

July 22, 1941.

K. R. WENDT

2,250,284

FREQUENCY CONTROL CIRCUITS

Filed Oct. 26, 1938

2 Sheets-Sheet 1

FIG. 1. FREQUENCY DIVIDERS

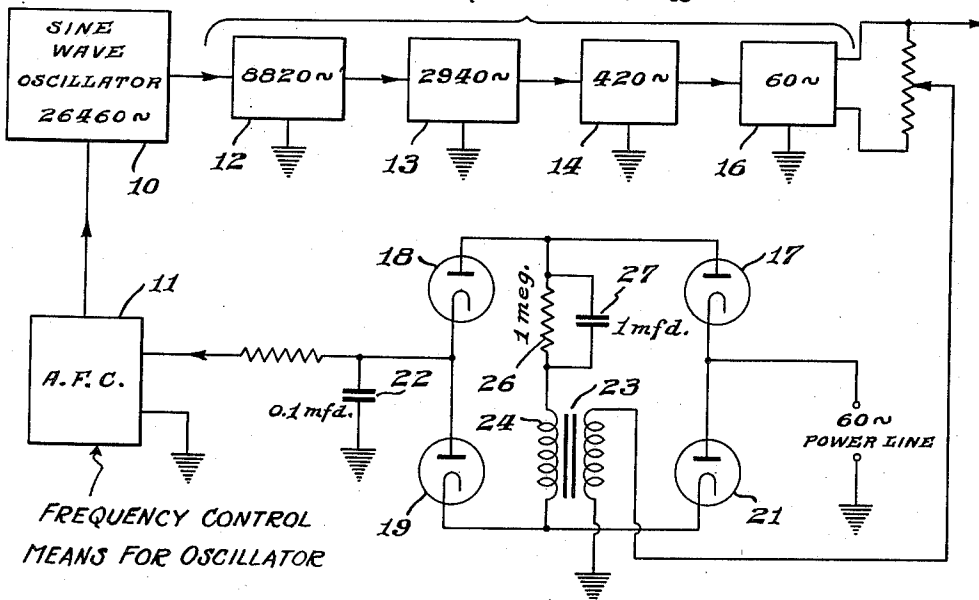


FIG. 2.

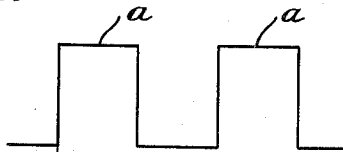


FIG. 3.

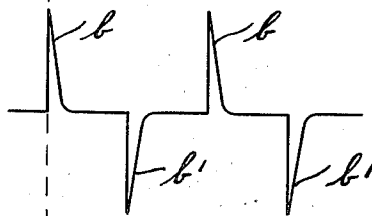
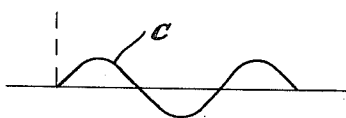


FIG. 4.



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FIG. 5.

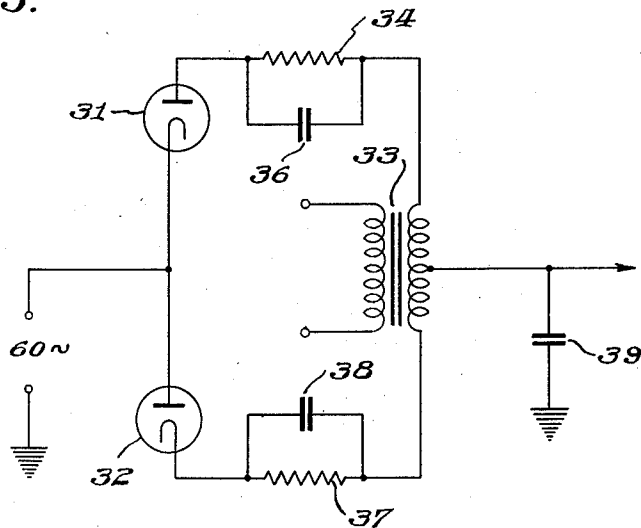
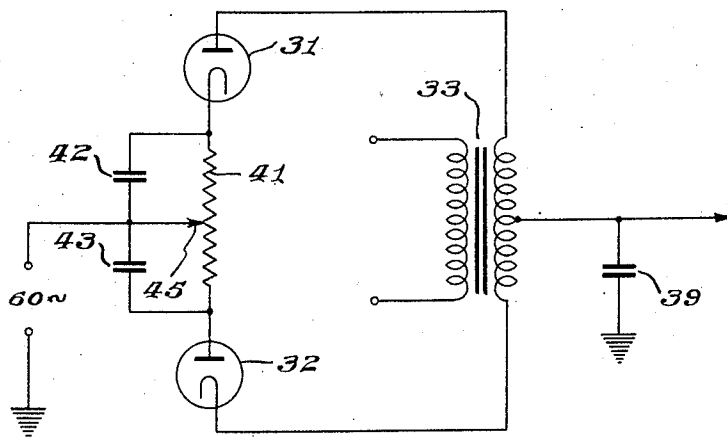


FIG. 6.



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UNITED STATES PATENT OFFICE

2,250,284

FREQUENCY CONTROL CIRCUITS

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Application October 26, 1938, Serial No. 237,051

9 Claims. (Cl. 250—36)

My invention relates to the frequency or phase control of oscillators and particularly to means for locking in an oscillator with a standard frequency source.

The invention will be described with reference to a television transmitter where it is desired to lock in a synchronizing impulse generator with the power line frequency. A system of this general character is described in Patent No. 2,137,010, issued November 15, 1938, in the name of A. V. Bedford and assigned to the Radio Corporation of America.

It is an object of my invention to provide an improved frequency control or lock-in circuit for oscillators.

It is a further object of my invention to provide an improved circuit for indicating the phase difference between electrical waves or signals.

A still further object of my invention is to provide an improved means for locking in a synchronizing impulse generator or a cathode ray tube deflecting circuit with a source of controlling frequency such as a power line.

In practicing my invention I charge a condenser across which the controlling voltage is to appear in accordance with the phase relation of the control source with respect to electrical impulses derived from the oscillator being controlled. The condenser is prevented from discharging between the occurrence of successive impulses by means of a rectifier in the charging circuit. Additional means is provided to permit a discharge rather than a charge of the condenser upon the occurrence of an electrical impulse if the phase relations are such as to require this for bringing the oscillator back to the desired phase relation. A control circuit operating on this principle is described and claimed in Patent No. 2,201,978, issued May 28, 1940, in the name of A. V. Bedford, entitled "Frequency control circuits," and assigned to Radio Corporation of America.

My circuit for obtaining this result differs from the Bedford circuit, however, and has certain advantages. In its preferred form it is a balanced bridge circuit comprising four diodes, the 60 cycle control voltage being impressed across one diagonal of the bridge and the impulses from the oscillator being impressed across the other diagonal. A resistor-capacitor or RC circuit is included in series with the impulse source in the last mentioned diagonal whereby a D. C. voltage builds up thereacross in opposition to the voltage impulses.

In operation the controlling condenser is either

charged through two of the diodes or discharged through the other two diodes, depending upon which side of the equilibrium point the phase has shifted.

The invention will be better understood by referring to the accompanying drawing in which

Figure 1 is a circuit diagram of a preferred embodiment of my invention,

Figures 2 to 4 are curves which are referred to in explaining the invention, and

Figures 5 and 6 are circuit diagrams of other embodiments of my invention.

Referring to Fig. 1, I have shown my invention applied to a television transmitter which includes a synchronizing impulse generator comprising an oscillator 10, an automatic frequency control or A. F. C. circuit 11 for the oscillator 10, and a group of frequency dividers 12, 13, 14 and 16. The oscillator 10 may be a conventional sine wave oscillator while the A. F. C. circuit may be of any suitable design as indicated in the second-mentioned Bedford Patent 2,201,978. The several frequency dividers may be multivibrators.

Referring to the control circuit, it comprises four rectifiers such as diodes 17, 18, 19 and 21 connected to form a bridge. It will be noted that the plates of diodes 17 and 18 are connected together, that the cathodes of diodes 19 and 21 are connected together, and that the bridge circuit is completed by connecting the cathode of diode 18 to the plate of diode 19 and the plate of diode 21 to the cathode of diode 17.

The 60 cycle supply from the power line is connected across one diagonal of the bridge through a control condenser 22, the power line output being connected between ground and the junction point of the cathode and plate of diodes 17 and 21, respectively, and the condenser 22 being connected between ground and the junction point of the cathode and plate of diodes 18 and 19, respectively.

Impulses from the frequency divider 16 are impressed across the other diagonal of the bridge through a transformer 23. The secondary 24 of this transformer is connected in series with an RC network comprising a resistor 26 shunted by a condenser 27, whereby there is built up across the condenser 27 a voltage which opposes the voltage across the secondary 24. The values indicated on the drawing for the RC network are merely by way of example.

It should be noted that the impulses supplied through transformer 24 across the one bridge diagonal never appear across the other diagonal since the bridge is balanced.

The voltage across the condenser 22 is applied to the A. F. C. circuit 11 whereby the frequency of the oscillator 10 is corrected in accordance with changes in the condenser voltage.

The way in which my circuit operates to produce the desired control voltage will now be described. The electrical impulses supplied from the frequency divider 16 to the transformer 23 are shown at *a* in Fig. 2. These impulses *a* preferably are substantially rectangular so that they have a steep side which produces a sharp impulse *b* (Fig. 3) across the secondary 24.

The sharp impulses *b* are obtained since the transformer 23 is designed to pass only the high frequency components of the impulses *a*. The impulses *a* may be of any convenient width, the impulses *b* of reverse polarity (Fig. 3) not being made use of.

The 60 cycle voltage wave supplied to the bridge from the power line is indicated at *c* in Fig. 4. In the example being described, the wave *c* is substantially a sine wave but it may have a different shape. Preferably, however, the sides of the wave *c* are sloping.

The impulses *b* appear across secondary 24 with a polarity which drives the plates of diodes 17 and 18 positive. Likewise, the plates of the diodes 19 and 21 are driven positive and all four diodes are electrically conducting at this instant whereby the condenser 27 of the RC network is charged through diodes 18 and 19 in series and through diodes 17 and 21 in series. As the time constant of the RC circuit is large as compared to the time between successive impulses *b*, a voltage builds up across condenser 27 and resistor 26 which is opposing and nearly equal to the voltage impulses *b*.

Now assume, for example, that the positive half of the wave *c* occurs at the same time as the impulse *b*. For the duration of the impulse *b*, all diodes are conducting. Thus the power line source charges the condenser 22 at this instant through the diode 21, the secondary 24, the RC network 25, 27 and the diode 18. It will be seen that the charge will depend upon the instantaneous value of wave *c* at the instant the impulse *b* occurs, and that this instantaneous charging value depends upon the phase relation of impulse *b* and the wave *c*.

If, at the instant an impulse *b* occurs, the instantaneous voltage of wave *c* is the same as the voltage across condenser 22, there will be no charge or discharge of condenser 22. If the instantaneous voltage of wave *c* is greater than the voltage across condenser 22 it will receive an additional charge as described above.

If the instantaneous voltage of wave *c* is less than the voltage across condenser 22 at the time an impulse *b* occurs, the condenser 22 will discharge a slight amount to lower its voltage to the new instantaneous value, this discharge being through diode 19, the secondary 24, the RC network and the diode 17.

Between impulses *b*, the condenser 22 retains its charge since it cannot discharge through the diodes 19 and 17 because of the opposing voltage across the RC network 26, 27. It will be noted that in order for the voltage across the RC network to have a high enough value to prevent a discharge of condenser 22 between impulses *b*, the impulses *b* should have a greater voltage than the sine wave *c*. Preferably, the voltage of an impulse *b* is several times the maximum instantaneous value of the controlling voltage *c*.

From the foregoing description it will be apparent that the condenser 22 is provided with both a charging circuit and a discharging circuit, and that means is provided to prevent the condenser from discharging between control impulses.

The above-described circuit is a preferred embodiment of my invention because it is always balanced if the diodes are similar as they preferably are.

In Fig. 5 there is shown a circuit which is satisfactory although it is sometimes difficult to balance. It comprises two diodes 31 and 32 with the cathode of one diode connected to the plate of the other diode. The control impulses *b* are impressed across the diodes 31 and 32 through a transformer 33 just as in Fig. 1. Two RC similar networks are provided, one comprising a resistor 34 and a condenser 36 between the transformer 33 and the diode 31 and the other comprising a resistor 37 and a condenser 38 between the transformer 33 and the diode 32.

The 60 cycle power line voltage *c* is applied between ground and the junction point of the cathode and plate of diodes 31 and 32, respectively.

The condenser 39 across which appears the control voltage or the phase indicating voltage is connected between ground and the midpoint of the secondary of transformer 33.

In operation, condenser 39 is charged through diode 32 and the RC network 38, 37 if the instantaneous sine wave voltage is greater than the voltage of condenser 39 at the instant the sharp impulse occurs. If the instantaneous sine wave voltage is lower at this time than the voltage of condenser 39, condenser 39 discharges through the RC network 34, 36 and the diode 31.

Discharge of condenser 39 between the occurrence of the sharp voltage impulses is prevented by the voltage built up across the RC network 34, 36 as in the case of the circuit in Fig. 1. The RC network 37, 38, which is the same as RC network 34, 36, prevents charging of condenser 39 between the occurrence of successive sharp voltage impulses. It will be seen that the circuit is balanced whereby none of the sharp voltage impulses *b* appears across the condenser 39.

In Fig. 6 there is shown a circuit which is similar to the circuit of Fig. 5 but which is easier to balance. In the two figures like parts are indicated by the same reference numerals. In Fig. 6 a single RC network is employed comprising a resistor 41 shunted by like condensers 42 and 43, this network being located between the cathode and plate of diodes 31 and 32, respectively.

The 60 cycle supply is applied to the control circuit through a variable tap 45 on resistor 41 whereby, except possibly for the presence of undesired stray capacities, the circuit may be properly balanced.

The operation of the circuit of Fig. 6 is substantially the same as that of the circuit in Fig. 5.

It may be noted that the impulses *a* and *b* need not occur at the same frequency as the control wave *c* but they should have a harmonic relation thereto. For example, assuming wave *c* to have a frequency of 60 cycles per second, impulses *a* may occur at the rate of 60 per second, 30 per second, or 20 per second.

It will be understood that the use of the transformer 23 may be avoided if the impulses *a* are

made narrow enough to be applied directly across the bridge diagonal. In general, however, it is advantageous to use a transformer both because the width of the impulse a then need not be adjusted to any specific value and because it conveniently permits operating the diodes above ground potential.

As indicated in the foregoing description, my balanced control circuits preferably include RC circuits across which there automatically builds up a biasing or opposing voltage which is slightly less than the amplitude of the sharp impulses b . However, batteries or other biasing sources may be substituted for the RC networks, the battery voltage being adjusted to a value slightly less than the amplitude of the impulses b , and satisfactory results will be obtained so long as the impulses b remain substantially constant in amplitude.

I claim as my invention:

1. A circuit for producing a voltage representative of the phase relation between the output of a first signal source and the output of a second signal source, said outputs having a harmonic relation to each other, said circuit comprising a condenser across which said voltage is to appear, a charging circuit including a rectifier, a discharging circuit including a rectifier, said second source being connected in said charging and discharging circuits to charge said condenser through said charging circuit, means for deriving from said first source voltage impulses of greater amplitude than the output of said second source, means for applying said impulses in a bridging connection to said charging and discharging circuits whereby said impulses are applied thereto in balanced relation to the connections of said second source in said charging and discharging circuits and for making said charging circuit effective to pass a charging current only in response to and for the duration of each of said voltage impulses and for simultaneously making said discharging circuit effective to discharge said condenser only during said voltage impulses and in response to the charging voltage being less than the voltage across said condenser.

2. A circuit for producing a voltage representative of the phase relation between the output of a first signal source and the output of a second signal source, said outputs having a harmonic relation to each other, said circuit comprising a condenser across which said voltage is to appear, said second source being connected to charge said condenser through a charging circuit, said charging circuit including means for providing a biasing voltage and including rectifier means in series therewith, said biasing voltage being poled to oppose current flow through said rectifier, a discharging circuit including a rectifier, means for deriving from said first source voltage impulses of greater amplitude than the output of said second source, means including said biasing source for making said charging circuit effective to pass a charging current only in response to and for the duration of each of said voltage impulses, and means for simultaneously making said discharging circuit effective to discharge said condenser only during said voltage impulses and in response to the charging voltage being less than the voltage across said condenser.

3. A circuit for producing a voltage representative of the phase relation between the output of a first signal source and the output of a second

signal source, a condenser across which voltage is to appear, a pair of rectifiers each having a cathode and an anode, the cathode of one rectifier being connected to the anode of the other rectifier whereby there is a junction point, means for supplying voltage impulses of a certain polarity from said first source across said rectifiers in series, said impulses being of short duration and of greater amplitude than the instantaneous voltage of the output of the second source, a source of biasing voltage of slightly less amplitude than said impulses connected in series with said rectifiers and said impulse supplying means with the biasing voltage in opposition to the voltage impulses of said certain polarity, and means for connecting said second source and said condenser in series between said junction point of one cathode and one anode and the circuit connecting the other cathode and anode of said rectifiers and in balanced relation with respect to said first source whereby said impulses do not appear across said condenser.

4. A circuit for producing a voltage representative of the phase relation between the output of a first signal source and the output of a second signal source, a condenser across which said voltage is to appear, a rectifier, means for charging said condenser from said second source through a charging circuit including said rectifier when said phase relation is on one side of an equilibrium point, a second rectifier, means for partially discharging said condenser through said second rectifier in response to the occurrence of voltage impulses derived from said first source when said phase relation is on the other side of said equilibrium point, and means for preventing said condenser from either charging or discharging between successive voltage impulses, said last means comprising a resistor-capacitor circuit, said condenser, said second rectifier, said last means and said second source comprising a closed series circuit, said resistor-capacitor circuit comprising a resistor shunted by a condenser.

5. A circuit for controlling the frequency or phase of an oscillator in accordance with the frequency of a controlling source, said circuit comprising a pair of rectifiers each having a cathode and a plate with the plates being directly connected to each other, a second pair of rectifiers each having a cathode and a plate with the cathodes being directly connected together, the cathodes of said first pair of diodes being connected to the plates of said second pair of diodes whereby a bridge circuit is formed, a condenser across which a controlling voltage is to appear, means for supplying voltage from said controlling source across one diagonal of said bridge through said condenser, the terminals of said one diagonal being the junction points of the cathodes of said first pair of diodes and the plates of said second pair of diodes, means for impressing across the other diagonal of said bridge periodic sharp voltage impulses of a certain polarity derived from said oscillator and having a harmonic relation to the frequency of the controlling source, said voltage impulses having a greater amplitude than the peak voltage supplied by the controlling source, and a resistor-capacitor circuit connected in series in said other diagonal and having a time constant such that there is built up thereacross a substantially steady voltage which opposes the voltage impulses of said certain polarity.

6. A circuit for producing a voltage represen-

tative of the phase relation between a first signal source and a second signal source, said circuit comprising a pair of rectifiers each having a cathode and an anode, the cathode of one rectifier being connected to the anode of the other rectifier whereby there is a junction point of said cathode and said anode, a transformer having a primary and a secondary, the remaining cathode and anode of said rectifiers being connected to each other through said secondary, a condenser across which said representative voltage is to appear, means for impressing the signal from said second source between said junction point and the mid-point of said secondary through said condenser, means for impressing the signal from said first source across said primary to produce sharp voltage pulses across the secondary, and means connected in series with said secondary and said rectifiers for preventing discharge of said condenser between successive impulses appearing across said secondary, said last means comprising a resistor shunted by a condenser.

7. A circuit for producing a voltage representative of the phase relation between the output of a first signal source and the output of a second signal source, a condenser across which said voltage is to appear, four rectifiers connected in the form of a bridge or ring with two adjacent rectifiers connected to conduct in one direction around the ring and the other two rectifiers connected to conduct in the opposite direction

around the ring, a biasing source, means for deriving sharp voltage impulses of a certain polarity from said first source and supplying them through said biasing source across the bridge diagonal having as its terminals the junction points connecting said two adjacent rectifiers in series to said other two rectifiers in series, the voltage across said biasing source being in opposition to and slightly less than the voltage of said impulses of said certain polarity, and means for supplying the signal from said second source across the other diagonal of said bridge in series with said condenser, the instantaneous voltage of the signal from said second source being less than the amplitude of said voltage impulses.

8. The invention according to claim 7 characterized in that said biasing source comprises a resistor having a condenser in parallel therewith to form a resistor-capacitor circuit, the time constant of said resistor-capacitor circuit being large compared with the time between the occurrence of said sharp voltage impulses.

9. The invention according to claim 7 characterized in that said means for supplying sharp voltage impulses across said first bridge diagonal comprises a transformer which passes high frequency components only and which has a secondary connected in series with said biasing source.

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