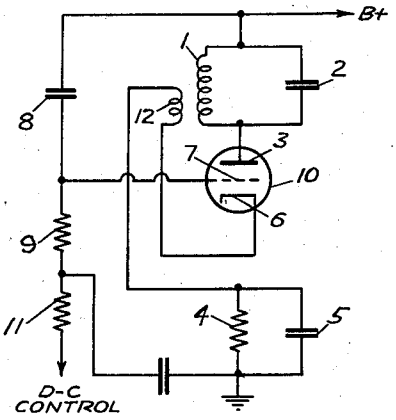
Aug. 9, 1960 J. F. BIGELOW 2,948,869

REACTANCE NETWORKS

Filed Dec. 27, 1955

FIG. 1



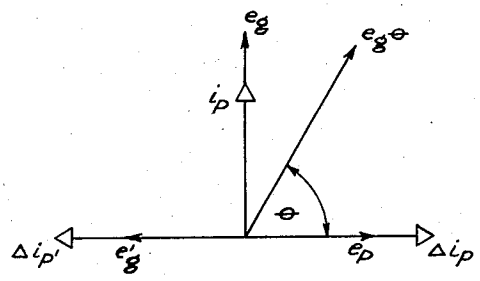


FIG. 3

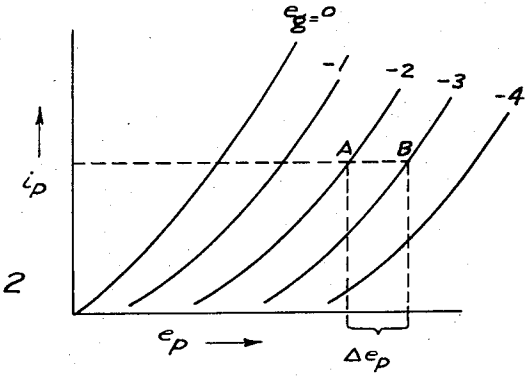


FIG. 2

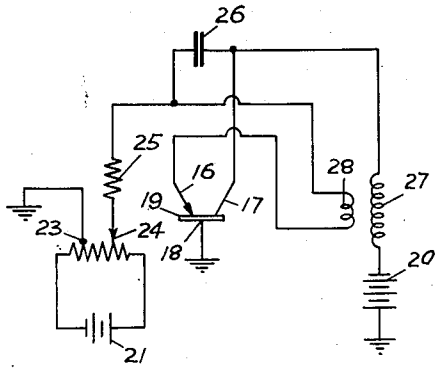


FIG. 4

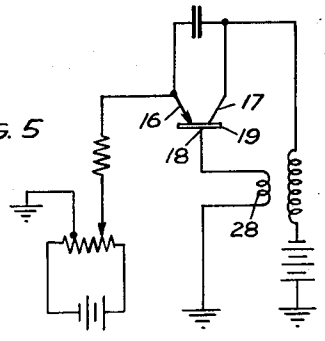


FIG. 5

INVENTOR
JOHN F. BIGELOW
BY Elmer J. Gorn
ATTORNEY

United States Patent Office 2,948,869 Patented Aug. 9, 1960

2,948,869

REACTANCE NETWORKS

John F. Bigelow, Philadelphia, Pa., assignor to Raytheon Company, a corporation of Delaware

Filed Dec. 27, 1955, Ser. No. 555,535

5 Claims. (Cl. 333—80)

This invention relates generally to variable reactance circuits, and more particularly to such circuits wherein triodes or transistors may be more efficiently embodied.

It is well known that a reactance may be simulated by means of a vacuum tube and associated elements. Such a reactance circuit usually requires a tube of the pentode type, and additional circuit elements, such as, a capacitor and a resistor, are utilized as a phase-splitting network. A variable reactance circuit of this type may be used for many purposes, such as, for example, adjusting or varying the resonant frequency of a tuned circuit. In the past, three electrode electrical elements, for example, triodes, have not been adaptable to these purposes because the rather low plate resistance of the triode presents a large real component of impedance along with the imaginary component which results in an unsatisfactory variable loading effect on the tuned circuit.

Accordingly, the present invention is directed toward an improved reactance network wherein a triode, or other three electrode device, may be embodied as a variable reactance element. It has been found that this objective may be attained by providing two feedback paths to the element, one of which functions to increase the apparent internal resistance of the element, thus reducing loading, and the other of which provides a reactive current through the element, thus causing the element to appear as a reactance to the load. This reactive current may then be easily controlled, thereby providing a variable reactance device capable of exercising control over a load circut.

The invention will be better understood as the following description proceeds, taken in conjunction with the accompanying drawing wherein:

Fig. 1 is a schematic diagram of a reactance network in accordance with the invention;

Fig. 2 is a plot of the plate characteristics of a triode useful in explaining the operation of the invention;

Fig. 3 is a vector diagram useful in further illustrating the operation of the invention; and

Figs. 4 and 5 are schematic diagrams of reactance networks in accordance with the invention wherein a transistor may be embodied as the three-electrode element.

Referring now to the drawing, and more particularly to Fig. 1 thereof, there is shown a reactance network comprising a three-electrode element **10**, such as, a triode, for example, having a tuned parallel resonant circuit comprising coil **1** and condenser **2** connected to its plate electrode **3**. Triode **10** is self-biased in a conventional manner by means of resistor **4** and by-pass condenser **5**, connected in circuit with cathode **6**, although it should be understood that other biasing methods may be conveniently substituted. Grid **7** is connected to a junction point between a condenser **8** and a resistor **9**, the other side of condenser **8** being connected to the resonant circuit, while the other end of resistor **9** is connected to a source of D.C. control voltage through resistor **11**. A pick-up coil **12**, allows voltage to be fed back degeneratively from coil **1** into the circuit of cathode **6** in order to effectively change the bias existing at the grid **7**.

As shown by the curves of Fig. 2, an increase in the value of voltage, e_p, existing at the plate of a triode, will ordinarily result in an increase in the plate current i_p, if the value of grid voltage e_g is maintained constant. This change of plate voltage and corresponding change of plate current may be used to represent the internal A.C. resistance of the tube, r_p, which may be further represented as

$$\frac{\Delta e_p}{\Delta i_p}$$

This resistance, r_p, may thus be considered as being shunted across the tuned circuit of Fig. 1, and since its value varies with change of plate current or voltage, it gives rise to an undesirable variable loading effect on the tuned circuit. In accordance with the present invention, this difficulty is overcome by feeding a portion of the voltage developed across the tuned circuit, back to the cathode circuit through pickup coil **12**. Since this voltage is 180° out of phase with the voltage across the tuned circuit, the effect will be to move the operating point from A to B as shown in Fig. 2, thus holding the change in plate current to any desired value. The ratio

$$\frac{\Delta e_p}{\Delta i_p}$$

may thus be controlled to impart a higher value to r_p than heretofore possible, thereby considerably reducing the loading on the tuned circuit.

Since, as shown by the vector diagram of Fig. 3, the change of current in the plate circuit Δi_p due to e_p, is 180° out of phase with the change $\Delta i'_p$ due to the feedback voltage e'_g, the amount of net current actually flowing may be controlled by the value assigned to e'_g due to the cancellation effect caused thereby. In order to make triode **10** appear as a reactance to the tuned circuit, a second feedback path is provided through condenser **8**. When signal voltage, as from an oscillator circuit (not shown), is applied across the tuned circuit, a current will flow through condenser **8** and resistance **9**, which current will lead by an angle depending on the value of condenser **8**. The voltage drop across resistor **9** due to this current will be in phase with the current through condenser **8**. This voltage drop will tend to appear on grid **7** of the tube, and is represented as $e_g\theta$ in Fig. 3. The vectorial combination of e'_g and $e_g\theta$ thus provides the total voltage e_g which is applied to grid **7**. This voltage e_g will then be amplified, and cause a final plate current i_p to flow which current may be made to lead the voltage across the tuned circuit by 90° by proper choice of the size of condenser **8**. Tube **10** will thus function as a capacitive reactance in parallel with the tuned circuit, the value of the reactance being controllable, as by a D.C. control voltage applied to grid **7**, to change the effective reactance of the tuned circuit, and hence the resonant frequency thereof.

As a further feature of the present invention, it has been found that the foregoing principles are equally applicable when a transistor is embodied in the circuit as the three-electrode electrical element. Such a device may include a semiconducting body and at least three electrodes called the base, emitter and collector electrodes which are in contact with the body. The semiconducting body may, for example, consist of a crystal of silicon or germanium while the emitter and collector electrodes may be fine pointed wires in rectifying small-area contact with the body. Such a device is shown embodied in the circuit of Fig. 4. Transistor **15** has an emitter electrode **16**, a collector electrode **17**, and a base

electrode 18 in contact with semiconducting body 19. Base electrode 18 may be grounded as shown. A variable voltage in the forward direction is impressed between emitter 16, and base 18, while a bias voltage in the reverse direction is applied to collector 17 from a suitable source such as a battery 20. The variable voltage applied to emitter 16 may also be provided by a suitable battery 21, across which a resistor 22 is connected. A tap 23 on resistor 22 may be grounded as shown, while a variable tap 24 is connected to emitter 16 through emitter resistor 25. Included in the circuit is a parallel resonant circuit comprising a condenser 26 and an inductor 27, one end of each of which is connected together. The other end of condenser 26 is connected to emitter 16, while the other end of inductor 27 is grounded thereby being effectively connected to base electrode 18. A pick-up coil 28 is provided to feed a portion of the voltage developed across inductor 27 back to emitter 16. Since the collector characteristics of a point contact transistor are very similar to the caracteristics of a triode as shown in Fig. 3, the feedback arrangement serves to increase the internal resistance of the transistor 15 in the manner previously described, thus reducing the objectionable loading effect on the resonant circuit. The magnitude of the reactance thereby placed in circuit with the resonant circuit is easily controlled by variation of emitter bias by means of tap 24.

If desired, an arrangement, such as shown in Fig. 5, may be utilized which is identical to that in Fig. 4 except that pick-up coil 28 feeds into the base 18 rather than emitter 16.

Although there have been described what are considered to be preferred embodiments of the present invention, various adaptations and modifications thereof may be made without departing from the spirit and scope of the invention as defined in the appended claims.

What is claimed is:

1. A variable reactance circuit comprising an electrical translation device having at least an input electrode, an output electrode, and an electrode common to the circuits of said input and output electrodes, an output load in circuit with said output electrode and said common electrode, feedback means directly connected to said common electrode and cooperative with said load for applying a feedback voltage from said output load to said common electrode which is 180° out of phase with and responsive to changes in a first voltage existing across said load whereby the current flowing through said load remains substantially constant with changes in said first voltage, and means interconnected between said load and said input electrode for simultaneously applying a second voltage substantially out of phase with said feedback voltage to said input electrode whereby current flowing through said device is out of phase with the voltage across said device.

2. A variable reactance circuit comprising an electrical translation device having at least an input electrode, an output electrode, and an electrode common to the circuits of said input and output electrodes, a tuned circuit connected to said output electrode and said common electrode, feedback means directly connected to said common electrode and cooperative with said tuned circuit for applying a feedback voltage from said tuned circuit to said common electrode which is 180° out of phase with and responsive to changes in a first voltage existing across said tuned circuit whereby the current flowing through said tuned circuit remains substantially constant with changes in said first voltage, and means interconnected between said tuned circuit and said input electrode for applying a second voltage to said input electrode which is substantially out of phase with said feedback voltage whereby current flowing through said device is out of phase with a voltage across said device.

3. A variable reactance circuit comprising an electron tube having at least an input electrode, an output electrode, and an electrode common to the circuits of said input and output electrodes, an output load in circuit with said output electrode and said common electrode, feedback means directly connected to said common electrode and cooperative with said load for applying a feedback voltage from said output load to said common electrode which is 180° out of phase with and responsive to changes in a first voltage existing across said load whereby the current flowing through said load remains substantially constant with changes in said first voltage, and means interconnected between said load and said input electrode for simultaneously applying a second voltage substantially out of phase with said feedback voltage to said input electrode whereby current flowing through said tube is out of phase with the voltage across said tube.

4. A variable reactance circuit comprising an electrical translation device having at least an input electrode, an output electrode, an electrode common to the circuits of said input and output electrodes, said device further having a family of characteristics such that an increase in voltage applied to one of said electrodes will cause an increase in the current drawn by said electrode, a tuned circuit connected to said output electrode and said common electrode, feedback means directly connected to said common electrode and cooperative with said tuned circuit for applying a feedback voltage from said tuned circuit to said common electrode which is 180° out of phase with and responsive to changes in a first voltage existing across said tuned circuit whereby the current flowing through said tuned circuit remains substantially constant with changes in said first voltage, and means interconnected between said tuned circuit and said input electrode for applying a second voltage to said input electrode substantially out of phase with said feedback voltage whereby current flowing through said device is made to be out of phase with the voltage across said device.

5. A variable reactance circuit according to claim 1 wherein said electrical device is a transistor.

References Cited in the file of this patent

UNITED STATES PATENTS

1,783,557	Bethenod	Dec. 2, 1930
2,351,934	De Kramolin	June 20, 1944
2,457,034	Curtis	Dec. 21, 1948
2,469,194	Delvaux	May 3, 1949
2,870,421	Goodrich	Jan. 20, 1959

FOREIGN PATENTS

905,881	France	Dec. 17, 1945

OTHER REFERENCES

Terman: Radio Engineering, third ed., published in 1947 by McGraw-Hill Book Co., Inc., pages 322–326.