May 1, 1945. M. G. CROSBY 2,374,734

DISCRIMINATOR CIRCUIT

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Fig. 1.

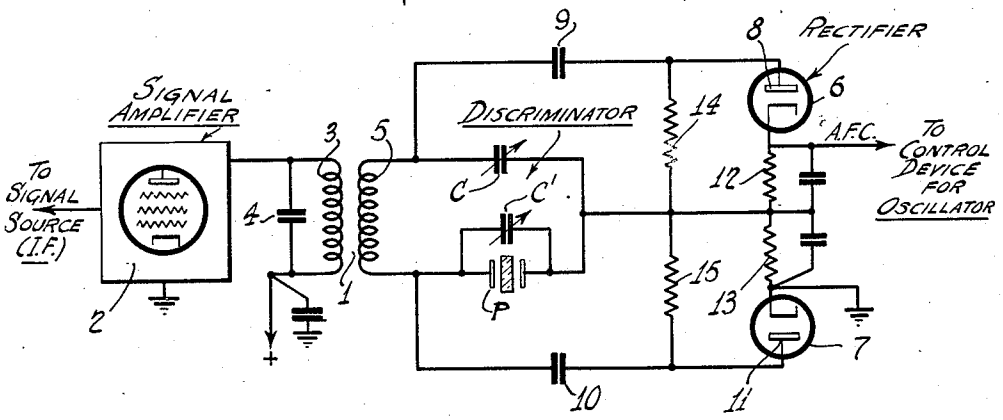
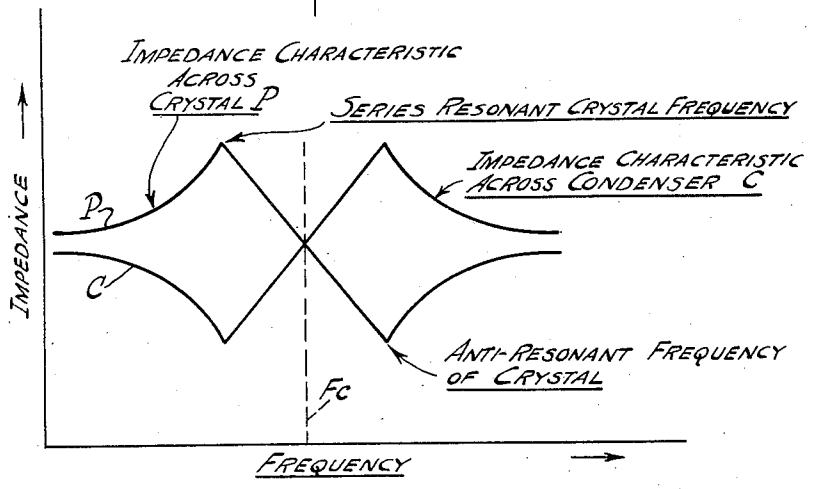


Fig. 2.



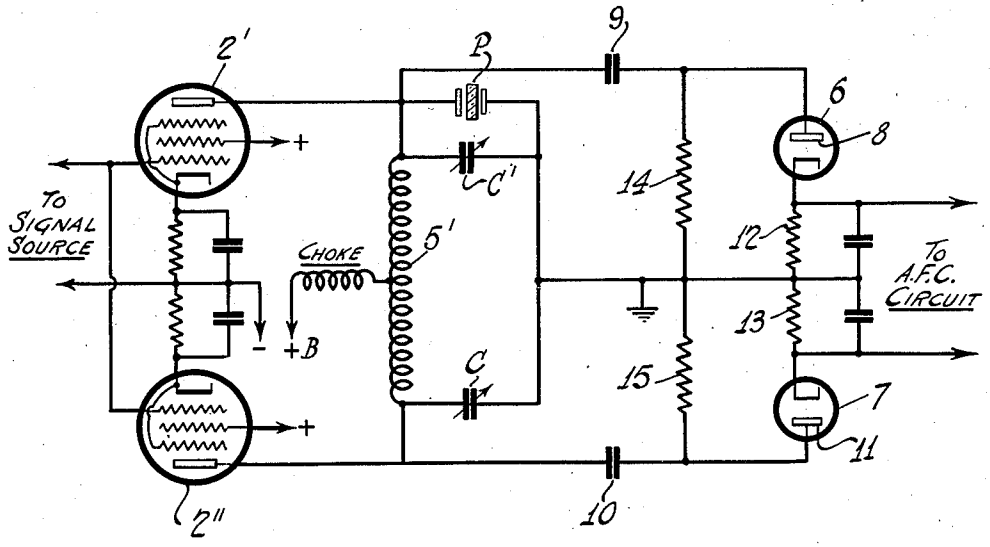
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Fig. 3.



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DISCRIMINATOR CIRCUITS

Murray G. Crosby, Riverhead, N. Y., assignor to Radio Corporation of America, a corporation of Delaware

Application February 5, 1943, Serial No. 474,801

8 Claims. (Cl. 250—40)

My present invention relates to discriminator circuits, and more particularly to novel and improved forms of discriminator circuits particularly adapted for automatic frequency control (hereinafter referred to as "AFC").

One of the main objects of my present invention is to provide a discriminator circuit, adapted to feed its output energy to a differential detector, which functions in the manner of an impedance inversion network.

Another important object of this invention is to provide a circuit capable of translating frequency deviations from a predetermined reference frequency into predetermined impedance changes thereby to provide resultant output energy whose amplitude is a function of the said frequency deviations.

Another object of my invention is to provide a pair of rectifiers in polarity opposition, and the rectifiers having respective input impedances whose respective impedance-frequency characteristics are of complementary form.

Still another object of my present invention is to provide an AFC discriminator-rectifier system of the type wherein opposed rectifiers have separate impedance input circuits of complementary characteristics, and both input circuits having a common middle frequency which is substantially that of the mean frequency of applied high frequency energy.

Yet other objects of my invention are to improve generally the simplicity and efficiency of AFC discriminator-rectifier circuits, and more especially to provide such circuits in an economical and readily-manufacturable manner.

The novel features which I believe to be characteristic of my invention are set forth with particularity in the appended claims; the invention itself, however, as to both its organization and method of operation will best be understood by reference to the following description, taken in connection with the drawings in which I have indicated diagrammatically several circuit organizations whereby my invention may be carried into effect.

In the drawings:

Fig. 1 shows a circuit embodying the invention,

Fig. 2 graphically illustrates the functioning of the discriminator circuit,

Fig. 3 shows a modified circuit employing the invention.

Referring now to the accompanying drawings, wherein like reference numerals in the figures indicate similar elements, the numeral 1 designates the input transformer which feeds high frequency signal energy to the discriminator circuit. The circuits preceding the transformer 1 may be the customary networks of a superheterodyne receiver. Numeral 2 denotes an amplifier of signal energy whose resonant output circuit includes the primary winding 3 of the transformer 1. If the receiver is a superheterodyne, then amplifier 2 may amplify intermediate frequency (I. F.) energy in the kilocycle (kc.) or megacycle (mc.) ranges. Those skilled in the art are fully acquainted with the general manner of providing AFC for a superheterodyne receiver. The AFC voltage output of the opposed rectifiers will be applied to any desired device for controlling the frequency of the local oscillator which feeds its oscillations to the first detector. The amplifier 2 could feed its I. F. output energy to a parallel path to a second detector (not shown), or the audio output could be derived from the opposed rectifiers per se.

The present invention is not limited to use in receivers, since it may be employed in transmitters, or in any oscillatory system, for the control of the frequency of oscillation. In such case the oscillatory energy to be controlled is fed to amplifier 2, and the AFC voltage is employed to regulate the frequency control device of the oscillator. See, for example, my U. S. Patent No. 2,279,659, granted April 14, 1942. These are all utilizations which are well known to those skilled in the art, and need not be described any further herein.

The condenser 4, in shunt across primary winding 3, tunes the primary circuit to the operating I. F. value. Across the secondary winding 5 there are connected condensers C and C' and a piezo-electric crystal P. The crystal P is mounted between the usual metallic electrodes, or crystal holders. The secondary circuit will be tuned so that coil 5 and condenser C resonate at the cross-over frequency F_c when condenser C' is shorted. C' is made equal to C in value. The value of F_c in the case of a superheterodyne receiver will be the operating I. F. value. In the case of a transmitter master oscillator, or any oscillator in general whose frequency is to be regulated, the cross-over frequency will be the predetermined oscillator frequency. At that cross-over frequency F_c the impedances presented to the opposed rectifiers 6 and 7 will be equal.

The rectifiers 6 and 7 may be diodes. The invention is not limited to diodes, as other types of rectifiers may be used. The anode 8 of diode 6 is connected by blocking, or isolation, condenser 9 to the junction of coil 5 and condenser C. The

isolation condenser 10 couples the diode anode 11 to the opposite end of coil 5. The cathodes of diodes 6 and 7 are connected by series resistors 12 and 13. The junction of resistors 12 and 13 is connected to the junction of series return resistors 14 and 15. The junction of resistors 14 and 15 is connected to the junction of condenser C and crystal P. The resistors 12 and 13 are the load resistors of the respective diodes 6 and 7. Each load resistor 12 and 13 is shunted by a respective high frequency current by-pass condenser. The cathode of diode 7 is grounded, while AFC voltage is taken off from the cathode end of resistor 12. The AFC voltage is applied to a control device for an oscillator.

Each rectifier is connected across a respective input impedance element C or P—C'. Considering Fig. 2, the impedance change with frequency variation across the input impedance element of rectifier 6 is depicted by curve C. It will be noted that over the linear portion of characteristic C, between the peaks thereof, the impedance rises with frequency. The impedance-frequency characteristic P across the input element P has a falling course over the linear portion thereof. The series resonant crystal frequency, or peak frequency, is on one side of F_c; the dip, or antiresonant, crystal frequency is on the opposite side of F_c. The impedance-frequency characteristics P and C are complementary. The discrimination will occur by virtue of the fact that complementary impedance is presented to each rectifier.

As is seen from Fig. 2, the impedances presented to rectifiers 6 and 7 are equal at F_c. If the applied oscillatory energy at winding 5 deviates in frequency from the value F_c in one direction, one rectifier will have a greater impedance presented thereto than the other rectifier. Hence, the rectified output of that rectifier will be higher. Should the oscillatory energy shift in frequency to the opposite side of F_c, then the other rectifier will have a greater impedance presented thereto and a correspondingly greater rectified output. The secondary circuit of transformer 1 is in the form of a "seesaw" circuit wherein a low impedance at one end of an artificial line is reflected as a high impedance at the other. A quarter wave section of artificial line has this effect. The general characteristics of impedance inverting networks have been described by W. H. Doherty in Proceedings of Institute of Radio Engineers, September 1936, at page 1172. Considering the crystal circuit from this view, when the impedance of crystal P goes low, the impedance at the other end, which is fed to the opposite diode, is high. Hence, the dip impedance of the crystal is presented to one diode, and the reflected dip impedance, in the form of a peak, is presented to the other diode. The result is a differential discriminator with a peak separation equal to the difference between the peak and dip of the crystal resonance characteristic. The peak spacing depends on crystal equivalent constants and holder capacity.

The condenser C' is included in the network feeding the rectifiers to complete the impedance inversion network. To tune the secondary circuit across winding 5, the first step is to short circuit out crystal P and shunt condenser C', and then tune coil 5 by condenser C to the value F_c. The second step is to remove the short circuit; the capacity of C' must equal that of condenser C. This makes the reactances of coil 5, condenser C and condenser C' all equal.

It will now be seen that as the applied signal currents shift in frequency relative to F_c, the rectifiers will have the input impedances thereof vary in corresponding complementary fashion. This is clearly depicted in Fig. 2. Therefore, the rectifier outputs of the rectifiers will be unequal, except at F_c. Since the rectified voltages across load resistors 12 and 13 are added in polarity opposition, the AFC voltage at the cathode end of resistor 12 will have a magnitude and polarity dependent on the extent and sense of deviation of the applied signal current frequency relative to F_c. The manner of utilizing this AFC voltage for oscillator frequency correction is well known.

In Fig. 3 there is shown a modification of the circuit in Fig. 1, wherein the impedance inversion network functions as the output load of coupling amplifier tubes 2' and 2''. The latter tubes have the signal grids thereof in parallel connection to the signal source. The plates of tubes 2' and 2'' are connected in push-pull relation to coil 5'. The coil 5' in this modification plays the same part as winding 5 of Fig. 1. Rectifier 6 is coupled across the combination of crystal P and condenser C'. The rectifier 7 is coupled across condenser C. The junction of resistors 14 and 15 is grounded. The AFC voltage, taken off from the cathode ends of load resistors 12 and 13, may be fed to any reactance tube device of the push-pull type. The adjustment of the inversion network will be the same as described for Fig. 1. The condensers C and C' could be a split-stator condenser. Further, if desired, the crystal P may be shunted by a tuned circuit to provide an adjustment for adjusting the frequency spacing between the peak and dip of the characteristic of the crystal. What is provided in Fig. 3, therefore, is a network 5'—C—C' forming a circuit, somewhat like a quarter wave section of line, such that when a low impedance is placed across one end a high impedance appears across the other. Thus with the crystal P across one end, its impedance dip will be transformed to an impedance peak at the other end. This will make the crystal filter characteristic of the output from one of the coupling tubes 2' the exact reflection of the characteristic of the output from the other coupling tube 2''.

While I have indicated and described two systems for carrying my invention into effect, it will be apparent to one skilled in the art that my invention is by no means limited to the particular circuits shown and described, but that many modifications may be made without departing from the scope of my invention as set forth in the appended claims.

What I claim is:

1. In a discriminator-rectifier network adapted for automatic frequency control, a pair of opposed rectifiers having a common output circuit, a common input network which has a resonant frequency equal to the mean frequency of applied signal energy, a pair of impedance elements coupled to said input network, one of said impedance elements being a condenser, means for connecting said condenser between the electrodes of one of the rectifiers, the second impedance element including a piezo-electric crystal, and means for connecting the crystal between the electrodes of the second rectifier.

2. In a discriminator-rectifier network adapted for automatic frequency control, a pair of opposed rectifiers having a common output circuit, a common input network which has a resonant frequency equal to the mean frequency of applied signal energy, a pair of impedance elements coupled to said common network, one of said im-

pedance elements having a capacity reactance, means for connecting said one impedance element between the electrodes of one of the rectifiers, the second impedance element being a piezo-electric crystal in shunt with a capacitative reactance, means for connecting the crystal and shunt reactance between the electrodes of the second rectifier, and the impedance elements being so chosen that impedance-frequency characteristics are provided at the input electrodes of said rectifiers which are complementary.

3. In a frequency discriminator system, a signal input circuit, an inductance coil coupled thereto, a pair of condensers, of equal capacity, connected in series across said coil, a piezo-electric crystal connected across one condenser, said coil and second condenser being resonant to a predetermined reference frequency in the absence of said crystal and one condenser, and the impedance-frequency characteristics across each of said crystal and said second condenser being complementary.

4. In a discriminator-rectifier system, a pair of opposed rectifiers having a common output circuit, an essentially capacitative signal input element connected between the input electrodes of one of said rectifiers, a second signal input element which is frequency discriminatory connected between the input electrodes of the second rectifier, a common signal input circuit coupled to both of said input elements and said input elements being so relatively chosen that they provide an impedance inversion network which has complementary impedance-frequency characteristics at the respective rectifier input electrodes.

5. In a discriminator-rectifier network, a pair of opposed rectifiers having a common output circuit, a common input network which has a resonant frequency equal to the mean frequency of applied signal energy, a pair of impedance elements coupled to said common network, means for connecting one element between the electrodes of one of the rectifiers, the second impedance element being a piezo-electric crystal, and means for connecting the crystal between the electrodes of the second rectifier, said pair of impedance elements being so relatively chosen that they provide an impedance inversion network.

6. In combination, a pair of opposed diode rectifiers having a common resistive output circuit, a common signal input network for said rectifiers which has a resonant frequency equal to the mean frequency of applied signal energy, a source of signal energy comprising a pair of tubes having parallel-connected signal input control elements and output elements connected to said common signal input network in push-pull relation, a pair of impedance elements in said common input network, one of said impedance elements being a condenser, means for connecting said condenser between the electrodes of one of the rectifiers, the second impedance element including a piezo-electric crystal, means for connecting the crystal between the electrodes of the second rectifier.

7. In combination, a signal input circuit, an inductance coil coupled thereto, a pair of condensers connected in series across said coil, a piezo-electric crystal connected across one of said condensers, said coil and the other of said condensers being resonant to a predetermined reference frequency in the absence of said crystal and one condenser, the impedance-frequency characteristics across each of said crystal and said second condenser being complementary, respective rectification devices connected with each of said crystal and second condenser, and means for deriving from the rectification devices the outputs thereof in polarity opposition.

8. In a frequency discriminator network, a signal input circuit which has a resonant frequency equal to a predetermined reference frequency, a pair of impedance elements being coupled to said input circuit, one of the impedance elements including a piezo electric crystal, the second impedance element consisting of a condenser, a pair of output terminals connected across said condenser, a second pair of output terminals connected across said crystal, and said impedance elements being so relatively chosen that complementary impedance-frequency characteristics are provided at the respective pairs of output terminals relative to said reference frequency.

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