Dec. 17, 1957 H. E. HOLLMANN 2,817,057

RESISTIVE REACTOR

Filed Nov. 19, 1952 2 Sheets-Sheet 1

Fig. 1.

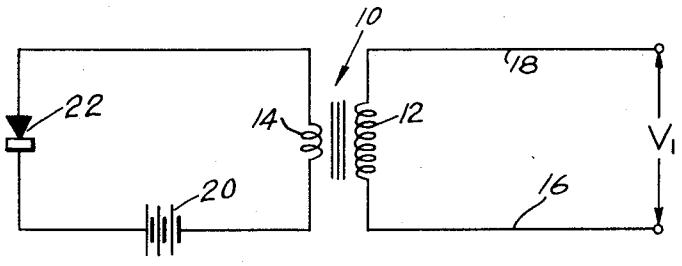


Fig. 2.

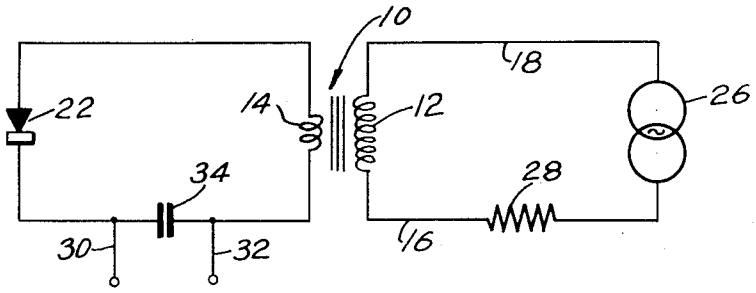
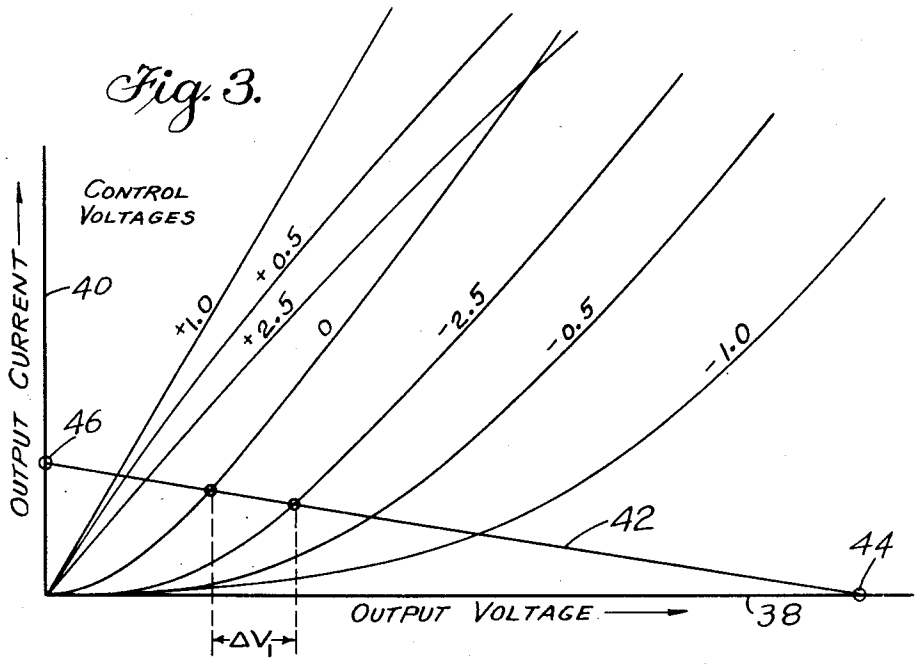


Fig. 3.



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Fig. 4.

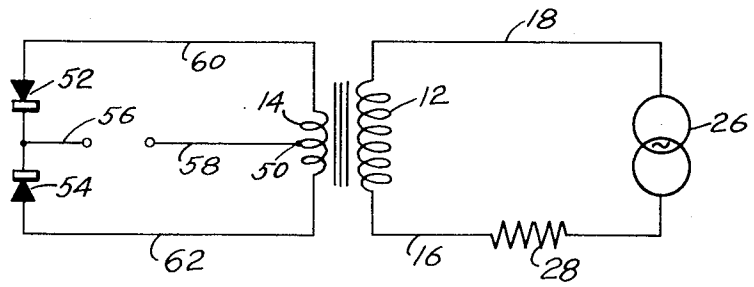


Fig. 5.

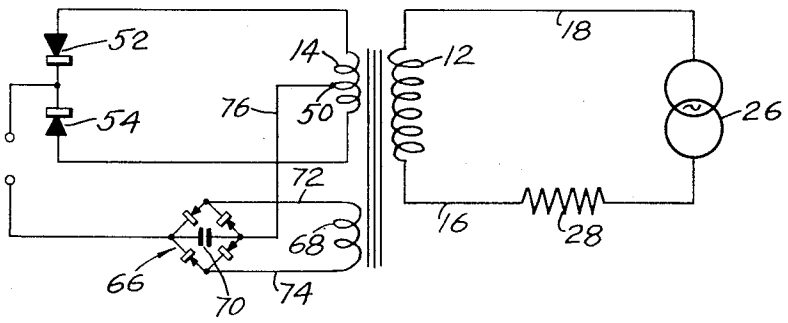
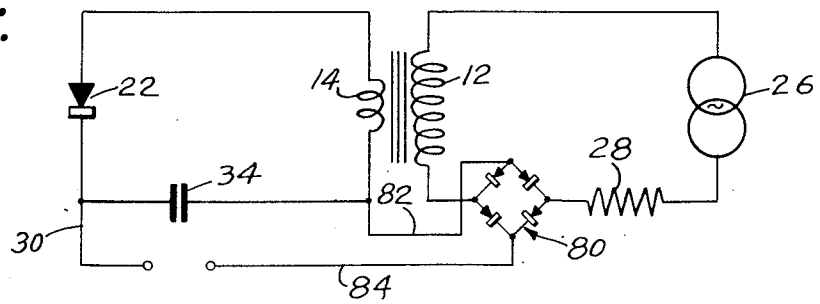


Fig. 6.



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RESISTIVE REACTOR

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Application November 19, 1952, Serial No. 321,529

3 Claims. (Cl. 323—60)

(Granted under Title 35, U. S. Code (1952), sec. 266)

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 an electric reactor and more particularly to a reactor of the type having a non-linear, controllable impedance.

Saturable reactors are useful in many applications but have the disadvantage that hysteresis phenomena severely limit the usable frequency range. In the instant invention, the secondary winding of a transformer is loaded by means of a non-linear resistor such as, for example, a crystal diode, a vacuum diode, a detector, or a rectifier. The non-linear load resistance is transformed into the primary circuit thus making the reactor non-linear. The primary impedance may be controlled by introducing a control voltage into the secondary circuit and, if necessary, superimposing a bias voltage on the control voltage.

The resistive reactor of the instant invention may be utilized in the same manner as a saturable reactor. The nonlinearity and controllability of a conventional saturable reactor is caused by the nonlinearity of its iron core, but the resistive reactor is non-linear and controllable by means of its external load. In other words, the non-linear permeability of the saturable reactor is replaced with the non-linear resistivity of the secondary load. This analogy makes the advantages of the resistive reactor evident since transformers as well as nonlinear resistors, e. g. crystal diodes, varistors, etc., operate up to very high radio frequencies whereas hysteresis effects impose frequency limitation on saturable reactors.

An object of this invention is to provide an improved apparatus wherein a non-linear impedance is utilized for controlling currents over a wide frequency range.

Other objects and many of the attendant advantages of this invention will be readily appreciated as the same becomes better understood by reference to the following description.

Fig. 1 is a schematic diagram of a resistive reactor;

Fig. 2 is a schematic diagram of an amplifier embodying the invention;

Fig. 3 is a presentation in graph form of the output characteristics of the circuit shown in Fig. 2;

Fig. 4 is a modified form of the amplifier shown in Fig. 2;

Fig. 5 is a similar view of a further modified form; and

Fig. 6 is a schematic diagram of another modified form.

The apparatus shown schematically in Fig. 1 illustrates the operating principles of the resistive reactor and comprises a transformer **10** having primary winding **12** and secondary winding **14**. Winding **12** is provided with A. C. input leads **16** and **18**. Bias battery **20** and nonlinear resistor **22** are connected in series across winding **14**. Transformer **10** has a turns ratio of

$$\frac{n_1}{n_2}$$

where n_1 is the number of turns in primary winding **12** and n_2 is the number of turns in secondary **14**. The impedance of the primary, computed from the expression

$$Z_1=\frac{V_1}{I_1}$$

wherein Z_1 is primary impedance, V_1 is the A. C. voltage applied to the primary winding through leads **16** and **18**, and I_1 is the current flowing through the primary, will have a characteristic value for any given bias voltage V_1 provided by battery **20**. The nonlinearity of the primary impedance with different values of bias voltage is explained by the fact that the A. C. resistance R_{eff} of the diode decreases markedly with increasing secondary voltage across the diode. The secondary voltage V_2 is equal to

$$\frac{V_1}{a}$$

where a is the turns ratio

$$\frac{n_1}{n_2}$$

Assuming an ideal transformer with negligibly small stray inductance, the primary impedance Z_1 is equal to a^2R_{eff} and, therefore, reflects R_{eff}. Since the resistance of the diode R_{eff} depends upon the bias voltage as well as the primary voltage V_1, the primary impedance Z_1 shifts to lower values for increases in primary voltage and vice versa.

A resistive reactance amplifier is shown schematically in Fig. 2 wherein elements common to Figs. 1 and 2 have been given like reference numbers. An alternating current source **26** and a load resistor **28** are connected in series across leads **16** and **18**. A variable control voltage is introduced into the secondary circuit through leads **30** and **32** connected across bypass capacitor **34** which is in series with non-linear resistor **22**. The purpose of the bypass capacitor is to permit the application of the control voltage across resistor **22** without breaking the secondary circuit with respect to voltages induced therein through transformer action. The change in resistance as the control voltage varies is reflected into the primary circuit where the increase or decrease in effective resistance in turn determines primary circuit currents. The changes in the primary circuit appear as voltage variations across load resistor **28**. The voltage across the resistor is proportional to the transformer turns ratio so that high amplifications may be realized. However, this proportionality holds only for ideal transformers; actual transformers become less ideal as the turns ratio increases. Voltage amplifications up to 15 are readily obtainable through the use of conventional audio transformers with a germanium or silicon diode as the non-linear resistance component. The voltage amplification is less than one if a transformer having a turns ratio of one or less is employed.

A family of output curves resulting from tests on the circuit of Fig. 2 is shown in Fig. 3. The output voltage across load resistor **28** is plotted along the abscissa **38** and the current through the load resistor is plotted along the ordinate **40** for various values of control voltage. The curves correspond to the plate characteristics of an electronic tube except that the output currents and voltages are A. C. instead of D. C. A load line **42** may be drawn and the voltage amplification of the apparatus

$$\frac{\Delta V_1}{\Delta V_c}$$

where ΔV_c is the change in control voltage, determined for any operating point just as in the case of electronic

amplifiers. The load line terminates at point 44, which is determined by the voltage of the supply source, and at point 46 which is determined by the resistance in the circuit.

Fig. 4 shows a balanced resistive reactor amplifier having the secondary circuit in the form of an A. C. bridge. Secondary winding 14 is provided with a centertap at point 50 to permit the introduction of the control voltage into a balanced configuration. Non-linear resistors 52 and 54, shown as crystal diodes, are connected in an opposing sense to lead 56 which, with lead 58, serves as the input for the control voltage. The other sides of non-linear resistors 52 and 54 are connected through leads 60 and 62 respectively to winding 14. The control voltage is impressed across the diagonal branch of the bridge so that the input circuit is free from the voltage supplied by source 26. The balanced arrangement is analogous to a push-pull magnetic amplifier of the type including a three-legged iron core structure.

Since the above described resistive reactor amplifiers exhibit a power gain as well as a voltage amplification, the circuits may be improved for certain applications by the use of feedback. The apparatus shown in Fig. 5 is the circuit of Fig. 4 with the addition of rectifier bridge 66, feedback winding 68 positioned to inductively pick up a part of the output signal, capacitor 70 adapted to short-circuit the carrier frequency of generator 26, and leads 72 and 74 to connect feedback winding 68 to rectifier bridge 66. Lead 76 serves to connect bridge 66 with the centertapped secondary winding at point 50. The feedback winding will provide either negative or positive feedback depending on the connections of leads 72 and 74 to winding 68.

The apparatus shown in Fig. 6 is a modified form of the amplifier shown in Fig. 2. The feedback voltage is taken directly from the output circuit by means of rectifier bridge 80 and added to the control voltage through leads 82 and 84. The operation of the amplifier is the same as for the amplifiers previously described. The feedback may be changed from positive to negative and vice versa by simply reversing the connection of leads 82 and 84 to bridge 80.

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 resistive reactor signal amplifier comprising a transformer having a primary winding and a centertapped secondary winding, an alternating current source, a load resistor, means effective to connect said current source and load resistor in series across said primary winding, a first crystal diode, a second crystal diode, means effective to connect said diodes in opposed relation in series across said secondary transformer winding, a first signal input lead connected to the juncture of said diodes, a second signal input lead connected to the centertap of said secondary transformer winding, and means for applying an input signal between said first and second input leads to develop an output signal across said load resistor which is of greater amplitude than said input signal.

2. A resistive reactor amplifier comprising a transformer having a primary winding and a centertapped secondary winding, an alternating current source, a load resistor, means effective to connect said current source and load resistor in series across said primary winding, a first crystal diode, a second crystal diode, means effective to connect said diodes in opposed relation in series across said secondary transformer winding, a first input lead connected to the juncture of said diodes, and a second input lead connected to the centertap of said secondary transformer winding, a source of control voltage and a source of bias voltage connected in series, and means for impressing said control voltage and said bias voltage across said first and second input leads.

3. A resistive reactor amplifier comprising a transformer having a primary winding and a centertapped secondary winding, an alternating current source, a load resistor, means effective to connect said current source and load resistor in series across said primary winding, a first crystal diode, a second crystal diode, means effective to connect said diodes in opposed relation in series across said secondary transformer winding, a first input lead connected to the juncture of said diodes, a second input lead connected to the centertap of said secondary transformer winding, a third winding inductively coupled to said primary and secondary transformer windings, a rectifier bridge connected effective to receive the output of said third winding and to deliver a D. C. output voltage, and connecting means effective to add said D. C. output voltage to the control voltage applied to said first and second input leads.

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