

July 7, 1936.

J. L. FINCH

2,046,618

CRYSTAL CONTROLLED OSCILLATION GENERATOR

Filed April 21, 1931

2 Sheets-Sheet 1

Fig. 1

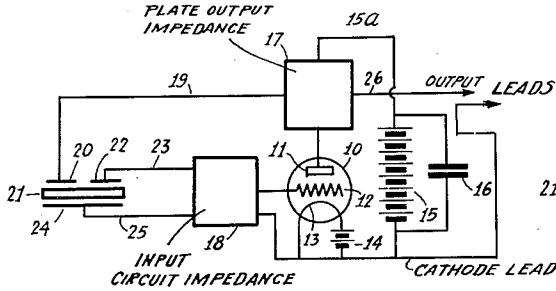


Fig. 3

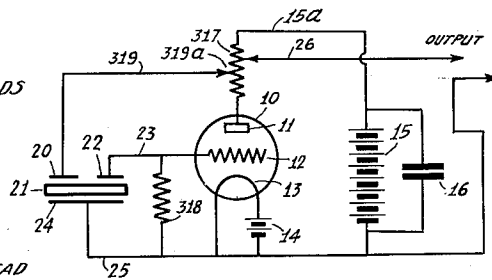


Fig. 2

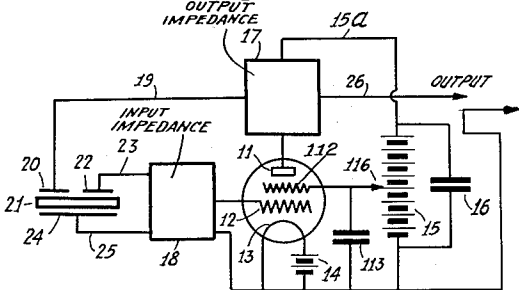


Fig. 4

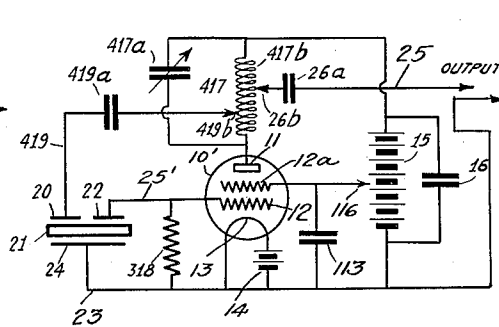


Fig. 5

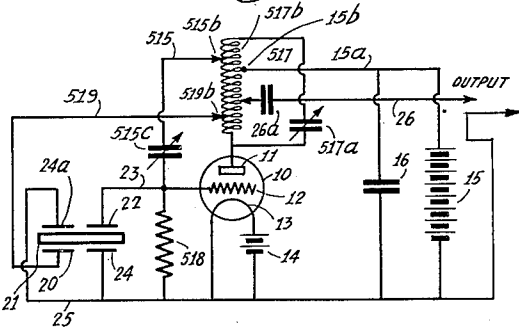


Fig. 6

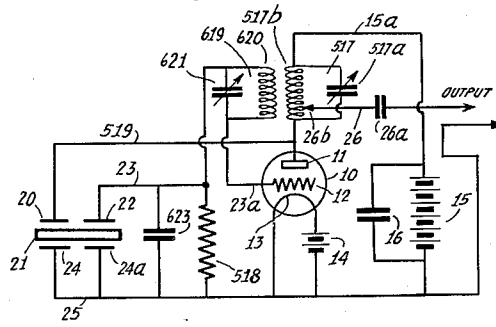


Fig. 7

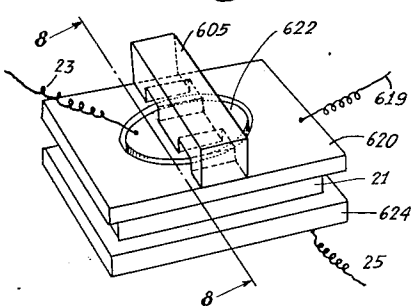
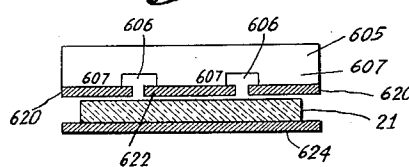


Fig. 8



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CRYSTAL CONTROLLED OSCILLATION GENERATOR

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2 Sheets-Sheet 2

Fig. 9

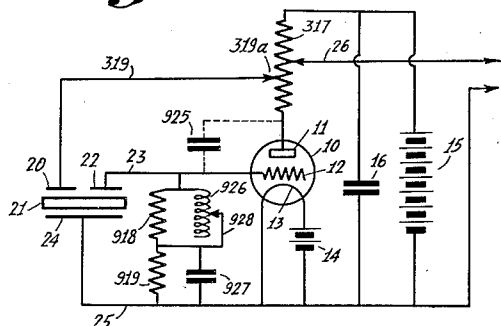


Fig. 10

Fig. 11

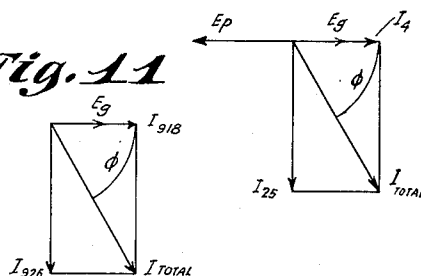


Fig. 12

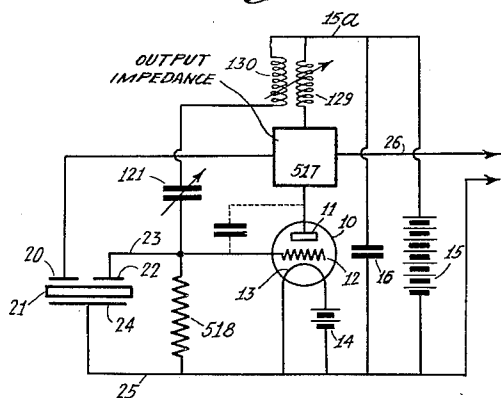


Fig. 13

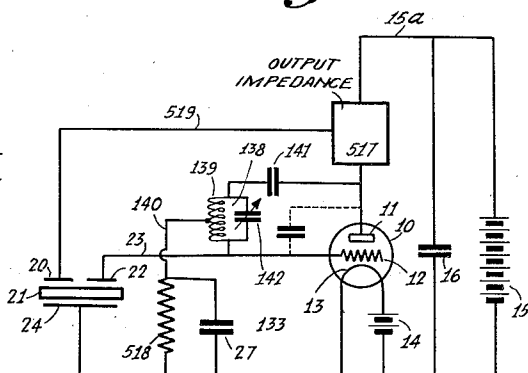
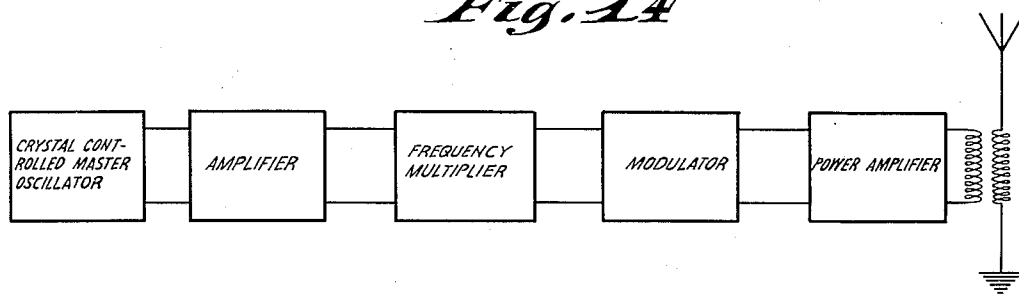


Fig. 14



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CRYSTAL CONTROLLED OSCILLATION
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Application April 21, 1931, Serial No. 531,684

16 Claims. (Cl. 250—36)

This invention relates to the piezo-electric art and deals more specifically with an oscillation generator whose frequency is maintained constant by means of a piezo-electric device.

It is an object of this invention to provide a crystal control circuit which is more forceful in its operation, and in which piezo-electric crystal resonators, which will not oscillate with ordinary circuits, may be used effectively as frequency stabilizing devices.

It is a further object of this invention to provide a piezo-electric crystal controlled circuit having a greater frequency stability than circuits heretofore known.

It is a further object of this invention to provide a crystal controlled oscillation generator having an increased power output as compared to prior art devices.

Further, it is an object of this invention to provide a crystal controlled oscillation generator in which the system may be made to oscillate at substantially higher frequencies.

And it is a further object of this invention to provide a crystal controlled oscillation generator in which the frequency of oscillation of the generator is determined by the thickness dimension of the crystal.

It is a further object of this invention to provide a crystal controlled oscillation generator in which the crystal vibrates in accordance with its longitudinal mode.

A further object of the invention is to provide a crystal controlled oscillation generator which during its normal operation generates a frequency which is resonant to the natural period of the crystal element when vibrating at a given mode.

It is a further object of this invention to provide a crystal controlled oscillation generator, the constants of which are so designed that the entire system oscillates at the resonant frequency of the crystal element.

And it is a further object of this invention to provide a crystal controlled oscillation generator in which the output circuit of the generator is coupled to the input circuit of the generator through the crystal.

Further, it is an object of this invention to provide a crystal controlled oscillation generator in which the feedback in said generator is realized only through the crystal element itself, all other feedbacks being eliminated.

Further, it is an object of this invention to provide a crystal controlled oscillation generator having its plate to grid capacity so reduced that

variations in potential in the output circuit are ineffective through the inherent capacity of the tube to produce variations in potentials in the input circuit.

And finally, it is an object of this invention generally to improve the operation of crystal controlled oscillation generators and to increase their frequency stability, as well as their power output.

These and other objects of the invention will be readily apparent to those skilled in the art from the following description taken in connection with the accompanying drawings, in which:

Fig. 1 is a simple schematic circuit diagram of an oscillator embodying the principles of the present invention;

Fig. 2 is a diagram of a circuit similar to Fig. 1, with the exception that a screen grid tube is used instead of the three element tube;

Fig. 3 is a schematic circuit diagram of a modified form of the invention;

Figs. 4, 5 and 6 relate to circuit modifications;

Figs. 7 and 8 relate to a schematic representation of the arrangement of the electrodes with respect to the crystal; Fig. 7 is shown as a perspective view and Fig. 8 is a sectional view taken on the line 8—8 of Fig. 7;

Fig. 9 relates to a modified form of the invention;

Figs. 10 and 11 are vector diagrams used in analyzing the operation of the circuit of Fig. 8;

Figs. 12 and 13 relate to modified forms of the invention; and

Fig. 14 is a schematic view of a complete system embodying the present invention.

Referring in detail to Fig. 1, a vacuum tube oscillation generator 10 having the usual plate 11, grid 12 and filament 13, is provided with a battery 14 for energizing the filament circuit and a voltage source indicated diagrammatically by the battery 15 to apply a potential to the plate 11. The condenser 16 is provided to shunt the radio frequency currents around the voltage source 15. Connected to the plate 11 of the generator 10 is an output circuit impedance 17 which is shown schematically to represent generically any well known type of output circuit of a vacuum tube oscillation generator such as, for example, a resonant circuit having parallel inductance and capacity. The plate voltage is fed from the source 15 to the plate 11 through the conductor 15a. Similarly, an input circuit impedance represented schematically and generically at 18 is shown connected between the grid and filament elements of the generator 10. It will also be understood that the input circuit 18 55

may be of any suitable type now commonly used in connection with vacuum tube oscillation generators. Connected to a suitable point of the output circuit 17 by means of the lead 19 is the electrode 20, which is associated with the piezo-electric crystal element 21, which element functions as the frequency control device. A second electrode 22 is associated with the crystal and is connected to the input circuit 18 by means of the lead 23. A third electrode 24 associated with the crystal is connected to the input circuit 18 by the lead 25. The details of the arrangement of the electrodes in association with the crystal element will be more fully described hereinafter.

- 15 The energy output of the oscillation generator 10 is taken off by means of a lead 26 which is connected to a suitable point in the output circuit 17.

The operation of this circuit is as follows:
20 Any voltage waves impressed on grid 12 of the tube 10 are amplified in the tube and are in turn impressed upon the plate circuit 17 by the plate 11. Energy is fed back from the output circuit 17 and is impressed on electrodes 20 and 24. If this energy is periodic and corresponds in frequency to some mode of mechanical oscillation of the crystal member 21, it will set up oscillations in said crystal. Due to these oscillations, and also due to the piezo-electric properties of the crystal, voltages of this same frequency will be impressed upon electrodes 22 and 24. These voltages are introduced into the input circuit 18 which can be such as to impress voltage waves upon the grid 12 identical with those originally assumed. Thus, this circuit will sustain oscillations and if other conditions are correct it will build up oscillations from an initial non-oscillating state, and the output of this generator may be taken off by the lead 26 and the cathode or ground lead as indicated.

It will be understood that a system such as disclosed in Fig. 1 operates at a frequency determined by the thickness dimension of the crystal and also at a frequency resonant to the natural period of the crystal. In view of these facts the frequency stability which can be realized with the present circuit is greater than with the circuits of the prior art which do not operate at resonance of the crystal.

- 50 Referring now in detail to Fig. 2, the circuit diagram therein disclosed is identical with that of Fig. 1, with the exception that a screen grid tube has been used having the additional grid 112 to which there is applied a positive potential by means of a variable tap 116 connected to the source 16. A by-pass condenser 113 is provided as shown.

The principle of operation of the present circuit is substantially the same as that set forth in connection with the operation of the circuit of Fig. 1, and it has been found in actual practice that substantially the same results are obtained in both cases with the exception that the power output is greater when using the screen grid tube and under certain conditions the degree of frequency stability is improved when using such tube.

- Fig. 3 relates to a modified form of the circuits shown in Figs. 1 and 2. This circuit comprises a vacuum tube oscillation generator 10 having plate 11, grid 12 and filament 13. The filament is energized by the battery 14. The plate voltage supply 15 and by-pass condenser 16 are provided for the purpose already described in connection with the preceding figures. The

lead 26 having a variable tap connection indicated by the arrow serves to connect the output circuit of the generator to the load. A plate resistor 317 is used instead of the output circuit 17, and connected to this resistor by a variable tap 319a is the lead 319 which also connects to the electrode 20, which electrode is associated with the crystal element 21. The electrodes 22 and 24 are connected respectively to the grid and filament of the generator by the leads 23 and 25 as has already been described. Instead of the conventional input circuit 18 a grid leak resistor 318 is connected between the grid 12 and the filament 13.

It will be seen that the circuit of this figure 15 is substantially the same as the preceding circuits, with the exception of the foregoing differences, and this circuit has been found in practice to give good results as a crystal controlled oscillator. This circuit also may be further modified by substituting a screen grid tube for the three element tube 10 in the same way that the circuit of Fig. 2 employs a screen grid tube instead of the three element tube of Fig. 1.

Fig. 4 illustrates a further modification of the present invention and briefly may be said to comprise a screen grid oscillator having a tuned output circuit. Referring in detail to Fig. 4, the vacuum tube oscillation generator 10' has the plate 11, control grid 12, screen grid 12a and filament 13, the filament being energized by the battery 14, and the plate voltage being applied by means of the potential source 15 having the usual by-pass condenser 16. The output circuit 417 connected to the plate 11 comprises a parallel inductance 417b and a variable condenser 417a which are in turn connected to the positive terminal of the plate voltage supply. The output is taken off by means of the lead 25 having a variable tap 26b which is adjusted lengthwise of the inductance 417a. A suitable blocking condenser 26a is provided in accordance with the well known practice of the prior art. The screen grid 12a is connected to the voltage source 15 by means of the variable tap 116, whereby suitable positive potential may be impressed upon this screen grid, and the by-pass condenser 113 is connected to the filament terminal as shown.

Connected from a suitable point on the inductance 417b to the electrode 20 by means of the variable tap 419b is the lead 419 having a blocking condenser 419a therein. The electrode 24 is connected to the filament and the electrode 22 is connected to the control grid 12 by means of the leads 25' and 23 respectively as has already been described above. The grid leak resistor 318 is connected between the grid and filament as shown.

The operation of the circuit of Fig. 4 is the same in principle as the operation of the circuits of the preceding figures, and this circuit has been found in practice to give highly practical results in that it has an improved characteristic of frequency stability as well as power output.

Coming now to Fig. 5, there is illustrated an arrangement for neutralizing the plate to grid capacity of the vacuum tube oscillator. Since the crystal controlled oscillators, constructed in accordance with the present invention, operate at the resonant frequency of the crystal and by virtue of the feedback of energy from the plate circuit to the grid circuit through the crystal itself, it has been found that a greater degree of control and generally more satisfactory operation may be had if all feedbacks which might take place in

the oscillation system are eliminated with the exception of that taking place through the crystal itself. To this end, the oscillation generator 10 has been provided with a neutralizing circuit for eliminating the effect of the plate to grid capacity in a manner hereinafter described.

Referring in detail to Fig. 5 of the drawings, a vacuum tube oscillation generator 10 having the usual plate 11, grid 12 and filament 13, has connected to its plate the output circuit 517 which comprises the parallel inductance 517b and variable condenser 517a. From an intermediate point of the coil 517b the lead 15a is connected from the tap 15b on the coil through the condenser 16 to the filament 13. The plate voltage from the source 15 is applied to the plate by means of the lead 15a. Output is taken from lead 26, which contains the blocking condenser 26a. A lead 515 connects from the variable tap 515b on the inductance 517b through the neutralizing variable condenser 515c to the grid 12. The lead 519 connects the electrode 20 to the variable tap 519b on the inductance 517b. The electrodes 24a and 24 are connected to the filament 13 by means of the lead 25 while the electrode 22 is connected to the grid 12 by means of the lead 23. The grid leak resistor 518 is connected between the grid and filament as shown.

It will be noted that the electrodes 24a and 24 are both at the same potential but they are placed on opposite sides of the crystal. This differs from the preceding circuits in which the electrode 24 was a single element. By virtue of the present arrangement of the electrodes 24a and 24 a different mode of vibration of the crystal may be had. It was pointed out in the Cady Patent No. 1,472,583 that by a similar reversal of the electrodes a harmonic frequency of the crystal resonator could be obtained:

The present circuit must be neutralized for the interelectrode capacity of the crystal resonator as well as for the plate to grid capacity of the tube. A system for neutralizing the interelectrode capacity of the crystal resonator is disclosed in a copending application of C. W. Hansell, which resulted in a patent issued on June 18, 1935, as Patent No. 2,005,083.

The circuit of Fig. 5 has been found in actual practice to have desirable power and frequency stability characteristics and its operation is effectively the same as the operation of the foregoing circuits employing screen grid tubes. While Fig. 5 has disclosed specifically plate circuit neutralizing of the inherent plate to grid capacity of the tube, it will be understood by any one skilled in the art that input neutralization may also be employed without departing from the spirit and scope of this invention.

Referring in detail to Fig. 13, an oscillator of the type disclosed in Fig. 5 is shown having its plate to grid capacity neutralized in accordance with the well known Rice system of neutralization. In this figure all of the parts forming the fundamental oscillator circuit have been designated by the same reference characters as those used in connection with Fig. 5, the only difference being the neutralizing arrangement which comprises the tuned circuit 138 having the coil 139 across the terminals of which is connected the variable condenser 142. One terminal of the coil 138 is connected to the grid 12, while the other terminal of the coil is connected to the plate 11 through the neutralizing condenser 141. From the midpoint of the coil 139 the lead 140 connects to the grid resistor 518 which is by-passed by the

condenser 27. The inherent plate to grid capacity of the tube is represented schematically by the dotted line condenser connected directly between the plate and grid of the tube. Also, any other well known neutralizing scheme may be used, such as, for example, the so-called Hartley neutralization by reverse inductive feed-back.

The circuit of Fig. 6 provides either an alternative method of neutralizing the plate to grid capacity feed-back in the tube, or for reinforcing the feed-back to produce stronger oscillations. Whether the circuit is arranged for neutralization of the plate to grid capacity, or whether it is arranged so that increased regeneration is had and therefore stronger oscillations, depends entirely upon the polarity of the coils 620 and 517a with respect to each other; the circuit for neutralization being the well known Hartley circuit and the one for regeneration being the well known Armstrong circuit.

Fig. 6 shows another modification of the present invention in that an inductive coupling has been introduced from the plate circuit to the grid circuit. The oscillation generator 10 having the plate 11, grid 12 and filament 13, has its output circuit 517 constructed in accordance with the disclosure of Fig. 5, similar reference numerals being used for similar parts in the both figures. A detailed description of these elements is not given in connection with this figure for the reason that this would be nothing more than a repetition of the description of the corresponding parts of Fig. 5. Similarly, the input circuit of the present figure is the same as that of Fig. 5 and corresponding parts are represented by corresponding reference numerals. However, the resonant circuit 619 connected in the input circuit of the oscillation generator and inductively coupled to the output circuit 517 is a distinctive feature of the present circuit. The input circuit 619 it is seen comprises the coil 620 which is inductively coupled to the coil 517b and the parallel capacity 621 is used to tune the coil 619 to resonance. A capacitor 623 is added in shunt with the resistor 518, across which a direct current voltage is built up due to grid rectification. This capacitor serves to aid in properly biasing the grid.

It will be understood that for the higher range of frequencies the inductance 620 may simply consist of the inductance of the grid circuit leads and the coupling of 517 may consist solely of the natural coupling between these leads. Also, capacitor 623 may be comprised of the natural capacity between the crystal electrodes 4 and 5 and between the conductors in the circuit.

In the present invention particular use has been made of crystals vibrating at their longitudinal mode or at a frequency determined by the thickness dimension. To facilitate such vibration of the crystal the special arrangement of electrodes shown in Figs. 7 and 8 has been devised. Referring in detail to Figs. 7 and 8, the bottom electrode 624 upon which the crystal element 21 rests has the lead 25 connected thereto which permits the electrode to be connected to the circuits as described above. One of the upper electrodes 620 is arranged to cover the whole of the crystal 21, with the exception that a portion is cut out at its center and in place of this portion the other upper electrode 622 is placed. The electrode 622 is supported evenly with respect to the electrode 620 by means of the insulating strip 605 having the cutout portions 606 and the supporting surfaces 607 (Fig. 8). 75

Both the electrodes 622 and 624 are held in fixed relation with respect to each other. The lead 619 and the lead 23 are provided to connect the electrode 620 and 622 respectively into the desired electrical circuit. Of course, it will be understood that the crystal resonator comprising the three electrodes and the crystal section are mounted within any suitable casing which may be hermetically sealed or evacuated as desired.

Also, any of the well known thermostatic temperature control arrangements may be employed in connection with this device.

The electrodes disclosed in Figs. 7 and 8 may take various other forms such as, for instance, grills in which the alternate bars below the crystal are connected together to form the electrode 24, and the remaining bars below the crystal forming the electrode 24a as disclosed in Fig. 6. Similarly, the two electrodes 620 and 622 above the crystal may consist of alternate bars of the grill connected together. The purpose of this arrangement is to provide excitation voltages to a sufficient area of the crystal and to disperse these excited areas over the total area sufficiently to cause the crystal to distend itself uniformly, and to disperse the areas from which the energy is picked up from the crystal to such an extent that the crystal is not damaged. For the mode of vibration of the crystal in which it bends, or for torsional vibrations in which the crystal twists, or for vibrations in which waves are set up at one point and travel along or across the crystal, other arrangements of the electrodes are required.

The action of a crystal resonator such as described in Figs. 7 and 8 and applied to Figs. 1 to 6 inclusive may be explained as follows:

Assume that the source of direct electromotive force is connected with its positive terminal to the electrode 620 and its negative terminal to the electrode 624 (Figs. 7 and 8). The field thus produced exerts a deforming force on the crystal which, for the sake of illustration, we can assume tends to increase the crystal's thickness and the energy required to do this is supplied from the electric source in the form of current flow. When the thickness of the portion of the crystal under electrode 620 is increased, that portion of the crystal under electrode 622 is also increased to some extent. This change in thickness causes current to flow in the circuit connecting electrodes 622 and 624, in the same direction as that flowing between electrodes 620 and 624. If electrode 622 is connected to electrode 624 through a resistance this will set up a voltage across it, the end connected to 622 being negative. Now, if we assume a source of alternating voltage as connected between 620 and 624 having frequency corresponding to the natural period of the crystal, mechanical oscillations of relatively high amplitude will be set up in the crystal. The thickness of the portion below the electrode 622 will vary practically the same as that under electrode 620 due to the relatively high "coupling" between these sections and the relatively small amount of energy necessary to maintain these oscillations. This action can be compared to the electric oscillations in an Alexanderson multiple tuned antenna, in which only one section is excited directly but the whole of which responds almost equally. Referring to Fig. 3, if we assume alternating voltage impressed on electrodes 20 and 24, and if we assume the crystal resonant to this same frequency, the current flowing in this circuit will be in phase with the

voltage. Also, since the resistor 318 is the major impedance in the circuit between electrodes 22 and 24, the current in this circuit will be essentially 180° out of phase with that on the electrode 20. The voltage on electrode 20 corresponds in phase to that on the plate electrode 11 of the vacuum tube and that on electrode 22 is identical with that on the grid 12. Thus, the condition is produced for oscillation in the circuit as a whole.

In the foregoing modifications of the invention it has been shown that the plate to grid capacity of the oscillator tube is an important factor in the operation of the system, and several arrangements for counteracting the effect of this capacity are disclosed. It has been found that in the operation of circuits of the foregoing type, maximum efficiency, both with regard to frequency stability and power output, may be assured by arranging the constants of the tube circuits so that the proper phase relationships exist between the alternating current voltages in the input and output circuits.

Referring in detail to Fig. 9 of the drawings, a three electrode vacuum tube is disclosed having an arrangement whereby the oscillations generated by the tube are controlled by means of the crystal element 21 in the manner more specifically described above in connection with Fig. 3. This circuit, however, differs from that of Fig. 3 in that in place of the resistor 318 a resistor 918 and a grid leak 919 are connected in series between the grid and the filament, and the resistor 918 is shunted by a reactor 926 having a variable connection 928 which runs from the end of resistor 918 to an adjustable point on the inductance 926. The blocking condenser 927 is connected between the filament and the lead 928 as shown.

The inherent plate to grid capacity of the tube is shown by the dotted condenser connected thereacross and designated by reference numeral 925.

Referring now to Figs. 10 and 11, a vector analysis will be made of the operation of this system, showing whereby with suitable adjustment of the values in the input circuit constants, maximum efficiency of the generator may be realized.

The vector diagrams of Figs. 10 and 11 are drawn assuming that the circuit is adjusted for the best condition of oscillation. Thus, the alternating voltage between the plate and filament is shown by the vector E_p , while the alternating voltage impressed between the grid and filament is shown by the vector E_g being 180° out of phase with E_p and being smaller in the same relation dependent upon the μ of the tube used in this particular circuit. Across the condenser 925 of Fig. 9 (inherent capacity of the tube) there is impressed an alternating voltage equal to the sum of E_p and E_g . This voltage causes a current to flow from the plate to the grid shown in Fig. 10 as I_{25} . This current leads the plate voltage by an angle of 90°. The piezo-electric action of the crystal causes a current to flow from the electrode 22 through resistor 918 and inductor 926. If we assume that the crystal is oscillating at resonance, and if we assume further that the lead connected to 22 does not react appreciably upon the crystal, then the current flow in 22 will be 180° out of phase with E_p . This is shown as I_4 in Fig. 10. The quantities I_4 and I_{25} add vectorially to give the total I as shown. Fig. 11 shows the current total (I total) to correspond

to that in Fig. 10. This current divides between 918 and 926 as shown in Fig. 11 as I_{918} and I_{926} , I_{918} leading I_{926} by 90° . Fig. 11 also shows the voltage between the grid and filament E_g which is, of course, in phase with I_{918} . This voltage is the same as that originally assumed, thus proving the original assumption to be correct.

A D. C. grid bias is realized due to the flow of current caused by grid rectification in the resistor 919. It is possible to omit the resistor 919 and to connect 918 directly to the filament circuit instead of in shunt with 926 as shown. In this case the resistor 918 serves as the grid leak.

Referring to Fig. 12, there is shown another means for neutralizing the plate to grid capacity feed-back in a crystal controlled oscillator. In this case a coupler with primary 129 and secondary 130 is added between the plate circuit 517 and the grid circuit as shown. A voltage is induced in the coil 130 which voltage is 180° out of phase with that between the plate and filament. This voltage is impressed upon the grid 12 through the coupling capacitor 121. Thus, a voltage is impressed on the grid by this means which is equal to and 180° out of phase with the voltage impressed on the grid through the plate to grid capacity shown in dotted lines. The plate impedance 517 may be a pure resistance, pure inductance, a combination of resistance and inductance, a combination of resistance and capacity, a combination of inductance and capacity, or a combination of inductance, capacity and resistance. When both inductance and capacity are present, the circuit 517 may be tuned to resonance or alternatively to a higher or lower frequency as compared to the natural period of the crystal. Also, the inductance 129 may be a part of the circuit 517 when inductance is used therein.

The foregoing figures and description relate solely to the crystal controlled oscillator itself. There will now be described briefly a signaling system employing radio frequency currents in which such a crystal controlled oscillator may be used, it being understood that the use of this crystal controlled oscillator is not limited to such a system, it being disclosed specifically in connection therewith merely for the purposes of illustration. For example, the crystal controlled oscillator of this invention may be used for all purposes for which crystal controlled oscillators are now used. Also the device of the present invention may be used in a receiving system operating on the heterodyne principle in which the local source of oscillations is controlled in accordance with the teachings of this invention.

Referring now to Fig. 14, the crystal controlled master oscillator is shown at the left and this feeds into an amplifier which in turn has its output connected to a frequency multiplier from which the energy is led to a modulator and from the modulator to a power amplifier which is in turn connected to a radiating antenna. It will be understood by those skilled in the art that the herein disclosed transmitting system is merely schematic and that certain operations may be performed in the same stage. For example, the modulation may be carried out in the power amplifier. The character of the transmitting system may be varied further in accordance with the well known practices of the prior art without departing from the spirit and scope of this invention, the purpose of this figure being merely to show one specific embodiment in which the present invention may be employed.

Having thus described my invention, I claim:

1. In combination, a vacuum tube oscillation generator having filament, grid and plate elements, an input circuit interconnecting said grid and filament, an output circuit interconnecting said plate and filament, an electro-mechanical vibrator adapted to be stimulated electrically to vibrate mechanically and to respond electrically to said mechanical vibrations, the said vibrator being connected to said generator and adapted to control the frequency of said generator through said electrical response, a variable inductance connected in said input circuit, and a resistor connected in parallel to said inductance, said resistance and inductance acting to compensate interelectrode feed back from said plate to said grid elements whereby, at a desired resonance frequency of said vibrator, said grid and plate oscillate in potential 180 degrees out of phase.

2. In combination, a vacuum tube oscillation generator having filament, grid and plate elements, an input circuit interconnecting said grid and filament, an output circuit interconnecting said plate and filament, an electro-mechanical vibrator adapted to be stimulated electrically to vibrate mechanically and to respond electrically to said mechanical vibrations, the said vibrator being connected to said generator and adapted to control the frequency of said generator through said electrical response, a variable inductance connected in said input circuit, a resistor connected in parallel to said inductance, and a blocking condenser connected in said input circuit in series with said inductance said resistance, inductance and blocking condenser acting to compensate interelectrode feed back from said plate to grid whereby at a desired resonance frequency of said electromechanical vibrator, said grid and plate oscillate in potential 180 degrees out of phase.

3. In combination, a vacuum tube oscillation generator having filament, grid and plate elements, an input circuit interconnecting said grid and filament, an output circuit interconnecting said plate and filament, an electro-mechanical vibrator adapted to be stimulated electrically to vibrate mechanically and to respond electrically to said mechanical vibrations, the said vibrator being connected to said generator and adapted to control the frequency of said generator through said electrical response, a variable inductance connected in said input circuit, a resistor connected in parallel to said inductance, a blocking condenser connected in said input circuit, and a grid leak connected between said grid and said filament, said resistance, inductance and blocking condenser acting to compensate interelectrode feed back from said plate to grid whereby at a desired resonance frequency of said electro-mechanical vibrator, said grid and plate oscillate in potential 180 degrees out of phase.

4. A vacuum tube oscillation generator having filament, grid and plate elements, an input circuit connected between said grid and said filament, an output circuit connected between said plate and said filament, a three electrode piezoelectric device for controlling the frequency of said generator, one of said electrodes being connected to each of said grid, plate and filament electrodes, an inductive reactance connected between said grid and said filament, and a resistance connected in parallel with said inductance, said inductance and resistance acting to compensate plate to grid capacity feed back whereby

at a desired resonant frequency of said piezo-electric device, said grid and plate oscillate in potential 180 degrees out of phase.

5. A vacuum tube oscillation generator having
5 filament, grid, and plate elements, an input circuit connected between said grid and said filament, an output circuit connected between said plate and said filament, a three electrode piezo-electric device for controlling the frequency of
10 said generator, one of said electrodes being connected to each of said grid, plate and filament electrodes, an inductive reactance connected between said grid and said filament, and a condenser connected in series with said inductance
15 said inductive reactance and condenser acting to compensate plate to grid capacity feed back whereby at a desired resonant frequency of said piezo-electric device, said plate and grid oscillate in potential 180 degrees out of phase.

20. 6. In combination, a vacuum tube oscillation generator having filament, grid and plate elements, an input circuit interconnecting said grid and filament, an output circuit interconnecting
25 said plate and filament, an electro-mechanical vibrator adapted to be stimulated electrically to vibrate mechanically and to respond electrically to said mechanical vibrations, the said vibrator being connected to said generator and adapted
30 to control the frequency of said generator through said electrical response, a first unit comprising a resistor and an inductor connected in parallel to each other, a second unit comprising a grid leak and a condenser connected in parallel to each other, both said units being
35 connected in series between said grid and said filament.

7. A piezo-electric crystal holder comprising a first electrode, a second electrode having a hole therein, means for holding said second electrode
40 spaced away and insulated from said first electrode, a third electrode positioned within said hole, and means for supporting said third electrode from said second electrode and for insulating it therefrom.

45 8. A piezo-electric crystal holder comprising a first electrode, an enclosing electrode, means for holding said enclosing electrode spaced away and insulated from said first electrode, a third electrode centrally positioned with respect to said
50 enclosing electrode, and means for holding said third electrode spaced away and insulated from said other electrodes.

9. A piezo-electric crystal holder comprising a first electrode, a second electrode having an aperture therein, means for holding said second
55 electrode spaced away and insulated from said first electrode, a third electrode positioned within said aperture, and an insulated strip having cut-away portions located at the inner periphery of
60 said second electrode and the outer periphery of said third electrode for supporting said third electrode from said second electrode and for insulating it therefrom.

65 10. An oscillator comprising a tube having a cathode, a cold anode electrode and a cold control electrode, a voltage source and an impedance element connected between said cathode and said cold anode, a piezo-electric crystal, an electrode on one side thereof, two electrodes on the
70 other side thereof, one of said electrodes surrounding the other, means for connecting said first crystal electrode to said cathode, means for connecting the surrounding electrode to one of
75 said cold tube electrodes, and means for connect-

ing the enclosed crystal electrode to the other of said tube cold electrodes.

11. An oscillator comprising a tube having a cathode, an anode and a control electrode, a voltage source, an impedance element connected between said cathode and said anode, a piezo-electric crystal, an electrode on one side of said crystal connected to said cathode, two electrodes on one side of said crystal one of said two crystal
10 electrodes surrounding the other of said two crystal electrodes, said surrounding electrode and the enclosed electrode being connected to the anode and said control electrode respectively.

12. A piezo-electric crystal holder comprising a first electrode, a surrounding electrode, means
15 for holding said surrounding electrode spaced away and insulated from said first electrode, a third electrode centrally positioned with respect to said surrounding electrode, and means for holding said third electrode spaced away and in-
20 sulated from said other electrodes.

13. An oscillator comprising an amplifier including a cathode and having an input circuit including a grid and an output circuit including
25 an anode, an electro-mechanical vibrator having two electrodes one surrounding the other, one of said two vibrator electrodes being connected to said anode and the other of said two vibrator electrodes being connected to said grid, said electro-mechanical vibrator having a third elec-
30 trode opposite said two electrodes which is connected to said cathode, said vibrator being adapted to vibrate mechanically when stimulated electrically and to respond electrically when vibrated mechanically.

14. A crystal controlled oscillator comprising a tube having a cathode, a cold anode electrode and a cold control electrode, a voltage source and an inductance coil connected between said
40 control electrode and said cathode, and a three-electrode crystal holder comprising an electrode connected to said cathode and two crystal electrodes facing said first electrode, one of said two electrodes being concentrically located within
45 the other and being connected to one of said cold electrodes and the other of said two crystal electrodes being connected to the other tube cold electrode.

15. An oscillator comprising a tube having a cathode, an anode, and a control electrode, a voltage source and an impedance element connected between said cathode and said anode, a piezo-electric crystal, an electrode on one side of said
50 crystal connected to said cathode, two electrodes on the other side of said crystal, one of said two electrodes being in the shape of a plate and the other of said two electrodes being positioned concentrically within the plate, said plate-shape electrode and said other electrode being connected
55 to said anode and to said control electrode, respectively.

16. A crystal-controlled oscillator comprising a tube having a cathode, an anode, and a control electrode, a voltage source and a tunable resonant circuit connected between said cathode and
65 said anode, a grid leak resistor connected between said control electrode and said cathode, and a three-electrode crystal holder comprising an electrode connected to said cathode, and two electrodes facing said first electrode, one of said two
70 electrodes being concentrically located within the other and being connected to said control electrode, and the other of said two crystal electrodes being connected to said anode.

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