Jan. 23, 1951 S. I. RAMBO 2,539,204

FREQUENCY DISCRIMINATOR

Filed Sept. 12, 1946

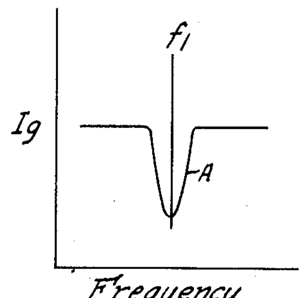

Fig. 1.

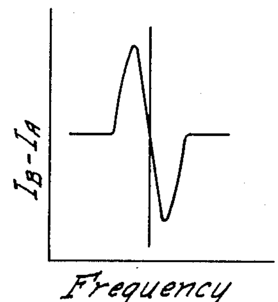

Fig. 3.

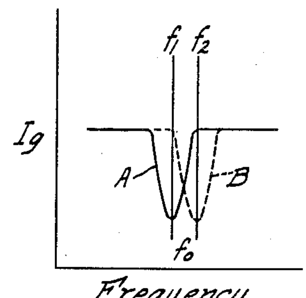

Fig. 2.

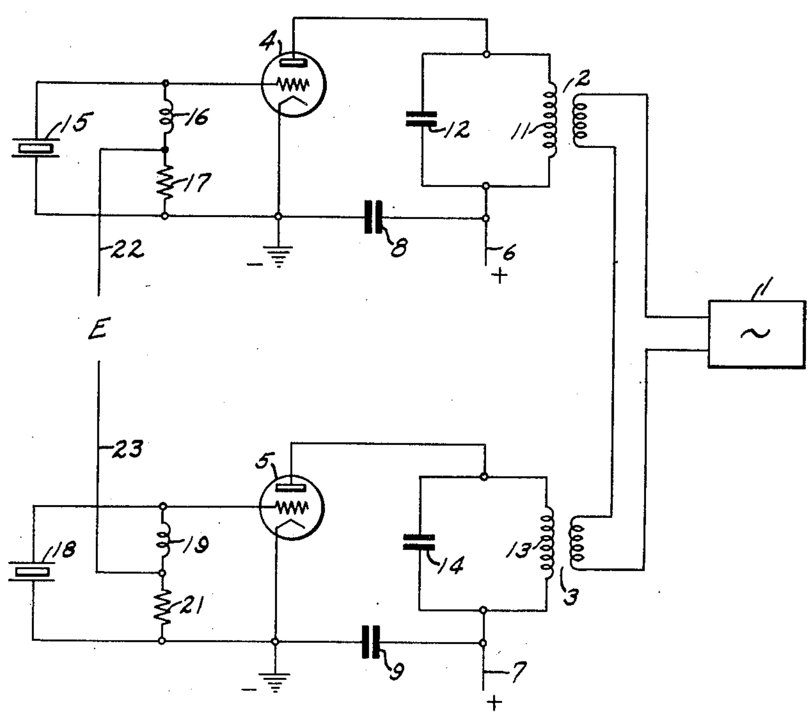

Fig. 4.

WITNESSES:

Leon M. Garman

Wm. C. Groome

INVENTOR

Sheldon I. Rambo.

BY F. W. Lyle.

ATTORNEY

Patented Jan. 23, 1951

2,539,204

UNITED STATES PATENT OFFICE

2,539,204

FREQUENCY DISCRIMINATOR

Sheldon I. Rambo, Baltimore, Md., assignor to Westinghouse Electric Corporation, East Pittsburgh, Pa., a corporation of Pennsylvania

Application September 12, 1946, Serial No. 696,569

3 Claims. (Cl. 250—27)

1

My invention relates to electronic tube circuits and, in particular, relates to such a circuit adapted to produce a continuous current voltage having a magnitude which is substantially proportional, in value and sign, to the amount by which the frequency of one of two alternating voltages differs from that of another alternating voltage. Such devices are frequently known as discriminators, or more precisely frequency discriminators, and several different circuits capable of producing such output voltages are known in the art. These arrangements may be used for varying the tuning or other frequency-determining elements of one circuit to correct any departures of its frequency from that of another circuit. They are likewise used as demodulators in receivers for frequency modulated radio waves.

The discriminators of the prior art are usually rather complicated and use a considerable number of electron tubes. My present invention relies upon a substantially different principle than the prior art discriminators and is much simpler, cheaper and involves a smaller number of tubes and circuit elements.

One object of my invention is, accordingly, to produce a discriminator which employs much simpler circuits than those of the prior art.

Another object of my invention is to provide a discriminator having a power output which can be made relatively large without the employment of cascaded amplifier tubes and the like.

Another object of my invention is to employ the properties of current in the plate or grid circuits of a three-electrode tube for frequency discrimination between two alternating voltages respectively impressed on a pair of electron-collecting electrodes of the tube.

Other objects of my invention will become apparent upon reading the following description, taken in connection with the drawing, in which:

Figure 1 is a graph representing the variation of the grid current in a three-electrode tube having alternating current of one frequency impressed on its grid circuit when the frequency of the voltage impressed on another electrode in the tube varies from equality with that of the voltage impressed on the grid;

Fig. 2 is a graph representing the variations in grid current of two electron tubes when alternating voltages of two different frequencies are impressed on their grid electrodes and an alternating voltage of a third frequency is impressed on the two anodes of said tubes;

Fig. 3 is a graph representing the variation of the difference of the voltages represented by the curves in Fig. 2; and

2

Fig. 4 is a diagrammatic showing of a circuit employing the tube properties illustrated in Figs. 1, 2 and 3 to produce a discriminator voltage proportional in sign and magnitude to the departures of an alternating voltage from a fixed or standing value.

Referring in detail to Figure 1 of the drawing, let us suppose that a voltage of constant frequency (i. e. a frequency which does not vary with time) is impressed on the plate electrode of an ordinary high-vacuum triode, while the frequency of a voltage impressed on the grid electrode is gradually varied. If the difference-frequency between the two alternating voltages just mentioned is plotted as abscissa and the grid current is plotted as ordinate, a curve of the general nature of A will be found to result. Conversely, if the plate current of the tube is measured under the same conditions, it will be found to be represented by a curve like curve A turned upside down. The curve A has a well-defined minimum when the difference-frequency between the two alternating voltages is zero.

Referring now to Fig. 2, the curves A and B respectively represent the grid current or plate current variations of two different tubes, respectively having two different ranges of variable frequencies impressed on their grid electrodes and two different constant frequencies impressed on their plate electrodes. It will be readily apparent to those skilled in the art that, if the difference between curves B and A of Fig. 2 be taken, a current like Fig. 3 will result which is equal to zero for the frequency corresponding to the intersection between the two curves A and B, and which has a straight-line relationship for a considerable range of frequencies on each side of said intersection. Since the currents being plotted are direct currents, it will be evident that the said difference current is a typical discriminator output current varying with a straight-line relationship from positive values for frequencies below that corresponding to said intersection to negative values for frequencies above that intersection.

A circuit well adapted to make use of the general principles just described appears in Fig. 4, in which a source of alternating voltage, which is to be discriminated as to departures from a constant value f_0, appears at 1. Coupling devices 2 and 3 impress this voltage on tube circuits connected to the anodes respectively of two tubes 4 and 5, which may, for example, be triodes of the ordinary high-vacuum type. Anode voltage for the tube 4 is impressed from the positive terminal 6 of a direct-current source having its negative terminal grounded, and anode voltage for the tube 5 is impressed from the positive terminal 7 of a similar direct-current source having its negative terminal grounded. The cathodes of the tubes 4 and 5 are likewise grounded and are, respectively, connected to the positive terminals 6 and 7 by bypass condensers 8 and 9. The anode circuit of the tube 4 comprises an anti-resonant circuit consisting of an inductor 11 shunted by a capacitor 12, and similarly the anode circuit of the tube 5 comprises an anti-resonant circuit consisting of the inductor 13 shunted by a capacitor 14. These circuits may be tuned to two different frequencies which may constitute, respectively, the frequencies f_1 and f_2 of Fig. 2. One convenient form of carrying out the arrangement is to have the inductors 11 and 13 constitute the secondary windings of the transformers 2 and 3. The grid circuit of the tube 4 comprises a piezo-electric crystal 15 shunted by an inductor 16 in series with the resistor 17 and having a natural frequency f_1 equal to that of the anti-resonant circuit 11, 12. It will be recognized by those skilled in the art that the tube 4 is connected with the crystal 15 in an oscillator circuit.

Similarly, the tube 5 has its grid electrode connected to its cathode through a piezo-electric crystal 18 shunted by an inductor 19 in series with the resistor 21. The crystal 18 should have a natural frequency equal to f_2 to which the net 13—14 is tuned. A lead wire 22 is tapped off from a convenient point on the resistor 17, and a lead wire 23 similarly tapped from a point on the resistor 21, such that the voltages thus impressed on leads 22 and 23 are of equal magnitude. The terminals of the leads 22 and 23 constitute the discriminator output circuit and the connections are such that the lead 22 will be of the same potential as the lead 23 when the frequency produced by oscillator 1 corresponds to f_0 the intersection between the curves A and B in Fig. 2. The lead 22 may be made positive to lead 23 when the frequency of the oscillator 1 is below that intersection frequency, and will be negative relative to lead 23 when the frequency of oscillator 1 is above that intersection frequency. It will be noted that the middle branch of the curve in Fig. 3 is the algebraic difference of the portions of curves A and B which lie between the limitations f_1 and f_2 and that while the portions of both curve A and curve B between these limitations are slightly curved throughout their length, their curvatures are so distributed that their algebraic difference is substantially rectilinear over a considerable range on each side of the center frequency f_0. Thus by employing the circuits of tubes 4 and 5 in conjunction with each other, an output voltage E is obtained which is more nearly rectilinear over its working range than could possibly be obtained were either one of these tubes omitted from the system. Over a range corresponding to the rectilinear portion of Fig. 3, the potential difference between leads 22 and 23 is thus proportional to the difference frequence of sources 1 and 4—5.

The output voltage from the leads 22 and 23 may be employed for any of the purposes filled by discriminator circuits. It may, for example, control a reactance tube which changes the tuning of the oscillator 1 to bring it back to its original value whenever it departs from the frequency corresponding to the intersection between curves A and B in Fig. 2. Similarly, the output voltage from the terminals of leads 22 and 23 may control a direct-current motor which

moves a tuning element in the frequency-determining circuit of oscillator 1 in such a sense as to restore its frequency to that corresponding to the intersection between curves A and B in Fig. 2 whenever it departs from that value. To take another instance, the output from the leads 22 and 23 may be employed like other discriminators to detect or demodulate frequency-modulated signals in a radio receiver. Such use of discriminator output voltages is well known in the radio art and requires no detailed description here.

While I have described the tubes 4 and 5 as two separate triodes, it will be evident to those skilled in the art that they may comprise tubes having a larger number of screening and control electrodes; and, more particularly, that instead of employing two separate tubes, the anti-resonant circuits 11 and 12 may, respectively, be connected to two electrodes in a tube having a single cathode, and the piezo-electric crystals 15 and 18 be connected to extra grid electrodes in the same tube. In short, the aforesaid anodes and control electrodes may comprise so-called grids in multi-electrode tubes, such as pentodes, heptodes and the like.

Similarly, while I have described the leads 22, 23 as being tapped off resistors in the control grid circuits of the tubes 4 and 5, it will be recognized by those skilled in the art that such voltages may be tapped off appropriate resistors in the cathode leads or the anode leads of the above-described tubes. By employing tubes having electrodes designed for the currents and the voltages involved, the voltages impressed on the leads 22 and 23 can be made substantially as high as desired. Likewise, any type of crystal oscillator circuit or other oscillator circuit of fixed frequency can be employed in place of the "Pierce" oscillator circuits shown in Fig. 4.

The curves A and B depend for shape on the same factors that determine the "Q" value of their resonant control circuits; hence, the slope of the rectilinear portion of the curve in Fig. 3 may be made as steep as desired by employing resonators of a high equivalent "Q" value. Since piezo-electric crystals normally have a high equivalent "Q" rating, the use of piezo-electric crystals at 15 and 18 results in a desirably-steep discriminator output voltage with vigorous corrective response to any departure of oscillator 1 from the desired frequency value.

I claim as my invention:

1. A frequency discriminator comprising a first pair of cold electrodes each cooperating with an electron-emissive cathode and respectively impressed with one of two voltages of different frequencies, a second pair of electrodes respectively associated with said first pair of electrodes and impressed with an alternating voltage of frequency intermediate between the said frequencies, an electrode from the first pair cooperating with an electrode from the second pair to constitute a cooperating set to produce and regulate current flow from each said cathode to one of said cooperating electrodes, and means for bucking current conducted from one of said cold electrodes against current conducted from another cold electrode in the same pair.

2. A frequency discriminator comprising a first pair of cold electrodes each cooperating with an electron-emissive cathode and connected thereto through a piezo-electric crystal shunted by an inductor in series with a resistor, one said crystal having a different resonant frequency from the

other, a cold electrode associated with each of said pair of electrodes and connected to the co-operating cathode through a direct-current source in series with an anti-resonant circuit tuned to the frequency of said crystal, means for impressing a voltage having a frequency intermediate between those of said piezo-electric crystals on each said anti-resonant circuit and terminal leads connected respectively to said resistors to buck against each other voltage drops thereon.

3. A frequency discriminator comprising a pair of three-electrode tubes having their cathodes connected together, the control electrode of one tube being connected to its cathode through an inductor in series with a resistor and also through a first piezo-electric crystal, the control electrode of the other said tube being connected to its cathode through an inductor in series with a resistor and also through a second piezo-electric crystal having a frequency different from said first piezo-electric crystal, means for connecting the anode of said one tube to its cathode through a direct-current voltage source and an anti-resonant circuit tuned to the same frequency as said first piezo-electric crystal, means for con-

necting the anode of said other tube to its cathode through a direct-current voltage source and a second anti-resonant circuit tuned to the same frequency as said second piezo-electric crystal, means for impressing on both said anti-resonant circuits a voltage having a frequency substantially midway between those of said piezo-electric crystals, and a line having two sides connected respectively to points on the two said resistors.

SHELDON I. RAMBO.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
2,105,096	Peterson	Jan. 11, 1938
2,280,525	Hunt	Apr. 21, 1942
2,361,625	Hansell	Oct. 31, 1944
2,369,954	Downey	Feb. 20, 1945
2,373,616	Sziklai	Apr. 10, 1945
2,379,764	Thomas	July 3, 1945
2,425,981	Bard et al.	Aug. 19, 1947