resistance which applies an out-of-phase voltage to the circuit at least approximately corresponding to the voltage response of the inherent resistance of the logarithmic element, the first resistor and the logarithmic element and the potentiometer being connected between the input terminals in series, a transformer having a primary winding connected across at least a portion of the circuit and a secondary winding connected across the potentiometer and applying an out-of-phase voltage with respect to the input voltages thereacross, the ratio of turns in the primary winding and secondary winding providing an out-of-phase voltage across the potentiometer at least approximating that of the inherent resistance, and output terminals including therebetween at least a portion of the potentiometer and the logarithmic element.

6. A logarithmic circuit having an extended logarithmic range as in claim 5, in which the primary winding of the transformer is connected with the input terminals.

7. A logarithmic circuit having an extended logarithmic range comprising a circuit including input terminals to which an input voltage is applied, an element having a logarithmic characteristic and operated at its logarithmic characteristic over a portion of an applied voltage range and having an inherent ohmic resistance which causes deviation from the logarithmic characteristic at higher applied voltages, a first ohmic resistor having a resistance which is substantially constant with change in current and connected in series with the logarithmic element and having a resistance of at least five times the resistance of the logarithmic element at its lowest operating current value, a vacuum tube having a plate and grid and cathode, an input terminal connected with the grid, a cathode resistor connected with the cathode and including a second ohmic resistor connected in series with the logarithmic element and the first ohmic resistor and having an ohmic value of resistance which applies an out-of-phase voltage to the circuit at least approximately corresponding to the voltage response of the inherent resistance of the logarithmic element, a load resistor connected with the plate, the tube applying an out-of-phase voltage with respect to the input voltage at the input terminals across the second resistor corresponding in value to the voltage across the equivalent ohmic resistive characteristic of the logarithmic element, the first resistor being connected with the plate, and output terminals including therebetween the second resistor and the logarithmic element.

8. A logarithmic circuit as in claim 7 in which the second resistor is a potentiometer having on ohmic value approximating the product of the plate load resistance and the inherent resistance of the logarithmic value divided by the resistance of the first resistor.

9. A logarithmic circuit having an extended logarithmic range comprising a circuit having input terminals to which an input voltage is applied, an element having a logarithmic characteristic and operated at its logarithmic characteristic over a portion of an applied voltage range and having an inherent ohmic resistive characteristic which causes deviation from the logarithmic characteristic at higher applied voltages, a first resistor having a resistance which is substantially constant with change in current and having a resistance value of at least five times the resistance of the logarithmic element at its lowest operating current value, a transformer having a primary winding and a secondary winding the latter being connected in series with the logarithmic element, the primary winding being connected across at least the first resistor; the first ohmic resistor and the logarithmic element and the secondary winding being connected between the input terminals in series, the primary winding and secondary winding having a turns ratio to provide across the secondary winding an out-of-phase voltage with respect to the input voltage at least approximately that of the inherent ohmic resistance of the logarithmic element, and output terminals including therebetween the secondary winding and logarithmic element.

10. A logarithmic circuit having an extended logarithmic range comprising a circuit having input terminals to which an input voltage is applied, a first resistor having a resistance which is substantially constant with change in current and having a resistance value of at least five times the resistance of the logarithmic element at its lowest operating current value, an element having a logarithmic characteristic and operated at its logarithmic characteristic over a portion of an applied voltage range and having an inherent ohmic resistive characteristic which causes deviation from the logarithmic characteristic at higher applied voltages and connected in series with the first resistor, a transformer having a primary winding and a secondary winding the latter being connected in series with the logarithmic element, the primary winding being connected between the input terminals, the first ohmic resistor and the logarithmic element and the secondary winding being connected between the input terminals, the primary winding and secondary winding providing across the secondary winding an out-of-phase voltage with respect to the input voltage and the voltage ratio between windings being approximately the ratio of the inherent ohmic resistance of the logarithmic element to the sum of the first resistor and the inherent ohmic resistance, and output terminals including therebetween the secondary winding of the transformer and the logarithmic element.

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