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FREQUENCY STABILIZING SYSTEM

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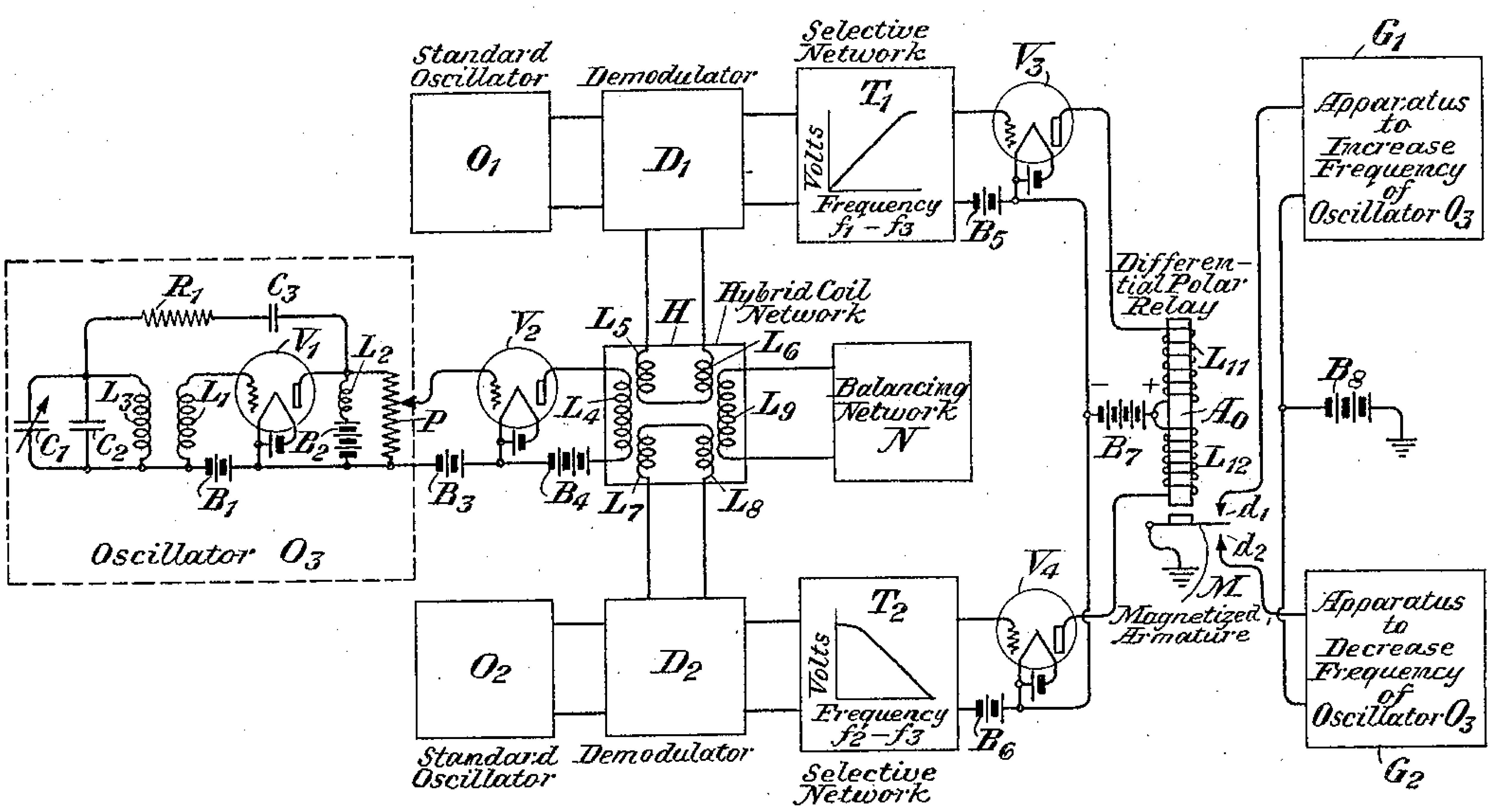

Fig. 1

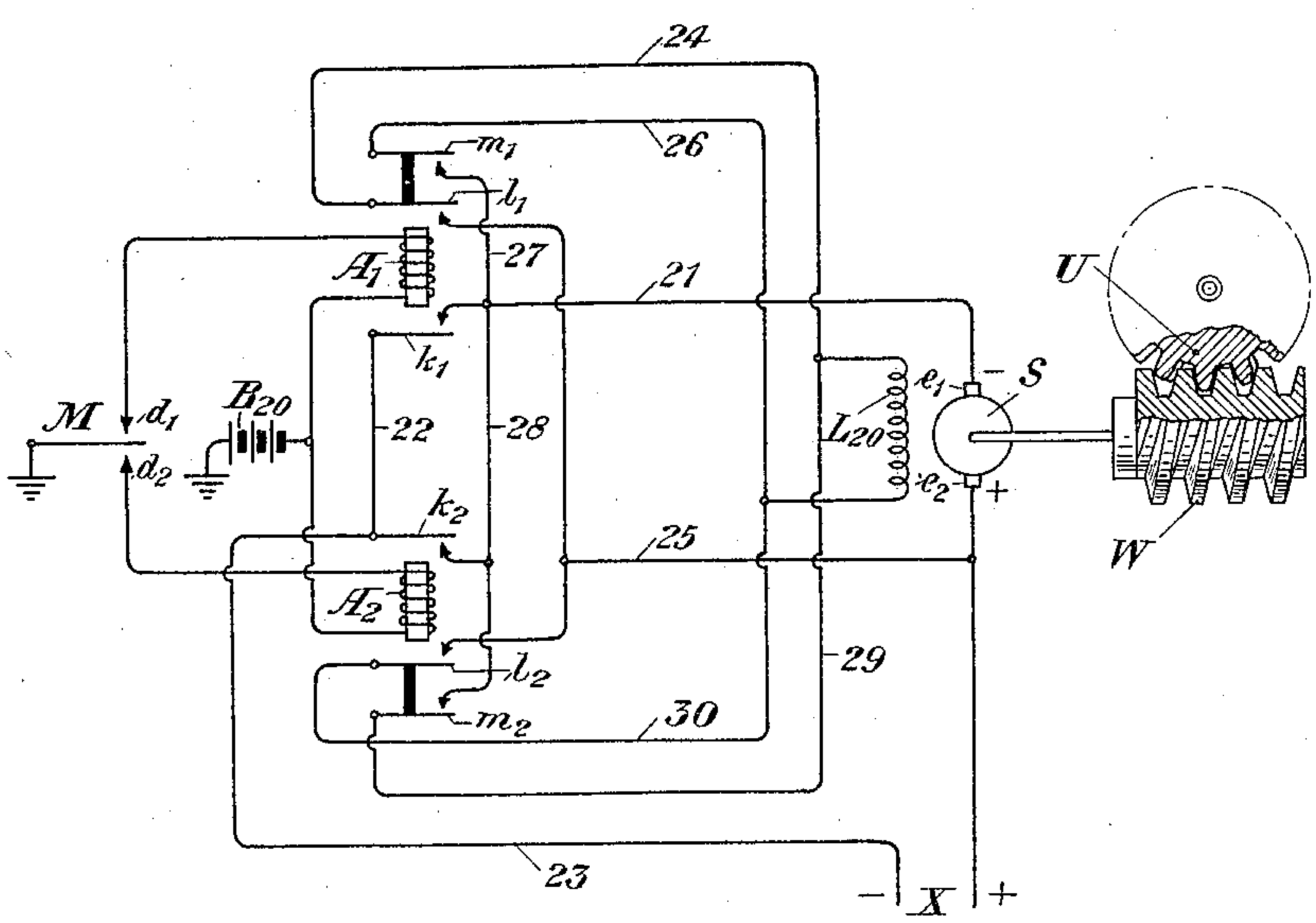

Fig. 2

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UNITED STATES PATENT OFFICE

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FREQUENCY STABILIZING SYSTEM

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This invention relates generally to alternating current generators. More particularly, this invention relates to arrangements for producing alternating current of highly constant frequency.

The production of currents of constant frequency forms a very important phase of fundamental research in the communication field. To this end oscillators have been designed possessing high inherent frequency stability, and their performance has been improved by maintaining as nearly constant as possible the battery supply potentials and the temperature of those elements which may be substantially affected by heat or thermal effects. However, with all the refinement of oscillator technique, there still remain small variations in frequency caused by slight variations in temperature and battery variations, as well as other uncontrollable factors. It is the object of this invention to provide arrangements whereby variations in the frequency of an oscillator, resulting from the factors above mentioned, may be substantially reduced.

This invention will be better understood from the detailed description hereinafter following when read in connection with the accompanying drawing, in which Figure 1 shows an arrangement for controlling the frequency of an oscillator, and Fig. 2 shows apparatus for producing the rotation of a motor in one direction or the other in order to increase or decrease the frequency of the current which may be derived from an associated oscillator.

Referring to Fig. 1 of the drawing, there are shown two standard oscillators designated O_1 and O_2 which are designed to maintain as high stability in their frequency characteristics as is possible. These oscillators may, of course, be of any well known type, preferably of some vacuum tube type, to each of which a piezo-electric device may be connected in order that the frequencies of the currents produced thereby may be maintained constant within very narrow limits.

The reference character O_3 designates an oscillator of nominal frequency stability the frequency of which may be varied in either direction by a change in one or more of the elements of its structure. For the purpose of illustration the oscillator O_3 may be of a resistance feed-back type, the frequency of which may be changed over a substantial, though limited range by varying one of its capacitative elements, for example, condenser C_1.

The oscillator O_3 includes a three-element vacuum tube V_1 of any well known type. The grid electrode of this vacuum tube is connected to its filament electrode through a winding L_1 and a battery B_1. The plate electrode of vacuum tube V_1 is connected to the filament electrode through a battery B_2 and a choke coil L_2, the battery B_2 providing the proper operating potential for the plate electrode of the vacuum tube system. All of the resistance of a potentiometer P is interposed between the plate and filament electrodes of the vacuum tube V_1. All of the current derived from the oscillator is impressed across the entire resistance of potentiometer P, and the voltage of this current may be controlled by the adjustment of the associated variable element of the potentiometer.

The oscillator O_3 also includes a parallel tuned circuit consisting of two condensers C_1 and C_2 and the winding L_3, which is inductively coupled to the winding L_1. The lower terminals of both windings L_1 and L_3 are connected to each other. Condenser C_2 may be invariable in its capacitative value, while condenser C_1 may be varied in its capacitative value to any desired extent within reasonable limits by changing the spacing between its component elements. Current is fed from the plate circuit of the vacuum tube V_1 to the parallel tuned circuit through a resistance R_1 and a condenser C_3.

The oscillator O_3 may be one which ordinarily produces current of some definite frequency, this frequency varying, however, somewhat from its assigned value. This frequency may be changed to the assigned value merely by a change in the capacity of condenser C_1. The condenser C_1 may, for example, consist of a stator and a rotor each of which may have one or more metallic plates, the plates of the stator being separated from those of the rotor by a dielectric such, for example, as air. It is the rotor which may be adjusted in its position with respect to the stator to effect any desired change in the frequency of the current produced by the oscillator when that frequency departs from the assigned value. It will be understood that the oscillator O_3 may be of any well known type to which a piezo-electric structure may be connected, the vibratory period of the piezo-electric element of which may be changed by a corresponding change in the surrounding temperature, so that the frequency of the generated current may be controlled merely by an adjustment in the temperature of the surrounding medium.

A vacuum tube of the three-electrode type, designated V_2, is employed to amplify the current derived from oscillator O_3. The grid electrode of tube V_2 is connected to the filament electrode through a battery B_3 and a portion of the resistance of potentiometer P. The plate electrode of the latter tube is connected to the filament electrode through a battery B_4 and an element of inductance to be subsequently described. Vacuum tube V_2 amplifies the current derived from oscillator O_3 in a well known manner.

The current generated by the oscillator O_3 and amplified by the vacuum tube V_2 is transmitted to demodulators D_1 and D_2 through a hybrid coil arrangement H. The hybrid coil arrangement may consist of a plurality of windings inductively related to each other, as shown. The winding L_4 may be connected between the plate electrode of vacuum tube V_2 and the positive terminal of battery B_4. The windings L_5 and L_6 may be connected to demodulator D_1 and in series with each other. The windings L_7 and L_8 may be connected to demodulator D_2 and in series with each other. The winding L_9 may be connected to a balancing network N which may be of any type well known in the art.

Current derived from oscillator O_1 is transmitted directly to demodulator D_1, and this current may have a frequency f_1. Current derived from oscillator O_2 is directly transmitted to demodulator D_2, and this current may have a frequency f_2. The balancing network N connected to the hybrid coil arrangement H is so adjusted that the current supplied by oscillator O_1 to the demodulator D_1 cannot reach demodulator D_2, and conversely, the current supplied to demodulator D_2 by oscillator O_2 cannot reach demodulator D_1.

In accordance with the accepted theory of demodulation, the output of demodulator D_1 will contain, among other components, current of the frequency f_1—f_3. Similarly, there will be found in the output of demodulator D_2 current of the frequency f_2—f_3, among other components. Currents having frequencies different from the values f_1—f_3 and f_2—f_3 may, if desired, be suppressed in any well known manner.

A selective network designated T_1 interconnects the demodulator D_1 with the grid circuit of a vacuum tube V_3 which is employed for the purpose of current rectification. A similar selective network designated T_2 is connected between demodulator D_2 and the grid circuit of a vacuum tube V_4 which is also employed for rectifying impressed current. The selective network T_1 may be one of those shown in an article authorized by Otto J. Zobel in the Bell System Technical Journal for July, 1928, entitled "Distortion correction", for example, the one shown at page 515 of the article. The selective network T_2 may assume the character of another of those shown in the article just mentioned, the one shown at page 525 being suitable for this purpose. If the networks shown in the article just mentioned are used, it will be necessary to interconnect the networks T_1 and T_2 with the grid circuits of the vacuum tubes V_3 and V_4 by means of transformers, in a well known manner.

It is a property of the selective network T_1 that the voltage impressed upon the grid electrode of the vacuum tube V_3 will increase almost lineally as the frequency f_1—f_3 increases. Similarly, the property of the selective network T_2 is such that the voltage impressed upon the grid electrode of the vacuum tube V_4 will decrease almost lineally as the frequency f_2—f_3 increases. By employing batteries B_5 and B_6 of the proper voltages, it will be possible to operate the vacuum tubes V_3 and V_4, respectively, as rectifiers, so that any increase in the effective potentials of the grid electrodes of vacuum tubes V_3 and V_4 will cause corresponding increases in the effective thermionic emissions between the filament and plate electrodes of these tubes. Of course, a decrease in the effective potentials of the grid electrodes of the vacuum tubes V_3 and V_4 will cause corresponding decreases in the currents flowing in their respective plate circuits.

A differential polar relay A_0 includes two widings L_{11} and L_{12} which are directly connected in the plate circuits of the vacuum tubes V_3 and V_4, respectively. The battery B_7 is connected to the plate electrodes of the tubes V_3 and V_4 through the windings L_{11} and L_{12}. Under normal conditions the current derived from battery B_7 divides equally between windings L_{11} and L_{12}, and since these windings produce mutually opposite magnetic fields, the armature M of relay A_0 will be normally unaffected by the fluxes produced by these currents. The armature M is preferably one which is permanently magnetized, and moreover, it normally remains midway between contacts d_1 and d_2. When the current of the frequency f_1—f_3 impressed upon the selective network T_1 becomes greater than the current of the frequency $f_2—f_3$ impressed upon the selective network T_2, then the plate current of the vacuum tube V_3 will be greater than the plate current of the vacuum tube V_4, and the flux produced by winding L_{11} will be greater than that produced by winding L_{12}. In that event the armature M will become attracted so as to close contact d_1. If, on the other hand, the plate current of the vacuum tube V_4 becomes greater than the plate current of the vacuum tube V_3, then the flux produced by the winding L_{12} will be greater than that produced by the winding L_{11} and the armature M will be repelled and it will close contact d_2.

When armature M closes contact d_1, apparatus designated G_1 will be operated in order to increase the frequency of the current produced by oscillator O_3. When armature M closes contact d_2, apparatus designated G_2 will be operated to decrease the frequency of the current produced by oscillator O_3. The battery B_8 may be employed for supplying the current required to energize either of the arrangements G_1 or G_2.

If the frequency of the oscillator O_3 increases by a small amount, then the frequency $f_1—f_3$ of the current derived from the demodulator D_1 will decrease, decreasing the effective potential of the grid electrode of the vacuum tube V_3 and correspondingly decreasing the flow of current from battery B_7 through the winding L_{11} of the plate circuit of vacuum tube V_3. Similarly, the frequency $f_2—f_3$ of the current derived from the demodulator D_2 will decrease, increasing the effective potential on the grid electrode of the vacuum tube V_4 and correspondingly increasing the flow of current through the winding L_{12} in the plate circuit of the vacuum tube V_4. Then the armature M will close contact d_2, operating the apparatus G_2 in order to decrease the frequency of the oscillator O_3.

If the frequency of the oscillator O_1 increases by a small amount, then the frequency of the current transmitted by demodulator D_1 of frequency $f_1—f_3$ increases, correspondingly increasing the effective potential impressed upon the grid electrode of the vacuum tube V_3 and correspondingly increasing the current flowing in the plate circuit of vacuum tube V_3 through the winding L_{11} of the differential polar relay. The armature M will then close contact d_1, setting into operation the apparatus G_1 in order to increase the frequency of the oscillator O_3. However, as the frequency of oscillator O_3 increases, then the currents of the frequencies $f_1—f_3$ and $f_2—f_3$ transmitted by demodulators D_1 and D_2, respectively, both change, and the system will reach stability when the frequency of oscillator O_3 has increased by an amount slightly less than one-half of the increase in the frequency of oscillator O_1.

If the frequencies of oscillators O_1 and O_2 both increase by the same amount, then the currents of frequencies $f_1—f_3$ and $f_2—f_3$ will both increase equally. However, the current flowing through the winding L_{11} will be greater than that flowing through winding L_{12}, and therefore the armature M of the differential polar relay will close contact d_1. The apparatus G_1 will then be set into operation to increase the frequency of the oscillator O_3 to the same extent that the frequencies of oscillators O_1 and O_2 have changed.

When the frequency of oscillator O_1 increases by a certain amount and the frequency of oscillator O_2 decreases by the same amount, then the values $f_1—f_3$ and $f_2—f_3$ will respectively increase and decrease by equal amounts. In that event the flow of current through the winding L_{11} will be increased by a certain amount and the flow of current through winding L_{12} will be increased by the same amount. The armature M of the differential polar relay will then remain in its mid-position, and there will be no change in the frequency of the oscillator O_3.

It will be apparent that the principles of this invention relate to arrangements whereby the current of a given oscillator will change in frequency by an amount which is the mean between the changes of the frequencies of two independent standard oscillators. Clearly, the constancy of the frequency of the given oscillator will be greatly superior to that constancy which may be derived from a single oscillator to the extent that the mean of two standard oscillators may be more nearly correct than either one individually. If the two standard oscillators are designed to have equal and opposite changes in frequency for equal changes in temperature and battery potentials, then the frequency of the controlled oscillator will be practically invariable with these changes, and only the random frequency variations of the standard oscillators will tend to change the frequency of the controlled oscillator.

Fig. 2 shows apparatus driven by a motor which may, for example, be used to change the capacity of the condenser designated C_1 of the oscillator O_3. The motor of this arrangement is of the direct current type including a field winding designated L_{20} and an armature S, with which brushes e_1 and e_2 are associated. The armature of the motor may be on the same shaft or be otherwise coupled to a worm W which controls the rotation of a gear pinion U. When the armature S of this motor rotates in a clockwise direction, the pinion U will be rotated in one direction, and when the armature is rotated in a counter-clockwise direction, the pinion U will be moved in the opposite direction. Each revolution of the worm W will advance the pinion U by one tooth.

When the armature M is in its mid-position, neither of two relays designated A_1 and A_2 will be operated. When armature M closes contact d_1, relay A_1 will be operated by current flowing from a battery B_{20} through the winding of relay A_1, contact D_1, armature M and ground. When contact d_2 is closed by armature M, relay A_2 will become operated, current then flowing from battery B_{20} through the winding of relay A_2, contact d_2, armature M and ground. When the relay A_1 is operated, the armature S of the motor will be rotated in one direction, and when the relay A_2 is operated, armature S will be rotated in the opposite direction, because of the fact that the polarity of the potential of source X applied to the field winding L_{20} of the motor will then be reversed.

When relay A_1 is operated, the brush e_1 will be connected to the negative side of the source X through a circuit which includes conductor 21, armature k_1, conductor 22 and conductor 23. The upper terminal of the field coil L_{20} will be connected to the positive side of source X through a circuit which includes conductor 24, armature l_1 and conductor 25. The lower terminal of field coil L_{20} will be connected to the negative side of source X through a circuit which includes conductor 26, armature m_1, conductor 27, armature k_1, conductor 22 and conductor 23. The armature S will then be rotated in a direction which may be assumed to be clockwise.

When relay A_2 is operated, the brush E_1 will be connected to the negative side of the source X through a circuit which includes conductor 21, conductor 28, armature k_2 and conductor 23. The upper terminal of the field coil 20 will be connected to the negative side of source X through a circuit which includes conductor 29, armature m_2, armature k_2 and conductor 23. The lower terminal of the field coil L_{20} will be connected to the positive side of source X through a circuit which includes conductor 30, armature l_2 and conductor 25. It will then be seen that the operation of relay A_2 will reverse the polarity impressed upon the field coil L_{20}. In that event the armature S will be rotated in a counter-clockwise direction.

It will be noted that the relays A_1 and A_2 are employed for the purpose of reversing the polarity of the source X impressed upon the field coil L_{20} of the motor. It will be further noted that the negative terminal of the source X is connected to the brush e_1 through either armature k_1 or armature k_2, depending upon whether relay A_1 or relay A_2 has operated. The brush E_2 is always connected to the positive side of the source X.

While this invention has been shown and described in a certain particular arrangement merely for the purpose of illustration, it will be understood that the general principles of this invention may be applied to other and widely varied organizations without departing from the spirit of the invention and the scope of the appended claims.

What is claimed is:

1. The method of controlling the frequency of a current of variable frequency which consists in generating two currents of the same frequencies and which are highly constant in their frequencies, producing a first direct current which varies in amplitude in accordance with the difference between the frequencies of one of the generated currents and the current to be controlled, producing a second direct current which varies in amplitude in accordance with the difference in the frequencies between the other of the generated currents and the current to be controlled, increasing the frequency of the current to be controlled when the first direct current is greater in amplitude than the second direct current, and decreasing the frequency of the current to be controlled when the amplitude of the second direct current is greater than the first direct current.

2. A frequency control system for a generator which is variable in frequency and which is to be controlled as to its frequency, comprising means for independently generating currents of the same frequencies and which are highly constant in their frequencies, means coupled to the generator of variable frequency and said generating means for producing a first direct current which varies in accordance with the difference in the frequencies between the current of the generator to be controlled and one of the currents of said generating means, means coupled to the generator of variable frequency and said generating means for producing a second direct current which varies in accordance with the difference in the frequencies between the current of the generator to be controlled and the other current of said generating means, means including a differential polar relay for increasing the frequency of the current of the generator to be controlled when the amplitude of the first direct current exceeds the amplitude of the second direct current, and means including said differential polar relay for decreasing the frequency of the current of the generator to be controlled when the amplitude of the second direct current exceeds the amplitude of the first direct current.

3. A frequency control system comprising two standard oscillators producing currents of the same frequencies, a third os-

cillator including a reactive element of adjustable magnitude which is variable so as to control the frequency of its sustained oscillations, means to independently beat the current of each of the standard oscillators with the current of the third oscillator in order to produce two currents having frequencies equal to the differences between the frequencies of the pairs of currents independently beaten, means to convert each of the currents resulting from the beating process into a direct current of an amplitude depending upon the frequency of the current resulting from the beating process, and means including a differential polar relay responsive to the greater of the direct currents to control the frequency of said third oscillator.

4. A frequency control system comprising two standard oscillators producing currents of the same frequency, a third oscillator which is adjustable in its frequency, means to combine the current of one of said standard oscillators with the current of said third oscillator to produce a current having a frequency equal to the difference between the frequencies of the currents combined, means to combine the current of the other of said standard oscillators with the current of the third oscillator to produce a current having a frequency equal to the difference between the frequencies of the combined currents, means to convert current resulting from the first combination into a direct current of an amplitude which varies with the variations in the frequency of the current resulting from said combination, means to convert the current resulting from the second combination into a direct current of an amplitude which varies in accordance with the variations in the frequency of the current resulting from the said combination, and means including a differential polar relay responsive to the greater of these direct currents to control the frequency of the third oscillator.

5. A frequency control system comprising an oscillator of adjustable frequency, two standard oscillators producing currents of the same frequencies, means coupled to the oscillator of adjustable frequency and one of said oscillators to produce a direct current of an amplitude corresponding to the difference between the frequencies of said oscillator of adjustable frequency and said standard oscillator, means coupled to the oscillator of adjustable frequency and the other of said standard oscillators to produce a direct current of an amplitude corresponding to the difference between the frequencies of said oscillator of adjustable frequency and said second oscillator, and means including a differential polar relay responsive to the greater of said direct currents to change the frequency of the current of said oscillator of adjustable frequency.

6. A frequency control system comprising two standard oscillators of variable frequency which are normally of the same value, an oscillator of adjustable frequency, a polar differential relay having two windings, means interconnecting said oscillator of adjustable frequency, one of said standard oscillators and one of the windings of said relay to transmit a current through said winding of the relay which varies in amplitude in accordance with the differences in the frequencies of said oscillators so interconnected, means interconnecting said oscillator of adjustable frequency, the other of said standard oscillators and the second winding of said relay in order to transmit a current through said second winding of said relay which varies in accordance with the differences in the frequencies of said oscillators so interconnected, and means to increase the frequency of the current of said adjustable oscillator when the current through one of the windings of said relay exceeds the current through the other of said windings and to decrease the frequency of the current of said adjustable oscillator when the current through the first of said windings is less than that through the other of said windings.

In testimony whereof, I have signed my name to this specification this 15th day of February, 1930.

WILLIAM T. WINTRINGHAM.