

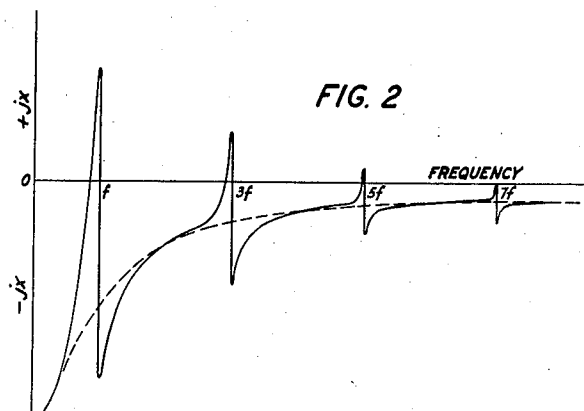
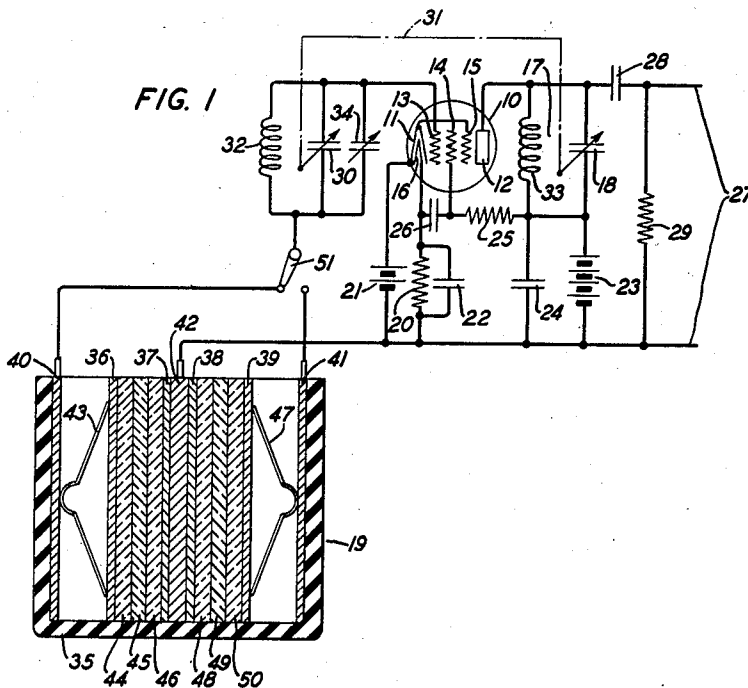
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PIEZOELECTRIC OSCILLATOR

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PIEZOELECTRIC OSCILLATOR

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This invention relates to oscillators having piezoelectric frequency control.

An object of the invention is to provide a piezoelectric controlled oscillator which may readily oscillate at harmonic frequencies of the piezo-
electric element.

Another object of the invention is to provide a single frequency control which will permit selection of the oscillation frequency and at the same time will adjust the reactances immediately associated with the piezoelectric element to magnitudes suitable for the selected oscillation frequency.

An additional object of the invention is to enable the use of a plurality of stacked different frequency piezoelectric elements to provide a corresponding number of series of harmonic frequencies any of which may be readily selected to determine the frequency of the oscillations produced to the exclusion of all others.

An additional object of the invention is to provide a piezoelectric controlled oscillator with a single frequency control which shall simultaneously vary the associated input reactance to maintain it positive.

Piezoelectric controlled oscillators provide a very nicely controlled constant frequency oscillation. If an electron discharge tube with the usual connection of piezoelectric crystal between the cathode and grid be employed the piezoelectric element may be operated at a very steep portion of its reactance characteristic. Where harmonic frequencies are to be produced it is necessary to take steps to assure that the reactance of the grid circuit shall remain positive and sufficiently large to enable oscillations to be maintained. This, for best operation, requires a readjustment of the reactance of the grid circuit for every change in the tuning of the oscillator where the oscillator is to operate with more than one crystal in a "stack." The readjustment of the grid circuit reactance will have to be frequently made as the oscillator is tuned throughout the entire range in which it is capable of oscillating. This makes the retuning operation of such an oscillator slow and vitiates its use for military or other purposes where it may be desirable to suddenly shift to another exactly predetermined oscillation frequency.

In accordance with this invention an oscillating system of the usual tuned plate circuit type having the piezoelectric crystal in the grid circuit is provided with a continuously variable positive reactance element in the grid circuit mechanically connected to the tuning element of the plate

circuit. Tuning the plate circuit to select an oscillating frequency simultaneously readjusts the grid circuit reactance to an appropriate value. A number of crystals may be stacked in the grid circuit to provide additional controlled frequencies.

Referring to Fig. 1 of the drawing, an electron discharge device 10 includes a cathode 11, an anode 12, an impedance control grid 13, a screen grid 14, a suppressor grid 15, and a heater 16. The oscillator comprises the usual variable tunable plate circuit 17 with its inductance element 33 and tuning condenser 18 and the grid circuit includes a frequency control piezoelectric device 19. The heater 16 is energized through a resistance 20 by a heating current source 21. Condenser 22 serves as a by-pass around resistance 20 for oscillation currents. A source 23 provides space current and is by-passed by capacity element 24. Screen grid 14 is connected to the space current source through a high resistance 25 and to the cathode through a by-pass capacity element 26.

The oscillator as so far described is of a well-known type adapted to supply oscillations of a frequency selected by tuned circuit 17 and more exactly determined and controlled by the natural resonance frequency of the highly reactive piezoelectric device 19. The oscillations are impressed upon load terminals 27 through the series high capacity blocking element 28. A shunt resistance 29 serves to stabilize the impedance into which the oscillator works.

A circuit of the general type illustrated in Fig. 1 having the plate circuit 17 tuned to approximately the natural frequency of the piezoelectric element in the grid circuit will tend to operate at a frequency near the fundamental frequency of the piezoelectric element and at some point on the positive portion of the reactance characteristic of the piezoelectric element since one of the fundamental requirements for oscillation in that type of circuit is positive reactance in the grid circuit.

The electrical equivalent of a piezoelectric element such as a quartz plate may be taken as an inductance and a capacitance in series with the series arrangement of inductance and capacitance shunted by a second capacitance. The resulting reactance of such a combination is indicated in Fig. 2. It is essentially a capacity reactance curve of the second or shunting condenser as indicated by the dotted line graph modified by the series resonance and antiresonance peaks which occur at substantially uniform intervals of the funda-

mental frequency of the combination. The resulting graph shown in solid lines indicates how the peaks carry the reactance across to the positive side at the fundamental frequency f and at odd harmonics of the fundamental. The device may accordingly oscillate at any of these frequencies if the tuning of the circuit 17, the magnitude of the positive reactance, and the phase relations be favorable. Such an oscillator may, therefore, be used for fundamental frequency, triple harmonic or higher odd harmonic frequency operation. However, it is usually impossible to make such a simple tuned plate circuit oscillator operate satisfactorily at higher harmonics than the third because of the lack of sufficient positive reactance in the grid circuit.

When it is desired to be able to operate at higher than a triple harmonic, resort is usually had to the introduction into the grid circuit of an additional positive reactance. This may be effected by inserting an inductance coil or a coil and a condenser shunting it in series with the piezoelectric element. If now the plate circuit 17 be tuned to approximately a desired natural fundamental resonance frequency or a desired harmonic resonance frequency of the piezoelectric element and if, in addition, the grid circuit positive reactance be suitably adjusted in magnitude for the desired frequency the circuit will operate at the desired resonance frequency of the piezoelectric element but will not operate at frequencies relatively closely adjacent for the reason that the reactance peak of the piezoelectric element is extremely steep and the net reactance of the grid circuit is positive for only a very small frequency range.

In accordance with applicant's invention, the grid circuit reactance external to the piezoelectric element is provided by a tunable loop including an inductance element 32 and a variable capacity element 30, the loop circuit being connected in series with piezoelectric device 19 between the grid 13 and cathode 11. Moreover, a supplemental variable capacity element 34 is provided in shunt to the tuned loop for purposes which will later appear. The grid circuit reactance external to the piezoelectric element is maintained positive at all frequencies or tunings of the plate circuit 17 by mechanically tying the tuning condenser 18 of the plate circuit to the tuning condenser 30 of the grid circuit reactance by any suitable mechanism 31 of well-known type. The inductance 32 is chosen slightly less than the inductance 33 and the condensers 18 and 30 may be identical or nearly so. Under these circumstances the reactance of the combination 30, 32 is always tuned to a slightly higher frequency than the circuit 17 and hence is of positive character, that is, inductive at the frequency to which circuit 17 is tuned. If the frequency of circuit 17 be lowered by manipulation of the mechanical control 31 the frequency of the combination 30, 32 will follow so as to prevent the positive reactance of the circuit 30, 32 becoming so large that the oscillator is no longer confined to a narrow range of frequencies. This is desirable to prevent hops to closely adjacent resonances, if such there be, or even to prevent oscillations simultaneously at two different but closely adjacent frequencies which may fall within the range for which the reactance is positive. If the frequency of circuit 17 be increased the frequency of the loop 30, 32 will also increase so as not to become a negative reactance which would cause the circuit as a whole to become in-

capable of oscillation under any circumstance. As has been stated, the condensers 30 and 18 may be made alike and their rotors insulated from each other and mounted on the same shaft. The inductance of coil 32 may be about 20 per cent less than that of coil 33.

As the inductance of coil 32 is less than that of coil 33 the decrease in reactance required to bring the resonances of the two tuned circuits close together may be had from a trimmer condenser 34 connected in shunt with condenser 13. At the outset of the operating adjustment the trimmer condenser which is variable is so adjusted that with the piezoelectric element in circuit the circuit as a whole is just on the point of singing with condensers 30 and 18 set at their minimum capacitance and with condenser 34 set on the low capacitance side. This maintains positive reactance in the grid circuit at all times. After this adjustment has been made, tuning the circuit 17 to a frequency near a harmonic frequency of the crystal will cause the circuit to oscillate at that harmonic. The tuning will be found to be extremely sharp.

The piezoelectric device has been treated as if it were a single quartz resonator. As illustrated in Fig. 1 it comprises an insulating container 35, four metal plate electrodes 36 to 39, inclusive, and three conducting plates 40, 41 and 42, the conducting plates each being provided with a terminal. Clamped between electrodes 36 and 37 by electrically conducting spring 43 which backs against plate 40 are three quartz or other piezoelectric resonators 44, 45 and 46 each designed to resonate at a distinct frequency. Similarly, clamped between electrodes 38 and 39 by a spring 47 which backs against conducting plate 41 are three additional quartz resonators 48, 49 and 50 each designed to operate at a frequency different from any of the other five resonators. Plate 42 is permanently electrically connected to the negative terminal of source 21. A switch 51 enables either stack or group of crystals to be connected to the oscillator. If desired, a strap connection may be made between the terminals of plates 40 and 41 to connect the two stacks simultaneously in a parallel connection.

In one design of oscillator in accordance with this invention a group of three stacked resonators have fundamental frequencies, respectively, of 2.3, 4.5 and 5. megacycles. With the one set of coils 32 and 33 the following harmonic output frequencies were produced.

Base frequency	Harmonic	Oscillator output frequency
<i>Megacycles</i>		<i>Megacycles</i>
4.5	3	13.5
5	3	15
2.3	7	16.1
2.3	9	20.7
4.5	5	22.5

The sharpness of the reactance curve of the piezoelectric elements is such that the oscillator is practically independent of slight variations in tuning (within .001 per cent if adjusted with reasonable accuracy) and, therefore, independent of circuit changes. Moreover, the effectiveness of the adjustment of the auxiliary grid circuit reactance presented by the combination 30, 34, 32 is such that operating in stacks of three, the ninth harmonic of a piezoelectric element may be readily selected and utilized.

The average power output of the triple stack crystal oscillator for which the frequencies have been given was about 4 watts, using a 6L6 vacuum tube with a source of 300 volts potential for the screen grid and plate current supply. The circuit operated satisfactorily over a temperature range from 0 to 60° C. with almost constant amplitude output. The large variations in power output obtained with quartz piezoelectric plates operated at their fundamental frequencies were found to be absent when the plates were operated at their harmonic frequencies indicating that the lower frequency modes of vibration the harmonics of which cause a large part of the instability of the output and fundamental frequency are ineffective at the harmonic frequencies.

Because the output frequency is so largely independent of the circuit characteristics and reflects so accurately the natural resonance of the piezoelectric element the circuit of the invention has been found very satisfactory for checking and measuring the resonance frequencies of piezoelectric elements.

What is claimed is:

1. A piezoelectric controlled oscillator comprising an electron discharge device having a plurality of electrodes, a tuned input circuit and a tuned output circuit which are electrically uncoupled to each other except through the electron discharge device, each of said circuits including an inductance element and a capacity element, the inductance element of the input circuit having a magnitude smaller than the inductance element of the output circuit and the capacity elements of the two circuits being of substantially equal magnitude, a piezoelectric element having two terminals connected respectively to two of the electrodes of the electron discharge device and means mechanically connected to the capacity elements to simultaneously vary their magnitudes in the same direction whereby as the tunings of the circuits vary the input circuit always exhibits positive reactance at the resonance frequency of the output circuit.

2. An oscillator comprising an electron discharge device having input terminals and output terminals, an input path connected between the input terminals including a piezoelectric element in series with a loop tuned circuit, an output path including a second loop tuned circuit connected between the output terminals, the paths including the loop tuned circuits being electrically uncoupled to each other except through the electron discharge device whereby the oscillation condition is attained only at frequencies for which both paths exhibit a positive reactance, the two loop tuned circuits including variable capacitors of substantially equal magnitude, the output circuit loop being tuned to approximately the resonance frequency of the piezoelectric element and the input circuit loop being tuned to a higher frequency, and means mechanically connecting the two variable capacitors for simultaneously vary-

ing the tunings of the loop circuits in the same direction.

3. A source of electrical oscillations comprising an amplifier having input terminals and output terminals, a loop tuned circuit and a stack of piezoelectric elements connected in series between the input terminals, a second loop tuned circuit connected between the output terminals, equal variable capacity elements connected respectively in the tuned circuits, and means mechanically controlling the variable capacity elements simultaneously to enable the oscillation source to be tuned to approximately a natural oscillation frequency of one of the piezoelectric elements.

4. An oscillator comprising an electron discharge device having an input circuit and an output circuit, an inductance element and a capacitance element comprising a tuned loop and a piezoelectric element connected in series in the input circuit, a variably tunable loop including an inductance element and a capacitance element connected in the output circuit, the output circuit and the input circuit being electrically uncoupled to each other except through the discharge device, the two capacitance elements being substantially equal and the loop in the input circuit being tuned to a slightly higher frequency than the tunable loop of the output circuit and unitary means mechanically connecting the reactance element of the tunable loop to the variable reactance of the input circuit to vary them simultaneously whereby the oscillator may be readily tuned to the fundamental or to a harmonic frequency of the piezoelectric element.

5. In combination, an electron discharge device having a cathode, an anode, and an impedance controlled element, a tuned loop circuit including a variable capacitance element connected between the anode and cathode, a piezoelectric element and a second tuned loop circuit in series with the piezoelectric element connected between the cathode and the impedance control element, the circuits connected between the anode and cathode and between the cathode and the impedance control element respectively being electrically uncoupled to each other the second tuned loop including a variable capacitance element substantially equal in magnitude and mechanically connected to that of the other tuned loop whereby the capacitances may be simultaneously varied to change the natural resonance frequencies of the loops, the second tuned loop being tuned to a higher frequency than the first one whereby the input circuit loop presents a reactance which is positive at the frequency of the anode-cathode loop so that oscillations may be produced at those tunings of the anode-cathode circuit which correspond to harmonic frequencies of the piezoelectric element at which a piezoelectric electromotive force of substantial magnitude is produced.

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