Feb. 7, 1933. A. HUND 1,896,238

FREQUENCY CONTROL SYSTEM

Filed Sept. 13, 1926

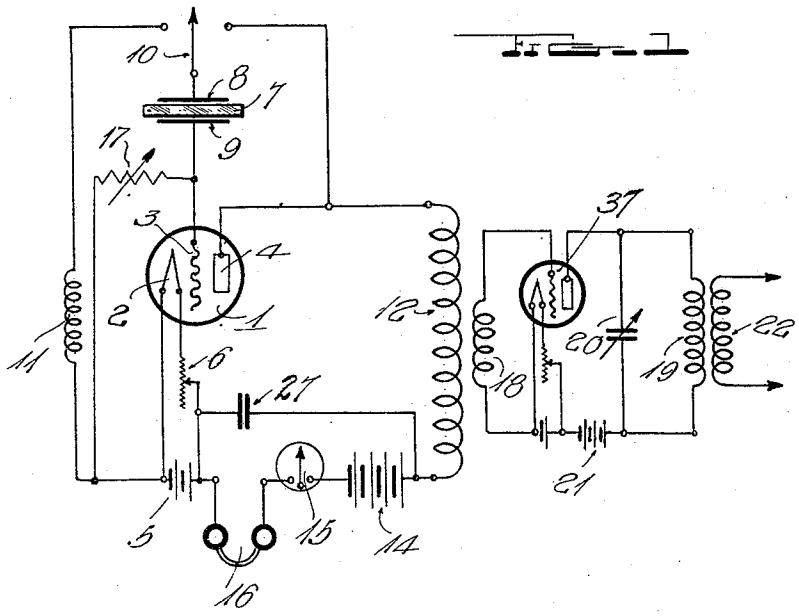


Fig. 1

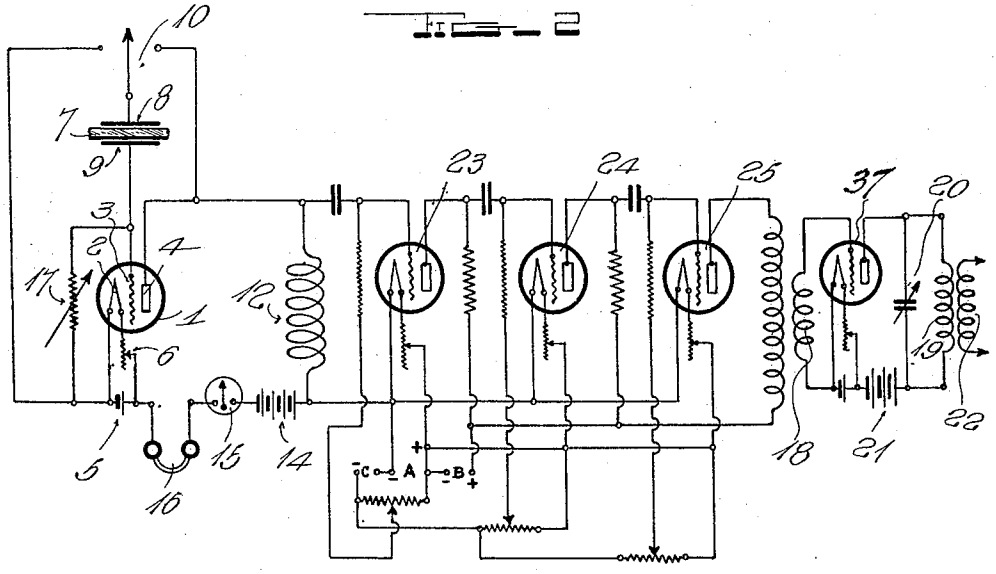


Fig. 2

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UNITED STATES PATENT OFFICE

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FREQUENCY CONTROL SYSTEM

Application filed September 13, 1926. Serial No. 135,241.

My invention relates broadly to piezoelectric oscillators and more particularly to circuits for sustaining constant frequency oscillations generated by piezoelectric crystals.

One of the objects of my invention is to provide a stabilized circuit arrangement for sustaining the high frequency oscillations of piezoelectric crystals and preventing the jumping of the frequency which may occur in such circuits due to improper cutting or preparation of the piezoelectric plate.

Another object of my invention is to provide a circuit arrangement for sustaining the oscillations of piezoelectric plates whereby the tendency of frequency change due to circuit oscillations, independent of the oscillations generated by the piezoelectric plate, is reduced to a minimum.

Still another object of my invention is to provide a circuit arrangement for sustaining the oscillations of a piezoelectric device in which the characteristics of oscillations generated by the piezoelectric device depend wholly upon the characteristics of the piezoelectric device without interference from parasitic oscillations which may normally occur in the circuit in which the oscillations of the piezoelectric crystal are sustained.

Still another object of my invention is to provide a circuit for sustaining the oscillations of piezoelectric plates wherein an electron tube circuit is coupled through a high frequency electron tube amplification system to a work circuit with special provision for eliminating the tendency of circuit oscillations in the electron tube circuits independent of the oscillations developed by the piezoelectric plates.

My invention will be more clearly understood from the following specification by reference to the accompanying drawing in which:

Figure 1 illustrates a circuit arrangement embodying the principles of my invention; Fig. 2 is a modified circuit arrangement showing the connection of a piezoelectric oscillator with a resistance coupled amplification system embodying the principles of my invention.

Heretofore in the art the characteristics of the electron tube circuits in which the oscillations of piezoelectric elements are sustained have been such that there is serious tendency for the setting up of undesired oscillations due to the constants of the circuit and independent of the oscillations developed by the piezoelectric crystal element. I have observed in a number of circuit systems in which the oscillations of piezoelectric plates are sustained the sudden jumping of the frequency. This jumping may be due to the improper cutting of a piezoelectric plate, that is the thickness oscillation does not occur exactly perpendicular to the plate since the plate may not have been properly prepared, as set forth in more detail in my U. S. Patent 1,822,928, dated September 15, 1931. Three slightly different thickness vibrations can then occur and a frequency jump to any one of the three is possible and may offset the frequency of the control circuit to which the piezoelectric plate delivers energy by a considerable number of cycles. I have found that frequency changes are due more particularly to circuit oscillations independent of the oscillations developed by the piezoelectric plate. The frequency may be entirely dependent upon the circuit constants instead of being due to the frequency of the crystal, or the frequency may be partially affected by the circuit constants.

A condenser is normally used for shunting the inductance in the anode branch of the piezoelectric crystal controlled electron tube oscillator and this condenser normally has a setting close to the resonance point in order to obtain maximum power output and as pure a sinusoidal current as possible. I have found that electron tube systems having an anode circuit and a grid circuit which are substantially in resonance for use in short wave operations that circuit oscillations occur due to the feed-back through the electron tube. A condition such as this occurring in a piezoelectric crystal control system gives rise to two currents one of which is due to the electromechanically vibratory device or crystal and the other due to the arrangement of the oscillator circuit. The result derived is a value of frequency which is not ex-

actly that due to the crystal and not exactly that due to the circuit constants but substantially intermediate the value between these two frequencies which are not very widely separated.

By my invention I provide a circuit arrangement for a piezoelectric crystal controlled oscillator wherein the output or anode circuit contains substantially pure inductance without a shunting capacity whereby the oscillations which are obtained are due to a strong fundamental current established by oscillations developed by the piezoelectric crystal, practically free of harmonics. The anode inductance is as large as possible and self-capacity effects avoided for eliminating the tendency toward circuit oscillations in the electron tube system. The slight sacrifice in efficiency by virtue of the off-resonance anode circuit is compensated for by the provision of an amplification system interposed between the output circuit of the oscillator and the work circuit in which the oscillations are usually employed.

Referring to the drawing in more detail, reference character 1 designates an electron tube having a cathode 2, a control electrode 3 and a plate element 4. The cathode 2 is heated by battery 5 under control of rheostat 6. The piezoelectric plate 7 is supported between conductive members 8 and 9 and by use of a switching device 10 the piezoelectric plate may be connected in shunt between the grid and plate electrodes or between the grid and filament electrodes through the choke coil 11. A grid leak 17 is connected between the grid electrode 3 and the cathode 2 in order to maintain the grid electrode at a suitable negative potential with respect to the cathode. The plate circuit includes an inductance 12 which is made as large as possible for the frequency for which the piezo-electric plate 7 is ground. A source of potential 14 is connected in the anode circuit in series with an indicator 15 and telephone headset 16, which may be shunted by means of a bi-pass condenser 27. It will be observed that the inductance 12 does not have a shunting capacity element thereacross and the self-capacity of this element is made as small as possible. In this manner the input and output circuits are rendered nonresonant so that the tendency for self-oscillations to be set up is extremely small. The circuit may then be set into oscillation entirely by the energy derived from the piezoelectric crystal.

In Fig. 2 I have illustrated a high resistance leak path 17 provided between the grid and filament electrodes for improving the efficiency of the oscillator by providing a negative grid bias to facilitate the starting of oscillations without the grid choke. The large inductance 12 has the effect of keeping the oscillations steady and rendering the input and output circuits non-resonant but arranged to sustain oscillations of the natural frequency of the piezoelectric element 7. The amplitude of the oscillations of the frequency corresponding to the fundamental frequency of piezoelectric plate 7 is increased by the amplification circuit including electron tube 37 having a coupling inductance 18 therein which couples with the inductance 12 in the oscillator circuit in Fig. 4. The output circuit of the amplifier may be tuned but the tuned circuit is so far removed from the oscillator circuit and shielded therefrom, that circuit oscillations in the oscillator circuit are not possible. The output circuit of the amplifier constituted by electron tube 37 includes inductance 19, shunted variable capacity 20 and high potential source 21. The work circuit connects across inductance 22 coupled with the output inductance 19.

In Fig. 2 I have shown a resistance coupled amplifier system constituted by electron tubes 23, 24 and 25 interposed between the output of the oscillator and the input circuit of the tuned amplifier system. The circuits of the resistance coupled amplifier system including tubes 23, 24 and 25 are not tuned and self-oscillation is prevented. The first tuned circuit occurs in the circuit of the amplifier constituted by tube 37 far removed from the oscillator circuit. The energy which is finally delivered to the work circuit through winding 22 is of constant characteristic depending entirely upon the frequency of the piezoelectric plate 7 and independent of circuit oscillations. The balancing of the resistance coupled amplifier system including the circuits of tubes 23, 24 and 25 preclude the setting up of circuit oscillations for interference with the oscillations generated by the piezoelectric crystal element. In the oscillator circuit per se the non-resonant characteristics of the input and output circuits prevent regenerative effects due to circuit characteristics although they permit the sustaining of oscillations of the frequency corresponding to the frequency of the piezoelectric crystal element.

While I have described my invention in certain preferred embodiments, I desire that it be understood that modifications may be made and that no limitations upon my invention are intended other than are imposed by the scope of the appended claims.

What I claim as new and desire to secure by Letters Patent of the United States is as follows:

1. A high frequency vacuum tube oscillator comprising an electron discharge device having cathode, grid, and anode electrodes, input and output circuits therefor, both of said circuits being substantially non-resonant to the frequency to be generated, a piezoelectric crystal element connected to a plurality of said electrodes, said input and output circuits and the grid to anode capacity being such that at the generated frequency, energy is adapted

to be transferred from said output circuit to said input circuit through a path independent of said crystal element, and an electron tube amplification system having resistance coupled stages and an output circuit for the last stage which is tuned to the frequency of said piezocrystal element.

2. In a piezoelectric control oscillator, the combination of an electron tube having grid, filament and plate electrodes, input and output circuits for said electrodes for the generation of oscillations, a piezoelectric crystal element connected to a plurality of said electrodes for sustaining oscillations in said circuits corresponding to the frequency of said crystal element, said circuits being non-resonant with respect to each other at the frequency of said crystal element, and an amplification system comprising a plurality of electron tubes interconnected by circuits having substantially aperiodic frequency characteristics, the output circuit of said amplification system located in a position remote from, and being tuned to the frequency of, said crystal element.

3. In a frequency control system, the combination of an electron tube having grid, filament and plate electrodes, input and output circuits of substantially aperiodic frequency characteristics connected to said electrodes for the generation of oscillations, a piezoelectric crystal element connected with a plurality of said electrodes for determining the frequency of said oscillations, said circuits being so arranged that, at the operating frequency, energy is adapted to be transferred from said output circuit to said input circuit through paths independent of said crystal element, means comprising a plurality of resistance coupled electron tube stages for increasing the amplitude of said oscillations, and an output circuit connected with said means at a point electrically remote from said crystal element and tuned to the frequency of said crystal element.

In testimony whereof I affix my signature.

AUGUST HUND.