Oct. 30, 1956 M. C. CREUSERE 2,769,137

SINGLE BIAS VOLTAGE CURVE SHAPING NETWORK

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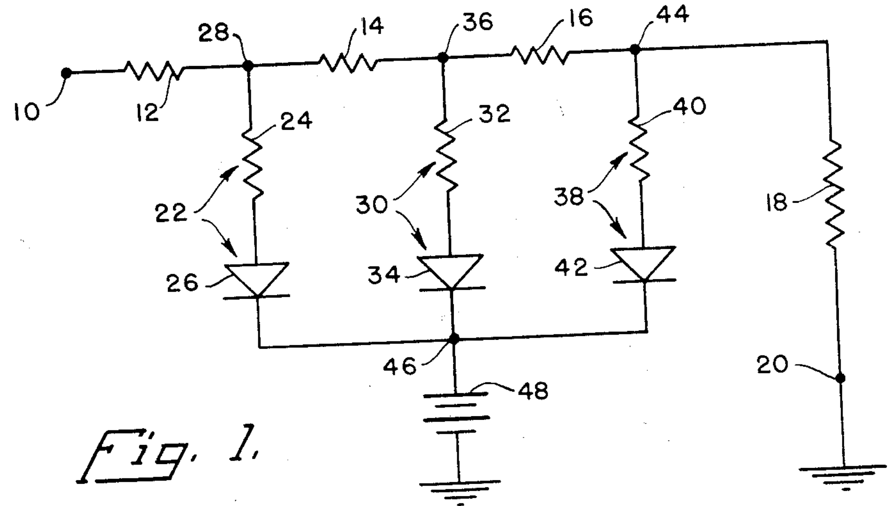

Fig. 1.

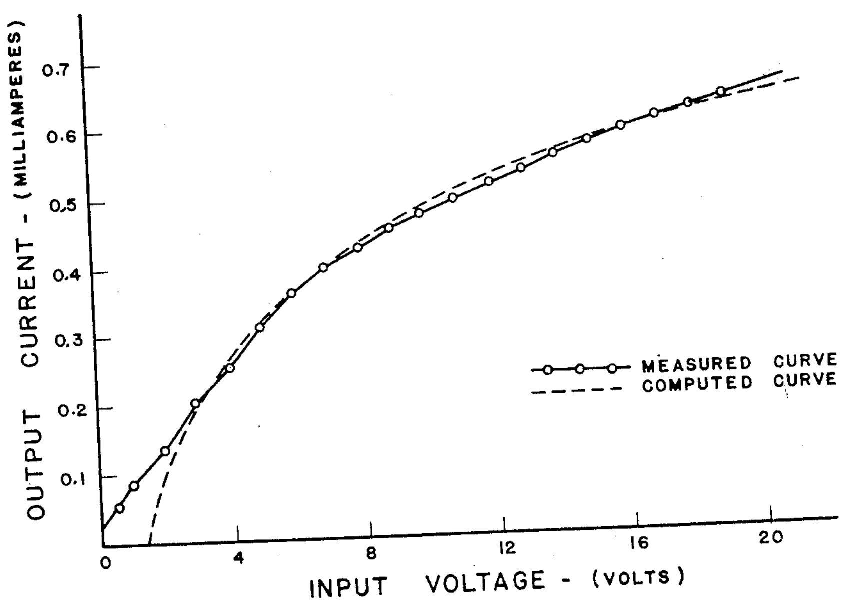

Fig. 2.

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SINGLE BIAS VOLTAGE CURVE SHAPING NETWORK

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The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

This invention relates to curve shaping networks and in particular to a single bias voltage curve shaping network which produces an electrical current which is a predetermined nonlinear function of the input voltage.

Curve shaping networks are particularly useful in D. C. computing circuits of analogue computers for producing a D. C. current which is a predetermined function of the input voltage, or current.

Previously known curve shaping networks require the use of a plurality of different valued bias voltages, which are generally obtained by means of a bleeder string of resistors. The disadvantages in using a bleeder string of resistors to obtain the desired values of the bias voltages lie in the power requirements necessary to provide the necessary current flow through the string and in the problem of dissipating the heat developed by the bleeder string. Heat dissipation is a serious problem particularly in electrical equipment designed for use in aircraft.

It is, therefore, an object of this invention to provide a curve matching diode network that requires a single bias voltage.

It is a further object of this invention to provide a curve matching network which requires a single bias voltage and which produces a D. C. current which is substantially a predetermined nonlinear function of the input voltage.

Other objects and many of the attendant advantages of this invention will be readily appreciated as the same become better understood by reference to the following detailed description when considered in connection with the accompanying drawing wherein:

Fig. 1 is a wiring diagram of the invention;

Fig. 2 is a graph of the output current of the curve shaping network as a function of the input voltage.

In Fig. 1, input terminal **10** of the curve shaping network is adapted to have applied to it a positive D. C. input voltage, E_{in}. E_{in} is applied across a string of resistors **12, 14, 16, 18** which are connected in series. Terminal **20** of the string is connected to ground. Shaping branch **22** consists of resistor **24** and diode **26** connected in series, and has one terminal of the branch connected to terminal **28** between resistors **12, 14**. Shaping branch **30** consists of resistor **32** and diode **34** connected in series and has one terminal of the branch connected to terminal **36** which is located between resistors **14** and **16**. Shaping branch **38** consists of resistor **40** and diode **42** connected in series, and has one terminal of the branch connected to terminal **44** which is between resistors **16** and **18**. The other terminal of each of the shaping branches **22, 30, 38** is connected to a common terminal **46**. A single source of bias potential **48**, such as a battery, is also connected to terminal **46** in such a manner that the potential of terminal **46** is above ground potential. Diodes **26, 34, 42** are connected to permit current to flow from terminals **28, 36** and **40**, respectively, to terminal **46**. Diodes **26, 34, 42** may be vacuum diodes or crystal diodes, and among crystal diodes there is a choice between point contact germanium diodes, junction germanium diodes, junction silicon diodes, etc.

The current flow i_{out}, through resistor **18** can be made a predetermined function of the input voltage, E_{in}, by the proper choice of the values of resistance of the resistors in the network and by the value of bias voltage E_b obtained from source **48**.

Referring to Fig. 2, the dotted curve is a graph of Eq. 1.

$$i_{out}=2.2374 \log_e 0.747 E_{in}$$

computed from the above equation. The solid line is the graph of i_{out} vs. E_{in} as obtained from the network of Fig. 1.

Assuming that diodes **26, 34, 42** have perfect characteristics; i. e., infinite back resistance and zero forward resistance, the current flow, i_{out} through resistor **18** is zero when input voltage E_{in} is zero. As E_{in} increases the current flow in resistor **18** is determined by the sum of the resistances of resistors **12, 14, 16** and **18**. Initially the curve of i_{out} vs. E_{in} is a straight line having a slope determined by the resistance of the sum of resistors **12, 14, 16** and **18**. This is true until the value of E_{in} reaches a magnitude at which the potential of terminal **28** equals E_b at which time diode **26** begins conducting a certain quantity of current around resistor **18**, and causes i_{out}, to increase more slowly as E_{in} increases. The graph of i_{out} vs. E_{in} for E_{in} greater than that necessary to cause the potential at terminal **28** to exceed E_b is a straight line segment having a different slope from the initial straight line. The value of E_{in} at which diode **26** commences conducting is a break point of the curve. A second break point occurs when E_{in} has obtained a magnitude which will raise the potential of terminal **36** to a point where it equals E_b, and a third break point occurs when E_{in} has reached a still greater magnitude at which terminal **44** equals E_b. As each break point is reached the subsequent straight line segment of the curve has a different, and in this example, a lesser slope than the preceding segment.

Since the derived values of i_{out} and E_{in} at the break points are known, and the slopes of the line segments forming the curve are also known, as well as the potentials at the nodes **28, 36, 44**, when the shaping branches connected to the respetcive terminals begin to conduct, it is possible by straight forward electrical circuit theory to determine the values of the resistors in the network. As the number of line segments, or the number of shaping branches, is increased the accuracy with which a given curve can be matched is improved.

In the above discussion it was assumed that diodes **26, 34, 42** had an infinite back resistance and a zero forward resistance, and on that basis the curve of i_{out} vs. E_{in} for the network would consist of a series of connected straight line segments. A different curve but still one which consists of a series of straight line segments will result if both the forward and back resistance characteristics of the diodes are considered to be finite values greater than zero. However, since the resistance characteristics of the diodes are actually nonlinear in both the forward and back direction, the i_{out} vs. E_{in} curve will consist of segments which are curved to an extent dependent on the relative magnitudes of the forward and back resistances of the diodes as compared to the network resistances. The effect of diode nonlinearity is to round off the corners of the segments of the curve and actually aids in obtaining a curve that is closer to the desired curve. In synthesizing the values of the components of the circuit the values of the forward and back impedance of the diodes must be considered in order to obtain accurate results.

The solid curve of Fig. 2 is a graph of the output current i_{out} as a function of the input voltage E_{in} for the circuit of Fig. 1 in which the components of the circuit are as follows:

Resistor **12**, 6K ohms
Resistor **14**, 4.5K ohms
Resistor **16**, 1.5K ohms
Resistor **18**, 6K ohms
Resistor **24**, 5.5K ohms
Resistor **32**, 5.0K ohms
Resistor **40**, 3.5K ohms
Diodes **26**, **34**, **42**, G. E. 4JA1A1 junction diodes
E_{in}, 0 to 18 volts
E_b, 3 volts

The maximum error between the theoretical values and the actual values as determined from the circuit has a maximum error of 5% and an average error of approximately 1% over an input range of E_{in} of from 3.5 to 17.5 volts.

Obviously many modifications and variations of the present invention are possible in the light of the above teachings. It is, therefore, to be understood that within the scope of the appended claims the invention may be practiced otherwise than as specifically described.

What is claimed is:

1. A curve matching network comprising a plurality of resistors connected in series to form a string, said string adapted to have applied thereacross a D. C. input voltage, a plurality of shaping branches connected in the network, each branch having two terminals, each branch being comprised of a precision resistor of calculated value and current rectifying means connected in series, one terminal of each branch connected to but a single terminal between resistors of said string, the other terminal of each branch being connected to a common terminal, a source of D. C. bias potential directly connected to said common terminal, said current rectifying means in each branch connected so as to permit current to flow only in the same direction in each of the branches, the values of said resistors being such that the magnitude of the D. C. current through one of the resistors of said string is substantially a predetermined nonlinear function of the input voltage.

2. A curve matching network comprising a plurality

of resistors connected in series to form a string and having two terminals, said string adapted to have a D. C. input voltage applied to one of the terminals of the string, the other terminal adapted to be grounded, shaping branches, the number of shaping branches being one less than the number of resistors in said string, each of said shaping branches having two terminals and comprising a resistor and current rectifying means connected in series, one terminal of each branch being connected to different terminals between pairs of resistors in said string, the other terminal of each branch being connected to a common terminal, a source of substantially constant D. C. bias potential connected between said common terminal and ground, said current rectifying means in each branch connected to permit current to flow toward said common terminal, said sources of D. C. potential connected to keep said common terminal at a potential above ground, the values of the resistors in said network being such that the D. C. current through the resistor of said string nearest to the ground terminal of said string is substantially a predetermined function of the input voltage.

3. A curve matching network comprising a plurality of resistors connected in series to form a string and having two terminals, said string adapted to have a D. C. input voltage applied to one of the terminals, the other terminal adapted to be grounded, shaping branches, the number of shaping branches being one less than the number of resistors in said string, each of said shaping branches having two terminals and comprising a resistor and current rectifying means connected in series, one terminal of each branch being connected to different terminals between pairs of resistors in said string, the other terminal of each branch being connected to a common terminal, a source of substantially constant D. C. bias potential connected between said common terminal and a ground terminal, said current rectifying means in each branch connected so as to permit current to flow only in the same direction in each of the branches, the values of the resistors in said network being such that the D. C. current through the resistors of said string nearest to the ground terminal of said string is substantially a predetermined function of the input voltage.

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