Nov. 3, 1931. A. CROSSLEY 1,830,642

PIEZO ELECTRIC CRYSTAL CONTROLLED OSCILLATING SYSTEM

Original Filed June 11, 1928

Fig. 1.

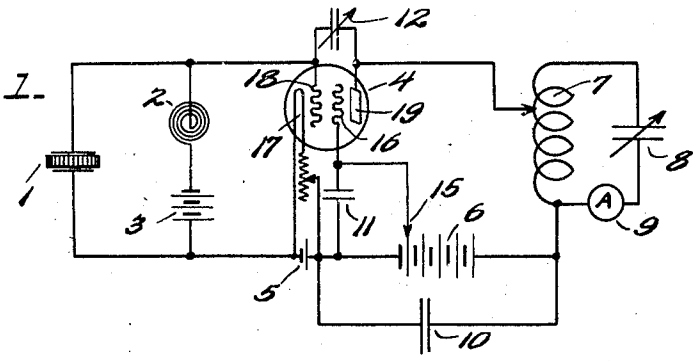


Fig. 2.

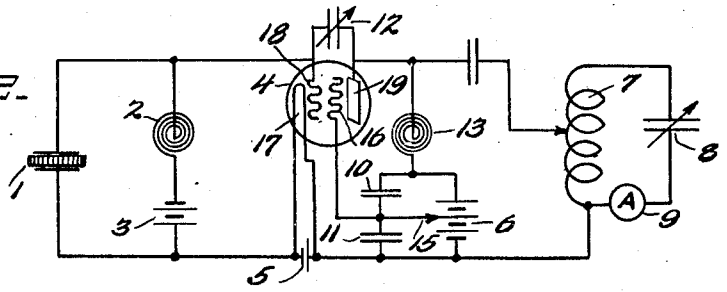


Fig. 3.

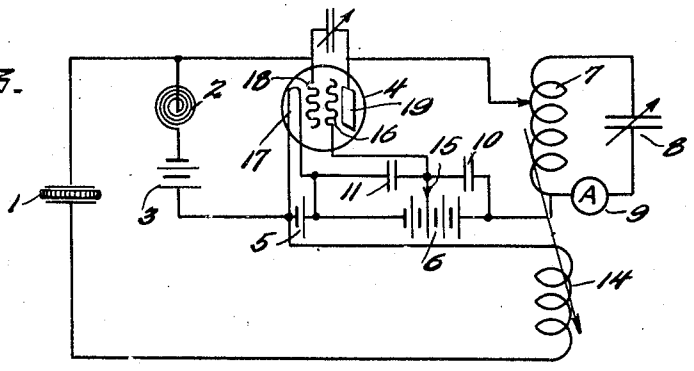
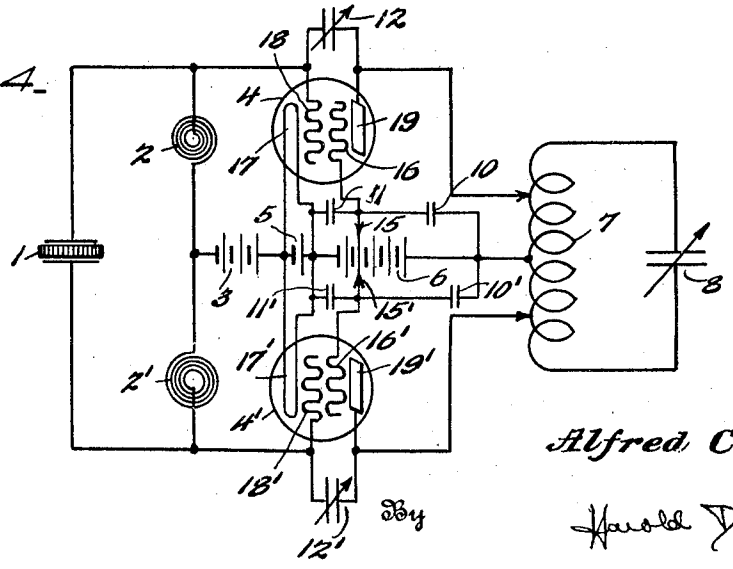


Fig. 4.



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UNITED STATES PATENT OFFICE

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PIEZO ELECTRIC CRYSTAL CONTROLLED OSCILLATING SYSTEM

Application filed June 11, 1928, Serial No. 284,571. Renewed October 9, 1930.

My invention relates broadly to circuits for the generation of electrical oscillations and more particularly to a piezo electric crystal controlled oscillator system.

One of the objects of my invention is to provide a circuit arrangement for sustaining the electrical oscillations of piezo electric crystal elements ground for any selected frequency characteristic with maximum efficiency.

Another object of my invention is to provide a circuit arrangement for sustaining the natural oscillations of a piezo electric crystal element independently of inherent characteristics of the electron tube employed in the oscillator circuit.

Still another object of my invention is to provide a piezo electric crystal oscillator system wherein the inherent interelectrode capacity of the electron tube system associated with the piezo electric crystal oscillator is compensated and oscillations sustained at the natural frequency of the piezo electric crystal independently of the characteristics of the electron tube.

My invention will be more fully understood from the following specification by reference to the accompanying drawings wherein:

Figure 1 is a diagrammatic illustration of the circuit arrangement of my invention showing a series feed crystal oscillator circuit; Fig. 2 shows an oscillator circuit embodying the principles of my invention for a parallel feed system instead of the series feed system of Fig. 1; Fig. 3 shows a modified circuit arrangement for an oscillator embodying the principles of my invention in which a system of double feed back is employed; and Fig. 4 illustrates the application of my invention to a push-pull type of oscillator system.

In the conventional piezo electric crystal controlled electron tube oscillating system the feedback means for obtaining the oscillation condition of the electron tube circuit is the capacity present between the grid and plate electrodes of the three electrode electron tube. This capacity is fixed by virtue of the permanent structure of the electron tube and its component parts, and the only means for obtaining greater grid voltage excitation is by resort to higher plate voltage or by the inefficient method of varying the amount of inductance in the plate circuit. For any given tube there is a definite frequency at which the circuit will oscillate at a maximum efficiency and any variation in frequency above or below this value will be accompanied by a reduced efficiency.

By reason of the inherent characteristics of the three electrode electron tube with its fixed feedback properties, maximum efficiency for fixed plate voltage is only obtainable at one particular frequency. The circuit arrangement of my invention provides means to overcome the limitations of the three electrode tube circuit, and for this purpose I employ a four electrode vacuum tube with special means for varying the feedback relation to obtain maximum efficiency.

The drawings show the special means employed for securing efficient operation of the piezo electric crystal controlled oscillator system. In Fig. 1 a variable capacity designated at 12 is used, while in Fig. 3 a combination of inductive and capacitive coupling is employed. The capacitive coupling in Figs. 1, 2 and 4 for the optimum efficiency condition should be decreased as the frequency is increased. Practice has shown that the capacity variation in the range from 2000 to 5000 kilocycles is from 25 to 4 micromicrofarads for optimum oscillation efficiency condition. The combination of inductive and capacitive feedback shown in Fig. 3 provides means for adjusting the feedback to a definite value by arranging the phase of the inductive feedback to be 180° out of phase with capacitive feedback, but of smaller value. The two feedback voltages add up algebraically, with the result that the total voltage is less than the voltage due to the capacitive feedback. The reverse inductive feedback acts as a limiting means and is desirable in certain cases where surges or stray magnetic feedback are present.

Referring to the drawings in more detail, reference character 1 designates a piezo electric crystal and holder, the crystal being con-

nected in series with the radio frequency choke coil and negative "C" battery 3. The four electrode electron tube is shown at 4 having the filament heating battery 5 and the plate battery 6 with the intermediate voltage contactor 15 which holds the shielding grid 16 at a definite voltage. The inductance 7 with condenser 8 connected in series with ammeter 9 complete the phase adjusting circuit. The by-pass condensers 10 and 11 function in by-passing the radio frequency current around the plate and shielding grid voltage sources. The condenser 12 is the means for varying the feedback to obtain maximum oscillation efficiency.

The four electrode electron tube 4 has four elements: The cathode 17 the control grid 18 the shielding grid 16 and the plate 19. The shielding grid 16 is positioned between the control grid 18 and the plate 19 and functions as an electrostatic shield, thus reducing the capacity between control grid 18 and plate 19 to a small fraction of its normal value. This negligible value of capacity between control grid and plate electrode practically eliminates any tendency for feedback in the tube and therefore makes this tube ideally suited for use in my piezo electric crystal oscillating system wherein I introduce a definite controlling feedback means in the form of the condenser 12 shown in the drawings. For best operation of this system it is necessary to provide a variable contactor 15 for the positive voltage source to the shielding grid 16 in order that a definite voltage be applied to this grid. Unless a voltage within ten per cent of the required amount is applied to the shielding grid 16 the circuit will not oscillate at maximum efficiency. It is also necessary to adjust the feedback condenser to a value which produces maximum oscillation efficiency without obtaining a dangerous value of current through the crystal.

In Fig. 4 I have shown a push-pull oscillator system having a piezo electric control circuit, with means for eliminating the effects of tube capacity and enabling oscillations to be sustained in the push-pull circuit which are independent of the characteristics of the tube system. The controlling grid 18 and plate 19 of electron tube 4 are interconnected by means of variable condenser 12. The control grid 18' and plate electrode 19' of electron tube 4' are interconnected by means of condenser 12'. The shielding grid 16 of tube 4 is shown at 16 connected to adjustable contactor 15 with battery 6. The shielding grid 16' of tube 4' connects through contactor 15' with battery 6 with condenser 11 connected in shunt thereto. Variable condenser 12' connects between grid electrode 18' and plate electrode 19'. Cathode 17' of tube 4' is heated from battery 5 which also serves to heat the cathode 17 of tube 4. Battery 3 is provided common to the input circuits of each of the tubes 4 and 4' and choke coil 2 is provided in the input circuit of tube 4, while choke coil 2' is positioned in the input circuit of tube 4'.

The piezo electric crystal oscillator system of my invention has been found to be extremely efficient in its operation for sustaining oscillations in accordance with the natural frequency of the piezo electric crystal element at an amplitude greater than that which it is possible to obtain in a tube system which is being forced to oscillate at the natural frequency of the piezo electric crystal element by virtue of the normal tendency of the tube system to oscillate at an amplitude determined by the capacity characteristics of the electron tube system.

The potential on the shielding grid is fixed from the source in the output system to that value at which the grid-plate capacity effects of the tube system are substantially eliminated, and oscillations may be sustained entirely by virtue of the artificial feedback due to the condenser 12 or the inductance 14.

The inductive feedback can be reversed and made to add to the capacitive feedback whereby the crystal will oscillate better if a minimum capacitive and a maximum inductive feedback is employed.

One of the advantages arising out of my invention is derived from the use of the four electrode or shielded grid tube which has substantially no capacitance between control grid and plate and the use of either external capacity or inductance of proper values to obtain maximum efficiency or output from a given crystal controlled system.

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 those 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. In a piezo electric crystal oscillator system, an electron tube having a cathode, a control grid and a plate, a shielding grid interposed between said control grid and said plate, a piezo electric crystal element connected with said control grid and said cathode, an oscillator system connected with said plate and said cathode, a high potential source in circuit with said plate, and means extending between said control grid and said plate to provide required feedback whereby said piezo electric crystal element operates to sustain maximum oscillations at the natural frequency thereof in said oscillator system.

2. In a piezo electric crystal controlled oscillator system an electron tube including a cathode, a plate, a control grid and a shield-

ing grid, a piezo electric crystal element, connections between opposite faces of said element, said control grid and said cathode, an oscillatory circuit, connections between said oscillatory circuit, said cathode and said plate, a high potential source connected in circuit with said plate, and a connection between a selected point on said high potential source and said shielding grid for substantially eliminating the capacity effects between the plate and grid of said electron tube and sustaining in said oscillatory system oscillations of a frequency corresponding to the natural frequency of said piezo electric crystal element.

3. In a piezo electric crystal control oscillator system, an electron tube including a heated cathode, a control grid and a plate, a shielding grid interposed between said grid and said plate, an input circuit including a piezo electric crystal element connected between said control grid and said cathode, an output circuit including a high potential source connected between said plate electrode and said cathode, an oscillatory system connected to said output circuit, a connection between a point on said high potential source and said shielding grid for substantially eliminating the capacity effects of said electron tube, and means connected between said control grid and said plate for facilitating the transfer of energy between said input and output circuits whereby said piezo electric crystal element sustains oscillations in said oscillatory system at the natural frequency of said piezo electric crystal element.

4. In a piezo electric crystal controlled oscillator system, an electron tube including a cathode, a plate, a controlling grid and a shielding grid, circuit connections from said controlling grid and said cathode to a piezo electric crystal element, an output circuit including said plate and cathode, an oscillatory system connected to said output circuit, and a source of potential in said output circuit, a tapped connection from an intermediate point on said source to said shielding grid, whereby oscillations of a frequency corresponding to the natural frequency of said piezo electric crystal element are sustained in said oscillatory system independent of the capacity effects of said electron tube.

5. In a piezo electric crystal controlled oscillator, a plurality of electron tubes each including a control grid, a shielding grid filament and plate electrodes, a piezo electric crystal element connected to each of said control grids, an oscillation circuit connected to each of said plate electrodes, and circuits connected with said shielding grid electrodes for sustaining in said oscillation circuit oscillations of a frequency corresponding to the natural frequency of said piezo electric crystal element independent of the frequencies fixed by the inherent capacity effects existing between said electrodes.

6. In a piezo electric crystal controlled oscillator, a pair of electron tubes, each including grid, filament and plate electrodes, an input system including the grid and filament electrodes of each of said tubes, an output system including the plate and filament electrodes of said tubes, a source of potential common to said output system, a shielding grid interposed between the grid and plate electrodes of each of said tubes and connected to a point along the potential source in said output system and a piezo electric crystal having its opposite faces connected to the grid electrodes of each of said electron tubes.

7. A vacuum tube device comprising a cathode, an anode, a control grid and a shield grid between said control grid and said anode, sources of potential for said electrodes, a variable capacity connected between said control grid and said anode, a piezo electric crystal connected with at least two of said electrodes for controlling the frequency generated and a connection between said shield grid and the source of potential for said anode.

8. The combination of a piezo electric element, a plurality of space discharge devices each provided with a control grid, a shield grid, a cathode, and an anode, said shield grid being interposed between said control grid and said anode, said control grids and said cathodes being connected in a series circuit containing said piezo electric element, a source of potential connection between said shield grids and said cathodes, said shield grids being thereby rendered positive with respect to said cathodes, and circuit connections between said anodes and said cathodes.

9. The combination of a piezo electric element comprising a plurality of terminals, a plurality of space discharge devices each including a control grid which is connected individually to one of said terminals, said discharge devices each including, in addition to said control grid, a cathode, a shield grid, and an anode, said cathodes being interconnected, a source of potential connected so as to render said shield grids positive with respect to said cathodes, and circuit connections between said anodes and said cathodes.

10. The combination of a piezo electric element comprising a plurality of terminals, a plurality of space discharge devices each including a control grid, said control grids being connected individually to different ones of said terminals, said devices each including, in addition to said control grids, a cathode, a shield grid, and an anode, an impedance element connected between said terminals, means interconnecting the cathodes of said devices with said impedance element at a point intermediate its connections to said terminals, a source of potential connected

between said cathodes and said shield grids whereby said shield grids are rendered positive with respect to said cathodes, and circuit connections between said anodes and said cathodes.

11. An electron tube device comprising a cathode, an anode, a control electrode and a shield electrode disposed between said control electrode and said anode, sources of potential for certain of said electrodes, a piezo electric element connected in a circuit including said cathode and another of said electrodes, and a capacity external to the electron tube connected to said control grid and said anode.

12. An electron tube device having a control grid, a shield grid, a cathode and an anode, a piezo electric element in a circuit including said control grid and said cathode, a tuned circuit connected to said anode and said cathode, a capacity external to said electron tube connected to said control grid and said anode, and a source of potential connected between said shield grid and said cathode.

13. In combination with an electron discharge device having a control grid, a shield grid, a cathode and an anode, circuits interconnecting said electrodes, a piezo electric element in the control grid circuit, means including said shield grid for reducing to a negligible amount the capacity effect between said anode and said control electrode, and means for feeding back a selected amount of energy from the anode circuit to the control grid circuit.

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