

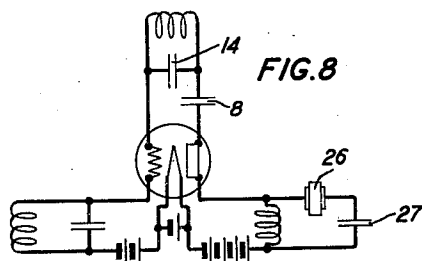
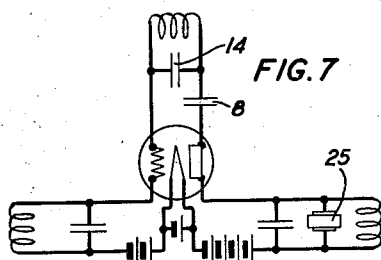
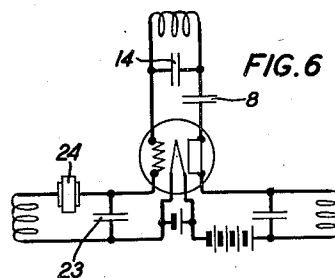
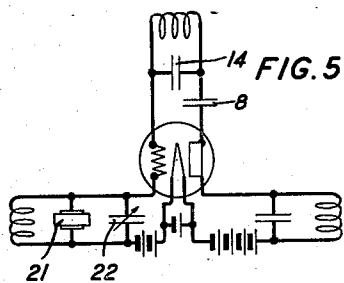
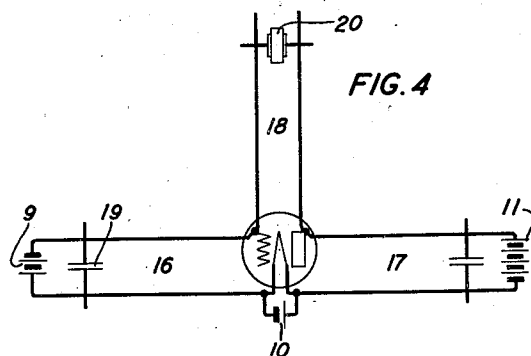
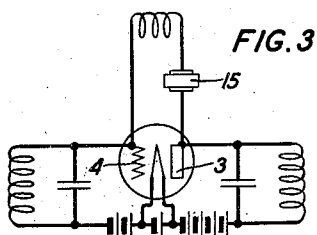
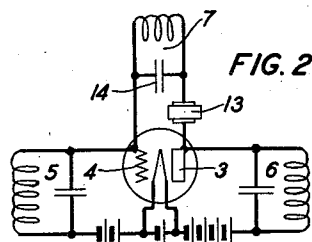
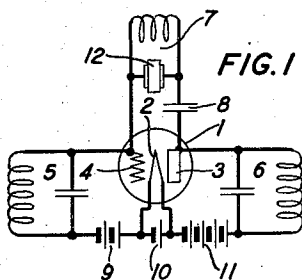
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2,189,770

PIEZOELECTRIC CONTROLLED OSCILLATOR

Filed July 19, 1938



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PIEZOELECTRIC CONTROLLED OSCILLATOR

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Application July 19, 1938, Serial No. 219,959

14 Claims. (Cl. 250—36)

This invention relates to piezoelectric controlled oscillators for generating ultra high frequency oscillations.

An object of the invention is to produce very stable oscillations of the order of a few centimeters in wave-length.

An additional object of the invention is to enable a vacuum tube electron discharge oscillator to oscillate at the harmonic frequency of a piezoelectric element substantially free from spurious lower frequency oscillations.

A further object is to so isolate the frequency control circuit of an oscillator from the remaining electrode circuits as to minimize couplings therebetween and to reduce their effect upon frequency control and stability.

The operation of electron discharge amplifiers at high frequencies has been attended with the difficulty that feedback from the anode to a control element through the interelectrode capacitance between the electrode and the control element tends to cause the apparatus to oscillate. A circuit designed to prevent such oscillation is that of Patent 1,325,879 issued December 23, 1919 to H. W. Nichols. With the advent of oscillations of a few centimeters in wave-length it has been found that additional couplings between the anode circuit and that of the control element are introduced by other mutual reactances notably those of the discharge device. An ultra high frequency amplifier designed to minimize these additional couplings of the electrode leads and to introduce other improvements in the design of the electron discharge device and its associated circuits is disclosed in the copending application of A. L. Samuel, Serial No. 78,594 filed May 8, 1936. In accordance with the present invention it is proposed to utilize a neutralized amplifier of any of the types disclosed in that application by introducing into the neutralizing circuit a piezoelectric element so connected that the circuit will behave as a neutralized amplifier except at or near those frequencies corresponding to resonant modes of the piezoelectric device. At such frequencies conditions for stability will not be satisfied and oscillations may occur. In effect, the piezoelectric device prevents the circuit from oscillating except within certain definite regions. If, therefore, these regions fall within the effective amplification band of the amplifier, the device may serve as a source of ultra high frequency oscillations of a very stable and well-defined frequency. As an alternative, the piezoelectric device may constitute an element of the

cathode-control element circuit or the cathode-anode circuit.

Additional aspects and features of the invention will become apparent upon consideration of the following detailed description in connection with the accompanying drawing, of which:

Fig. 1 shows a schematic circuit diagram of one embodiment of the invention;

Figs. 2, 3 and 4 illustrate modifications of the circuit of Fig. 1;

Figs. 5 and 6 illustrate oscillating systems in which the piezoelectric element is included in the cathode-control element circuit; and

Figs. 7 and 8 show oscillator circuits having the piezoelectric element in the cathode-anode circuit.

Referring to Fig. 1 the oscillator circuit comprises an electron discharge device 1 which, as illustrated, includes a cathode 2, an anode 3 and a control element 4. The electrodes are each provided with two separate leads to eliminate the mutual reactance or coupling involved when a single lead is used to connect the same electrode to two or more circuits. Preferably, the electron discharge device conforms in structure to one of the disclosures of Figs. 1, 2, 3, 9 or 10 of my copending application, Serial No. 78,594 filed May 8, 1936. Accordingly, the different leads to an individual electrode may be brought out from the electron discharge device at widely separated points and in some instances at opposite sides or ends of the tube as disclosed in the copending application. It is to be understood that the disclosures of that application are effectively incorporated in this specification although the electron discharge device is in each instance illustrated herein diagrammatically for the sake of simplicity. It is also to be understood that although in each instance the electron discharge device is illustrated herein as a triode, the principles of the invention are equally applicable to multi-electrode discharge devices of any kind which are capable of transmitting oscillations of the order of a few centimeters in wave-length. The oscillator circuit of Fig. 1 involves three external circuits 5, 6 and 7, each connected between a pair of electrodes. Tuned circuit 5 comprising an inductance and capacity connected between the control electrode 4 and the cathode 2 may hereinafter be referred to as the input circuit because of its analogy to the input circuit of the usual vacuum tube amplifier. Tuned circuit 6 including an inductance and a capacity element and generally similar to circuit 5, connected between

the anode 3 and cathode 2 may likewise be referred to as the output circuit. A loop 7 comprising an inductance and a piezoelectric element 12 in shunt thereto is connected to the control element 4 and through a large capacity blocking condenser 8 to the anode 3. The oscillator circuit also includes the polarizing sources 9, 10 and 11 of any well-known types.

The piezoelectric element 12 is so designed and constructed as to have a natural resonance frequency or a harmonic resonance frequency at the frequency of the oscillations which it is desired to produce. Under non-oscillating conditions the device 12 may be regarded as a static capacity element. In shunt to that capacity element is a capacity path including the large blocking condenser 8 in series with the interelectrode capacitance between the anode 3 and the control element 4. If the inductance element of the circuit 7 be so designed that together with the static capacitance of the element 12 and the shunt path by way of element 8 the circuit be resonant to a particular frequency it will, during a non-oscillating condition of the device 12, function to neutralize the effect of interelectrode capacitance between the elements 3 and 4 at the frequency to which the circuit 7 is tuned in accordance with the principle disclosed in U. S. Patent 1,325,879, issued December 23, 1919, to H. W. Nichols. Under these circumstances if the circuits 5 and 6 be tuned to substantially the same frequency as the circuit 7 there may be no feedback from the circuit 6 to the circuit 5 through the internal interelectrode capacitance of the device. If, in addition to this precaution, the leads to the circuits 5, 6 and 7 be widely separated to reduce any mutual or coupling effects the device will constitute a neutralized amplifier of the general type disclosed in the Nichols patent and more specifically disclosed in the copending application, Serial No. 78,594 to which reference has already been made. The separation of these leads is indicated diagrammatically in the drawing and the structures for effectively securing such separation are fully disclosed in the copending application, Serial No. 78,594.

The effect of the piezoelectric element 12 is to upset the neutralizing condition at or near those frequencies corresponding to the resonance modes of the piezoelectric element. Accordingly, while oscillations within the effective transmission band of the circuits 5 and 6 will normally be prevented by the neutralizing circuit, the piezoelectric element permits oscillations within that band provided that they are sufficiently close to its resonance frequency. It is possible, therefore, to cause the device to oscillate at a selected resonance frequency or a selected harmonic frequency of the piezoelectric element if that frequency falls in the effective transmission band of the circuits 5 and 6.

Fig. 2 discloses an oscillator similar to that of Fig. 1 and differing only in that the piezoelectric element 13 is connected between the tuned loop 7 and the anode instead of directly in the tuned loop. It will be understood, of course, that the tuned loop circuit 7 together with the shunt path including the static capacity of the device 13 in series with the interelectrode capacitance between anode 3 and the control element 4 should be made resonant to substantially the resonance frequency of circuits 5 and 6 so as to neutralize the feedback between the circuits 6 and 5 within the effective frequency transmission band of

the circuits 5 and 6 except at or near the selected resonance frequency of the piezoelectric device 13.

The oscillator circuit of Fig. 3 differs from that of Fig. 2 only in the omission of the capacity element 14. In this instance the resonant or tuned loop includes in series the inductance, piezoelectric element 15 and the interelectrode capacitance between electrodes 3 and 4 of the electron discharge device.

Fig. 4 illustrates an electron discharge oscillator in accordance with the invention in which the tuned loops 5, 6 and 7 of the preceding figures are each replaced by a Lecher circuit such as 16, 17 and 18. As is well known, the Lecher circuit comprises closely adjacent parallel conductors which function as a distributed capacity and inductance. At the terminals adjacent the electron discharge device the Lecher circuit is connected to the interelectrode impedance of the two electrodes with which it is associated. At its outer terminal the Lecher circuit is effectively terminated by a short-circuiting capacity element, such as element 19, of relatively large capacity provided with sliding terminal connections to enable tuning in well-known manner. Such a piezoelectric circuit will ordinarily be constructed of an odd number of quarter wavelengths at the desired oscillation frequency. The neutralizing circuit 18 connected between the anode 3 and control element 4 may be terminated by a piezoelectric device 20 which, as in the case of the preceding circuits, permits oscillations to take place at a selected resonance frequency of the device within the effective transmission band of the circuits 16 and 17 but which does not interfere with the neutralizing function of the circuit 18 at other frequencies within that band. As in the case of the capacity element 19 the piezoelectric element 20 is mounted with a slidable terminal connection to properly tune the circuit 18. In addition to the other expedients for preventing oscillation due to fortuitous coupling, the circuits 16 and 17 may be extended in opposite directions from the electron discharge device and the circuit 18 at right angles thereto as indicated schematically in the drawing.

Fig. 5 shows a modified oscillator circuit with the piezoelectric element 21 included in the input circuit. A variable tuning condenser 22 enables the input circuit to be tuned. The grid and anode are indicated with leads at their opposite ends in accordance with the disclosure of application Serial No. 78,594 to eliminate coupling of their individual external circuits which might otherwise be introduced. Moreover, although the circuits of Figs. 1 to 4, inclusive, are shown diagrammatically with the control element leads and the anode leads at a single end of the respective electrode, it is to be understood that opposite end lead connections like those of Fig. 5 may be used in each of the circuits of Figs. 1 to 4 for the control element and the anode and, moreover, where linear cathodes are employed for the cathode as well.

Fig. 6 presents a circuit differing from that of Fig. 5 only in that the inductance coil piezoelectric element 24, and auxiliary condenser 23 of the tuned input circuit are connected in series to form the closed loop instead of in parallel as in Fig. 5.

Fig. 7 illustrates another oscillator of the neutralized amplifier type in which the piezoelectric element 25 is connected in the output circuit in shunt to the inductance coil in the same manner

as the element 21 in the input circuit of Fig. 5.

Fig. 8 shows a further modification in which the piezoelectric element 26 is connected in series with an auxiliary condenser 27 and an inductance coil to constitute a tuned loop circuit similar to the input circuit of Fig. 6.

In each of the figures, the polarizing sources for the control element and the anode are shown as in Fig. 1 as is also the cathode heating source. It will be apparent that in the circuit of Fig. 4 the Lecher conductors may serve as the unidirectional path for each of the three external circuits since the terminating condensers effectively short-circuit the Lecher paths and preclude any effect of the short-circuited outer portions of the Lecher conductors upon the tuned portions. It will also be understood that as in Fig. 1, very large capacity blocking condensers 8 may be utilized in the circuits of Figs. 5 to 8, inclusive, to protect the control element from the high positive potential of the anode polarizing source.

It will be unnecessary to explain the operation of the circuits of Figs. 5 to 8, inclusive, in detail since it will of course be understood that in each instance the tuned circuit between the control element and the anode including capacitance 14 together with the path including blocking condenser 8 and the inherent interelectrode capacitance between the anode and the control element is made antiresonant at the resonance frequency of the input and output circuits to constitute a neutralized amplifier. The piezoelectric elements 21, 23, 25 and 26 may each have a mode of resonance of a fundamental or of a harmonic type at a single frequency within the effective transmission band of the input and output circuits of the amplifier. Accordingly, at that single frequency the piezoelectric element may upset the neutralized condition and permit oscillations to occur.

As explained in the specification of application Serial No. 78,594, the electron discharge device may be so designed as to cause nodes to occur at the points where the lead-in wires pass through the dielectric envelope of the discharge device.

What is claimed is:

1. In combination, an electron discharge device having a plurality of electrodes including a cathode, an anode and a control element, and three individual circuits connected respectively between the cathode and the anode, the cathode and the control element and the anode and the control element each of the three circuits comprising a tuned loop, the circuit connecting the anode and the control element and including the anode-control element interelectrode capacitance being anti-resonant at the resonance frequency of the other two individual circuits to constitute a neutralized amplifier and a piezoelectric element connected in one of the three individual circuits and having a mode of oscillation at a single frequency within the effective transmission band of the two circuits which connect the anode to the cathode and the control element to the cathode.

2. The combination of claim 1, characterized in this, that the piezoelectric element is connected in the circuit between the cathode and the control element.

3. The combination of claim 1, characterized in this, that the piezoelectric element is con-

nected in the circuit between the cathode and the anode.

4. In combination, an electron discharge device having a plurality of electrodes including a cathode, an anode and a control element, and three individual circuits connected respectively between the cathode and the anode, the cathode and the control element and the anode and the control element, each of the three circuits comprising a tuned loop, the circuit connecting the anode and the control element including a piezoelectric element having a mode of oscillation within the frequency region closely adjacent the resonant frequencies of the loops of the other two circuits.

5. The combination of claim 4, characterized in this, that the tuned loop of the circuit between the control element and the anode includes the inherent interelectrode capacitance between the control element and the anode.

6. The combination of claim 4, characterized in this, that the leads from the electrodes to each individual circuit are separate from the leads to the other individual circuits so as not to introduce a mutual reactance.

7. The combination of claim 4, characterized in this, that the piezoelectric element has a harmonic frequency mode of oscillation within the effective transmission band of the input and output circuits which respectively connect the control element and the anode to the cathode.

8. The combination of claim 4, characterized in this, that the piezoelectric element has only one mode of oscillation within the effective band width of the input and output circuits.

9. The combination of claim 4, characterized in this, that the tuned loop between the anode and the control element includes an inductance element and the piezoelectric element in series.

10. The combination of claim 4, characterized in this, that the piezoelectric element is connected between a terminal of the tuned loop and the anode.

11. The combination of claim 4, characterized in this, that each of the three individual circuits comprises a pair of Lecher conductors.

12. In combination, an electron discharge device having a plurality of electrodes including a cathode, an anode and a control element, and three individual Lecher circuits connected respectively between the cathode and the anode, the cathode and the control element and the anode and control element, the circuit connecting the anode and the control element including a piezoelectric element having a mode of oscillation within the frequency region closely adjacent the resonant frequencies of the other two Lecher circuits, and connections from the Lecher circuits to the electrodes of the discharge device such that the leads to one common electrode extend in opposite directions and such that the leads to another common electrode extend in perpendicular directions to minimize external coupling between the Lecher circuits.

13. In combination, an electron discharge device having a plurality of electrodes including a cathode, an anode and a control element, three individual circuits connected respectively between the cathode and the anode, the cathode and the control element and the anode and the control element, each of the three circuits being resonant at substantially the same frequency whereby the device may operate effectively as a neutralized amplifier within the effective transmission band of the circuits connected between

the cathode and control element on the one hand and cathode and anode on the other, and means connected to one of the three circuits which overrides the neutralizing characteristic of the circuit to cause oscillation at a selected frequency within that band.

14. A source of high frequency electrical oscillations comprising an electron discharge device having a cathode, an anode and a control element, three individual Lecher circuits connected

respectively between the cathode and anode, the cathode and the control element, and the anode and the control element, the three Lecher circuits being resonant at substantially the same frequency, and means connected to the Lecher circuit between the anode and control element to cause feedback therethrough from the anode-cathode circuit to the circuit of the anode and control element at a single frequency.

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