Oct. 20, 1931. R. A. HEISING 1,828,498

OSCILLATION CIRCUITS

Filed May 26, 1928

FIG. 1

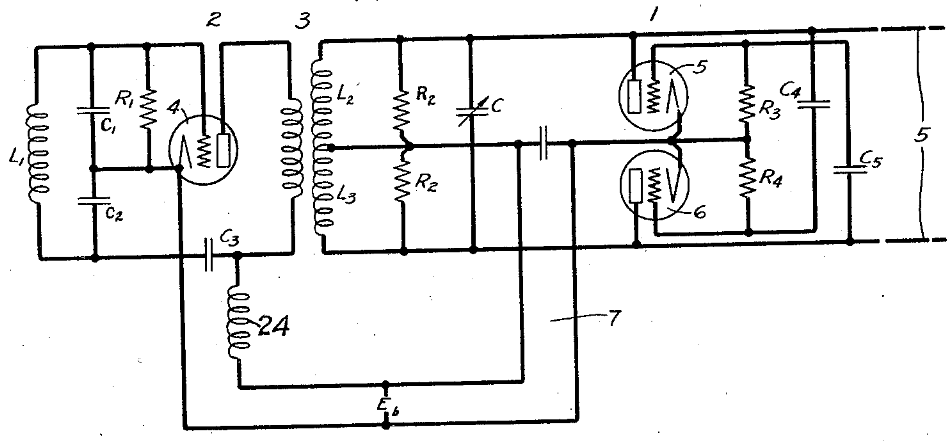
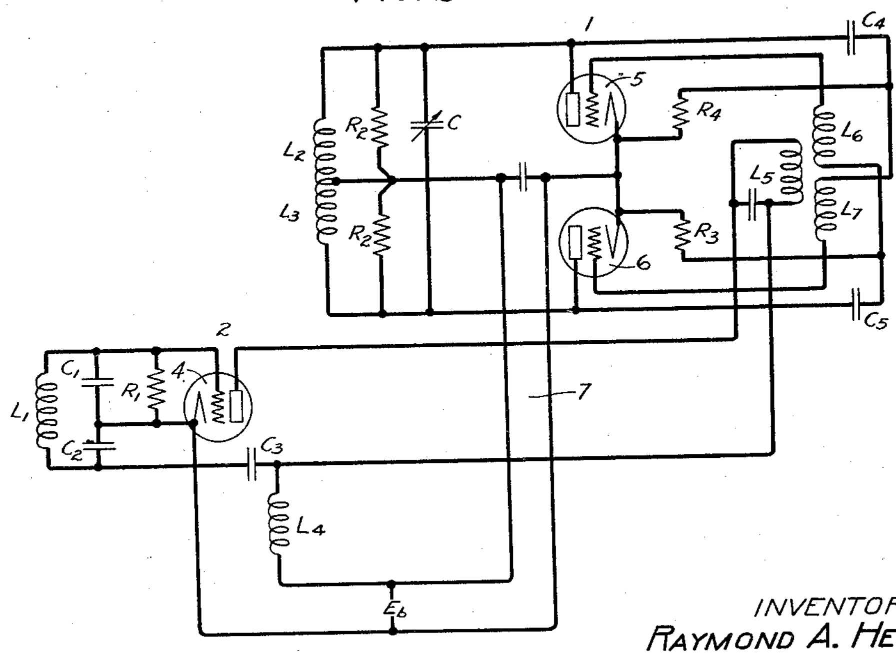


FIG. 2



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UNITED STATES PATENT OFFICE

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OSCILLATION CIRCUITS

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This invention relates to the production of oscillations and particularly to methods of and systems for the production of oscillations the frequency of which has a definite relation to the frequency of the current from a given source.

It is an object of the invention to condition an electric discharge oscillator whereby it may be more easily coerced to change its frequency by an impressed wave.

Another object of the invention is to facilitate self-synchronization between an electric discharge oscillator to be controlled and a controlling source.

By "self-synchronization" is meant the phenomenon by which, when two sources of waves of approximately the same frequency are juxtaposed so as to admit of an interchange of energy, such sources tend to produce waves having the same frequency, that is, one source, the controlled source, is pulled into step with the other, the controlling or reference source. The controlling source is not necessarily self-excited, as in the case of the more usual type of oscillator but may be separately excited as in the case of an amplifier. It may, in fact, be any circuit in which electrical variations occur and which is related to the controlled source in such manner as to tend to modify its operation.

Where the two sources are similarly related to each other, so that the conditions do not forbid the interflow of energy in either direction impartially, it has been found that the resultant frequency will usually tend to be close to that of one or the other source, the choice depending on their relative operating characteristics as determined by the constants of their electrical elements. Applicant has discovered that an electrical discharge oscillator, or any oscillator whose frequency is determined by the natural frequency of a resonant circuit, may be more easily coerced to follow the variations of frequency of a circuit tending to control it if a resistance is inserted in such frequency determining circuit. The resistance will be especially efficacious if connected to the output electrodes, that is, across or in parallel with the frequency determining circuit instead of in series with said circuit. In such a position the resistance modifies the impedance as a whole presented to the output current of the controlled oscillator in such a manner that such impedance will remain constant when, for example, the frequency adjustment of the controlled oscillator is varied.

The principle of the invention is applicable in any situation where self-synchronization may occur. The necessary conditions are satisfied in part if each of the two frequencies generated by the oscillators are expressible by rational numbers, or in other words, if there is a rational fractional relation between the two frequencies. An irrational number, sometimes called an incommensurable number, is one which cannot be divided by any other without a remainder, or, perhaps more simply defined, which cannot be expressed as either an integer or as an integer and a decimal having a finite number of places. The quantity $\sqrt{2}$ is therefore irrational. The quantity—and the quantity indicating the base of the natural system of logarithms are irrational numbers. Between any two rational numbers there is an infinite quantity of irrational numbers. Strictly, the expression "irrational quantity" should perhaps be used instead of "irrational number" since a quantity which can be expressed in strictly numerical form cannot be irrational and the so-called irrational numbers are really expressions of an operation on some other number like $\sqrt{2}$. Referring again to the matter of the relation of frequencies, as a practical matter, of course, the frequencies of the two oscillators should have a very simple relation, otherwise there would not be sufficient coercive force. For example, frequencies like 3 and 7 could be synchronized only if the oscillator to be coerced was designed to be very sensitive to coercive influences. If its frequency were changed, it would very easily snap away from the frequency of the other oscillator. In the case of two frequencies which have several common multiples, it might be possible by very careful design to synchronize them by using the higher common multiples, but if one oscillator attempted to change in frequency enough to make a lower common multiple effective, the oscillators would find it easy to pick the new relation of frequencies required by that condition and would be held together more strongly than before.

Another requirement is that at least one of the two generators must have a non-linear characteristic, that is, it must have a modulating characteristic. There can be no coercion in the absence of such a characteristic.

The invention may be more fully understood from the following description when read in connection with the accompanying drawings, Figs. 1 and 2 of which illustrate two alternative circuit arrangements embodying the principle of the invention.

In the system of Fig. 1 the oscillator indicated generally by reference numeral 1 is pulled into step with oscillator 2 through coercion transmitted through the transformer 3 which couples the output circuit of oscillator 2 with the frequency determining circuit L_2, L_3, C of oscillator 1. The oscillator 2 typifies any circuit capable of exerting a coercive force on the oscillator 1 and therefore may alternatively be, for example, an amplifier separately excited by an oscillator of any type whatever. The relation of the two circuits 1 and 2 corresponds to that which is commonly described as adapted for "self-synchronization" of the two sources immediately or remotely coupled in this manner. The condition of self-synchronization may be satisfied by an equality relation between the two frequen ies concerned or they may be related harmonically or, even more generally, they may have any rational fractional relation. As a necessary preliminary condition, the two coupled circuits must be adjusted so as to separately generate frequencies closely approximating those which they will eventually generate when self-synchronized.

The oscillator circuit 2 is represented as a conventional type of electric discharge oscillator characterized by a capacitive coupling between the input and output circuits of the associated electric discharge device, in this instance the device 4, this coupling being constituted by condensers C_1 and C_2. The frequency determining circuit, to which both the input and output circuits must be connected and to which they are connected through the above condensers, is constituted by inductance L_1 and said condensers C_1 and C_2. The oscillator is easily recognized to be of the Colpitts type as disclosed in his U. S. Patent 1,624,537, granted April 12, 1927. The grid of the electric discharge device is given a definite negative polarizing potential by resistance R_1 in a well known manner. The anode, or plate, of the device is supplied with direct current potential from source E_b through inductance coil L_4 which functions as a choke coil to prevent the flow of the generated alternating current in the direct current plate supply leads. By-pass condenser C_3 provides a low impedance path for the alternating current in shunt to the plate current source and said choke coil, the choke coil and by-pass condenser therefor together constituting, in effect, a filter.

The oscillator 1 is of the push-pull type and closely approximates the circuit disclosed in Fig. 5 of British patent to Eccles et al. 149,018. Considering each of the two included vacuum tube devices 5 and 6 separately so far as concerns its relation to the remaining circuits, the circuit approximates a conventional form of the Hartley oscillator as disclosed, for example, in his U. S. Patent 1,356,763, granted October 26, 1920. It is characterized principally, and thereby is principally distinguished from the Colpitts oscillator above described, by an inductive coupling between the input and output circuits of the associated electric discharge device; in this instance, each of the devices 5 and 6. This coupling is effected through inductances L_2 and L_3 which, with condenser C constitute the requisite frequency determining circuit. The circuit is completed from the input electrodes of the devices 5 and 6 to the corresponding inductances L_3 and L_2 respectively by condensers C_5 and C_4 respectively. The input electrodes are given a steady negative bias by leak resistances R_3 and R_4 similarly as in the case of oscillator 2. The anodes, or plates, of the electric discharge devices 5 and 6 are supplied with direct current potential from source E_b through circuit 7 and the frequency determining circuit. The wave generated by the above described system of self-synchronized circuits is delivered to the utilization circuits, not illustrated, by circuit 5. The cathodes of the three electric discharge devices, two for oscillator 1 and one for oscillator 2, may be energized in any manner conventional with electric discharge devices generally. In order to avoid unnecessary complication such means are not illustrated.

The invention particularly relates to the function of resistances R_2 shown connected across the frequency determining circuit of the controlled oscillator 1. The theoretical reasons for the action of the controlling wave in pulling the controlled oscillator into step with its own frequency, or similarly in coercing it into having a frequency which is integrally commensurably related to the frequency of the controlling wave, is more or less obscure and incapable of simple mathematical analysis. A theoretical analysis of the reasons whereby the presence of resistances such as R_2 facilitate the process is not any less obscure or difficult of simple explanation. However, probably the result of using such resistances is to change the controlled oscillator from one having a vigorous or strong oscillatory characteristic to one having a less vigorous or strong oscillatory characteristic, and therefore to tend to make the other oscillator predominate in the display of forces by which each tends to pull the other into step with itself.

In a particular situation in which the circuit of the invention has been used these resistances have taken the form of a plurality, of the order of 4 to 6, of incandescent lamps of a normal 50 watt rating, although any other type of resistance on the same order of value, that is, 1000 ohms or thereabouts, may equally well be used.

Although the mid-point of the series arrangement of said resistances need not be connected to the frequency determining circuit at its mid-point as illustrated, there may be practical advantages in so doing. For example, for very high frequencies it may quite easily result, in the absence of such connection, that the middle portion of the resistance as a whole, for example, a middle lamp, might be substantially short-circuited by its distributed capacity, so as to no longer be effective as a resistance. The connection as shown would obviate that difficulty.

Although the principle of the invention would find expression in other relationships involving the frequency determining circuit and the resistance or resistances, it is preferable to connect it or them across such frequency determining circuit, as illustrated, that is, effectively in parallel with such circuit. When so positioned the resistance as a whole can be considered as one of two parallel paths provided for the generated alternating current, the other path comprising the parallel tuned circuit. This latter path would normally, on account of the parallel resonant, that is, anti-resonant, relationship of its elements, have a relatively high impedance and certainly an impedance large as compared with that of the resistance which therefore would principally determine the output impedance. Accordingly any slight variation of the circuit conditions affecting the frequency determining circuit as a variation of the oscillation frequency by variable condenser C would not appreciably affect the impedance as a whole presented to the output circuit of the devices 5 and 6. This positioning of the resistances accordingly stabilizes the operation of the circuit.

It should, of course, be understood that the invention is not specific to the particular type of oscillator illustrated or that a push-pull oscillator must, or preferably should, be used. As a matter of fact the particular type of oscillator is immaterial so long as it is of the type characterized by the use of a frequency determining circuit. Also it is immaterial as to the circuits connected to the output of the controlled oscillator. Such oscillator can be used to excite further electric discharge devices, such as oscillators or amplifiers, or may deliver power to an antenna or to a transmission line by coupling in any suitable fashion. When the frequencies of the controlled and controlling oscillations are to be made the same, a possible resultant compromise frequency may be avoided by the use of an electric discharge amplifier or other unilaterally conducting device between the controlled and controlling circuits. The circuit illustrated is therefore best adapted for the condition in which the frequencies are unequal as when one is a harmonic of the other.

Fig. 2 illustrates an alternative form of self-synchronized system embodying the principle of the invention. Reference characters used in this figure represent circuit details which are similar in construction and function to those having the same identification in Fig. 1 and these details therefore need not be considered again in this instance. The only substantial difference between the circuits of the two figures relates to the method of coupling the controlled oscillator with the controlling oscillator or circuit. Fig. 2 illustrates the case, alternative to the corresponding case illustrated by Fig. 1, in which the coupling is effected through the input circuits of the controlled oscillator. This arrangement is perhaps to be preferred over that of Fig. 1 when used with relatively low frequencies since greater control is obtainable. Especially when the oscillation frequencies are harmonically related a condenser, as illustrated, connected across inductance L_5 the resultant resonant circuit being tuned to the controlling oscillator frequency has been found to be of considerable assistance in the pulling-in function. The coupling is effected through inductance coil L_5 included in the output circuit of oscillator 2 and inductances L_6 and L_7 which are magnetically related thereto and included respectively in the input circuits of electric discharge devices 5 and 6 of controlled oscillator 1.

If the introduced controlled frequency is the same as for an odd harmonic of the controlling frequency the phases of the potentials impressed on the grids of the respective tubes should be opposite and the polarizations of the windings of inductances L_6 and L_7 should be such as to bring about this result. If the frequency of the oscillator is an even harmonic of the controlling frequency the polarizations should be such that these phases are alike.

It will be obvious that the general principles herein disclosed may be embodied in many other organizations widely different from those illustrated without departing from the spirit of the invention as defined in the following claims.

What is claimed is:

1. In combination, a source of alternating current, an oscillator comprising two electric discharge devices each having an anode, a cathode, and a controlling electrode, a frequency determining circuit constituted by a parallel relation of inductance and capacity elements, means connecting the cathodes of said devices in common to a point in said inductance intermediate its ends, means for connecting the termini of the inductance and capacity elements constituting said frequency determining circuit between the anode and controlling electrode of said devices in relatively reverse order, and a resistance connected between the anode and cathode of at least one of said devices.

2. The combination recited in claim 1 including a resistance connected between the anode and cathode of each of said devices.

In witness whereof, I hereunto subscribe my name, this 25th day of May, 1928.

RAYMOND A. HEISING.