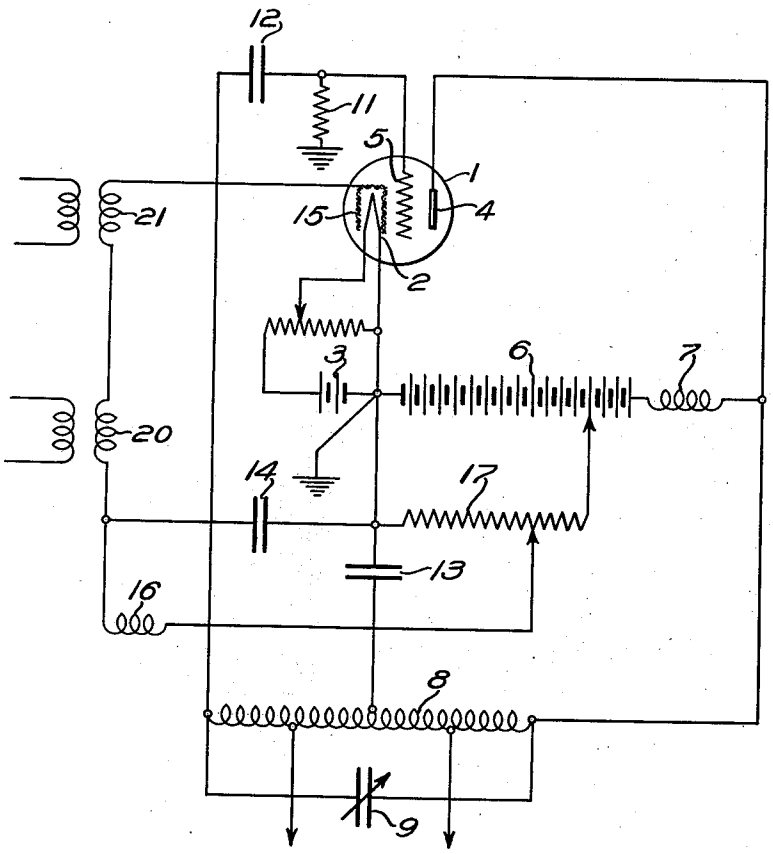
March 30, 1937. R. N. HARMON 2,075,112

VACUUM TUBE CIRCUIT FREQUENCY CHANGING

Filed July 14, 1932



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Patented Mar. 30, 1937 2,075,112

UNITED STATES PATENT OFFICE

2,075,112

VACUUM TUBE CIRCUIT FREQUENCY CHANGING

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Application July 14, 1932, Serial No. 622,389

6 Claims. (Cl. 250—36)

This invention relates to oscillation generators and particularly to oscillation generators of the vacuum tube type in which the frequency is controlled by separate oscillating means.

Oscillation generators, particularly for use in connection with radio broadcasting, must have a very constant frequency. It is usual to obtain this by producing the frequency from a lower frequency which is readily controlled or is of a very constant character. The oscillation of piezo-electric crystals and of tuning forks are familiar illustrations of such control frequencies.

In order to obtain a frequency of an order suitable for radio transmission purposes from a piezo-electric crystal or an electrically driven tuning fork, it is usual to multiply the frequencies in a succession of steps in each of which an oscillation generator is used which produces many and strong harmonics, one of which is separated from the others by filtering and impressed upon the input of the next step. In order that the output shall contain strong harmonics, it is usual to cause the grid potential to oscillate over an amplitude so great that the response thereto in the plate circuit will not be linear. The non-linear character of the response is depended upon for production of the harmonics.

In my invention I am able to produce the desired frequency with a smaller number of steps because I have discovered a more effective way of producing a distorted plate current.

It is an object of my invention to obtain the desired frequency from a given frequency by means which shall not require many steps and in which the adjustments need not be nice.

It is a further object of my invention to provide means for obtaining an output of any one of a large number of frequencies from two or more standard input frequencies and to hold the output frequency to the selected value with certainty and without requiring careful adjustment.

It is a further object of my invention to take advantage of a characteristic of a screen-grid tube, namely that when the screen-grid potential is approximately equal to the plate potential the plate current becomes very distorted.

It is a further object of my invention to control an oscillation generator by means of potentials impressed upon the screen grid.

It is a further object of my invention to obtain oscillations of a high frequency by the action of control oscillations of lower frequency with only a small number of steps.

It is a further object of my invention to provide an oscillation generator capable of delivering a large number of different frequencies and also capable of dependably delivering the selected one of said frequencies without requiring any high degree of care in adjustment to obtain said selected frequency.

It is a further object of my invention to produce in the output circuit a harmonic equal to a harmonic of a control or of a combination of control frequencies.

Other objects of my invention and details of the structure employed will be evident from the following description and the accompanying drawing, in which the single figure of drawing is a diagrammatic representation of a circuit embodying the principles of my invention.

In the figure the vacuum tube 1 is supplied with the usual filament 2, heated by current from a source 3. The plate 4 of the tube 1 and the control grid 5 thereof are connected through the usual circuits to constitute a Hartley oscillator. The source of power for this oscillator is the battery 6. A radio-frequency choke coil 7 between the positive end of this battery and the connection to the plate 4 confines the high-frequency oscillations to the tuned circuit which comprises an inductor 8 and a condenser 9. The tuning of the circuit is accomplished by adjusting one of the reactors. In the illustration only the condenser 9 is shown as adjustable but the inductor 8 may also be made adjusable, if desired.

The control grid 5 is supplied with the usual grid resistor 11 and grid condenser 12 through which it is connected to the terminal of the inductor 8 opposite that connected to the plate 4. The center point of the inductor 8 is connected to the filament 2 through a stopping condenser 13.

A stopping condenser 14 is inserted between the filament and a connection to the screen grid 15. A radio frequency choke coil 16 prevents the high frequencies impressed upon the screen grid from reaching the resistor 17 which is connected across a portion of the battery 6 and acts as a potentiometer from which, through the radio frequency choke coil 16, a direct-current potential is impressed on the screen grid. The connection to the screen grid includes the secondaries 20 and 21 of two transformers. The primaries of these transformers are supplied from any suitable sources with frequencies of fixed magnitudes.

In the operation of the device, the screen grid 15 is at a direct-current potential somewhat lower than the potential of the plate 4. The tube, therefore, would, if it were not for the secondaries 20 and 21, operate as an oscillation gen-

erator producing a frequency determined by the tuning of the circuit 8—9 and yielding a substantially undistorted plate current.

The potentials introduced by the secondaries 20 and 21 cause the device to depart from the ordinary behavior of an oscillator. Each time that the potential of the grid 15 is sufficiently increased by the voltages introduced by these secondaries 20 and 21 to cause it to be nearly equal with the plate potential, the plate current, instead of being a linear function of the potential upon the control grid 5, becomes a non-linear function thereof, that is, the plate current, instead of being of a nearly pure sine-wave form, becomes highly distorted and contains many harmonics.

As the tuning of the circuit 8—9 is adjusted the frequency of the current therein or some harmonic of that frequency will become equal to the frequency delivered by the transformer secondary 20, the transformer secondary 21 or the combination of them or some harmonic thereof. Whenever this occurs, the interaction of the equal harmonics will be superposed upon the ordinary feed-back action of the oscillator, with the result that the particular frequency of current in the circuit 8—9 at which this occurs will be maintained even though the tuning of this circuit is materially different from that for which this would be the resident frequency.

If the adjustment of the circuit 8—9 be altered continuously from one extreme value to the other and the current therein observed throughout such alteration, it will be found that the current remains persistently of one frequency until the tuning differs so much from the resonant tuning for said frequency that this is no longer possible and then changes to a frequency corresponding to the next value for which the above-stated relation holds. At new frequency, it will again persist until the tuning has been changed enough to cause it to become close to the tuning for the next frequency value corresponding to said condition. In the intervals between the settings of the condenser corresponding to the several frequencies just described the current is unstable. An oscillographic observation of it shows a blur instead of indicating any definite frequency. The settings separating such intervals are not sharp points, for the condenser may be changed some little distance from the adjustment corresponding to exact resonance before the current changes from the fixed frequency to the unstable character.

The current is stable at any one of a large number of frequencies. Which one, may be determined by the tuning. A gradual change of frequency cannot be obtained by a gradual change of the tuning. Frequencies between those that thus persist cannot be obtained by any tuning.

The condition that the frequency of the current in the circuit 8—9 or some harmonic thereof shall equal the frequency impressed by one or the other transformer or by their combined action or some harmonic thereof can be expressed algebraically by the equation

$$f_3=\frac{p}{q}(nf_1+mf_2)$$

in which f_1 is the frequency impressed by the secondary 20, f_2 the frequency impressed by the secondary 21 and the quantities n, m, p and q are integers.

By properly selecting the coefficients n and m, the frequencies f_1 and f_2 may be combined in a very large number of ways so that the number of frequencies at which the system may be stable is large. If the constants p and q are each unity, the combination of harmonics of f_1 and f_2 coact directly with the fundamental of the current in the circuit 8—9.

If q is greater than unity, while p remains unity, the combination equals a harmonic of the current in the circuit 8—9. On the other hand, if q is unity and p is greater than unit, a harmonic of the combination is coacting with the fundamental in the circuit 8—9.

As a rule, the higher the index of the harmonic, the smaller the portion of the total energy present in the current as such harmonic, consequently it is true in general that the device is more stable when the quantities n, m, p and q are small. I have found that a quite substantial alteration in the setting of the condenser 9 may be made without causing a change in frequency when n and m are neither greater than 10.

The stability is greater when p and q are each unity, particularly if n and m are in the upper part of the permissible range. On the other hand, p may be as large as 10 without introducing need for a very critical setting of the condenser. When p is unity, q may be somewhat larger than in other circumstances but while desirable results can be obtained with q as large as 10, it is usually preferable to avoid requiring a very high harmonic of the current in the circuit 8—9 for stabilizing purposes.

In one application of this invention I supply two different frequencies to the primaries of the transformers having secondaries 20 and 21 by connecting these primaries to two different tubes in a series of harmonic amplifiers like those heretofore used for frequency multiplication. I select two which occur early in the series and then the device just described may be used instead of the whole of the series from the selected tubes onward. By this means, I am able to get a frequency sufficient for broadcasting purposes from a crystal or a tuning fork using a much smaller number of tubes than has heretofore been required.

The invention is, however, not limited to this application. It can be used to produce any desirable harmonic or sub-harmonic from one standardized frequency such as a fork or a crystal frequency. It can also be used to produce any desired combination from two sources of constant frequency.

Although, in the preferred form of my invention, the controlling frequencies are introduced into the screen-grid circuit, it is possible to obtain at least the easier of the results described herein by using the control frequency in other places; in the plate circuit, for example, or in the circuit of the control grid.

Many other variations of the structure will occur to those skilled in the art. The omission of a specific description of such variations is not intended as a limitation. No limitation except those imposed by the accompanying claims or required by the prior art is intended.

I claim as my invention:

1. A frequency changer comprising an electron discharge device having at least four electrodes, a circuit interconnecting one of said electrodes with another of said electrodes, a second circuit interconnecting the electrode last mentioned with a different one of said four electrodes, said circuits being coupled and provided with tuning means to constitute an oscillation generator, a

plurality of sources of different control frequencies and means for simultaneously impressing said control frequencies upon the fourth electrode of said discharge device.

2. A frequency changer comprising an electron discharge device having at least four electrodes, a circuit interconnecting one of said electrodes with another of said electrodes, a second circuit interconnecting the electrode last mentioned with a different one of said four electrodes, said circuits being coupled and provided with tuning means to constitute an oscillation generator, a plurality of sources of control frequencies and means for simultaneously impressing said control frequencies upon the fourth electrode of said discharge device, said tuning means being tuned to oscillate at a frequency which bears the following relationship to the control frequencies

$$f_3=\frac{P}{Q}(nf_1\pm mf_2)\ .$$

where f_1 and f_2 are control frequencies, and the coefficients "P" "Q" "n" and "m" are integers.

3. A frequency changer comprising an electron discharge device of the screen grid type, a circuit connecting one of the grids of said device and the cathode, another circuit connecting the anode of said device with said cathode and including a source of potential, said circuit being coupled to constitute said discharge device, an oscillation generator, a control frequency potential and means for impressing said potential upon the remaining grid of said discharge device, means to maintain said grid normally below the potential of said anode, the control frequency potential being of such value as to raise the potential of said remaining grid to the value of said plate potential at least once in each period.

4. In combination with an electrical discharge device having a cathode, an anode and at least two control electrodes, a source of energy and a connecting circuit between said anode and cathode, a coupling between said circuit and one of said control electrodes adapted to cause said discharge device to produce spontaneous electrical oscillations, a resonant means connected in said circuit to determine the frequency of said oscillations, a source of periodic energy in circuit with the other of said two control electrodes, the resonant frequency of said oscillations being substantially a multiple of the frequency of said last-named source.

5. In combination with an electrical discharge device having a cathode, an anode and at least two control electrodes, a source of energy and a connecting circuit between said anode and cathode, a coupling between said circuit and one of said control electrodes adapted to cause said discharge device to produce spontaneous electrical oscillations, resonant means connected in said circuit to determine the frequency of said oscillations, an independent source of periodic energy in circuit with the other of said two control electrodes, the potential of said electrodes being such as to cause substantial distortion in the current of the circuit interconnecting said cathode and anode.

6. In combination with an electrical discharge device having a cathode, an anode and at least two control electrodes, a source of energy and a connecting circuit between said anode and cathode, a coupling between said circuit and one of said control electrodes adapted to cause said discharge device to produce spontaneous electrical oscillations, resonant means connected in said circuit to determine the frequency of said oscillations, a source of periodic energy in circuit with the other of said two control electrodes, the potential of said electrodes being such as to cause substantial distortion in the current of the circuit interconnecting said cathode and anode, and the tuned frequency of said oscillations being substantially a multiple of the frequency of said last-named source.

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