

Nov. 3, 1931.

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1,830,329

FREQUENCY CONTROL FOR OSCILLATION GENERATORS

Filed Aug. 23, 1927

2 Sheets-Sheet 1

Fig. 1

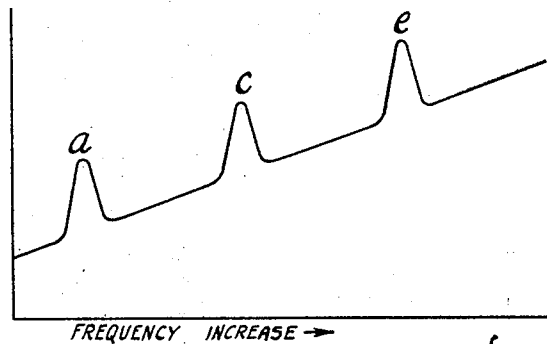


Fig. 2

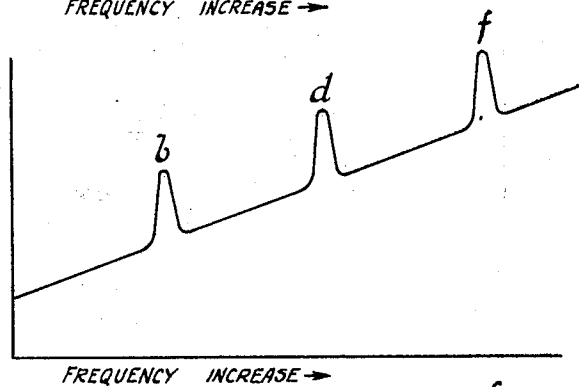


Fig. 3

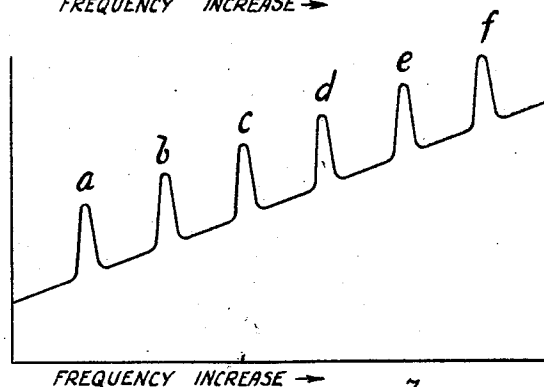
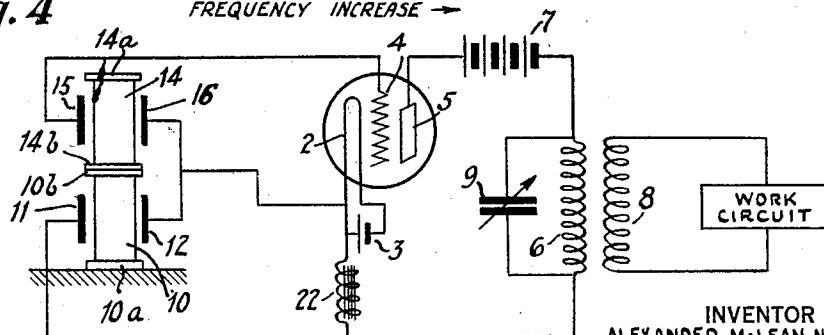


Fig. 4



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Fig. 5

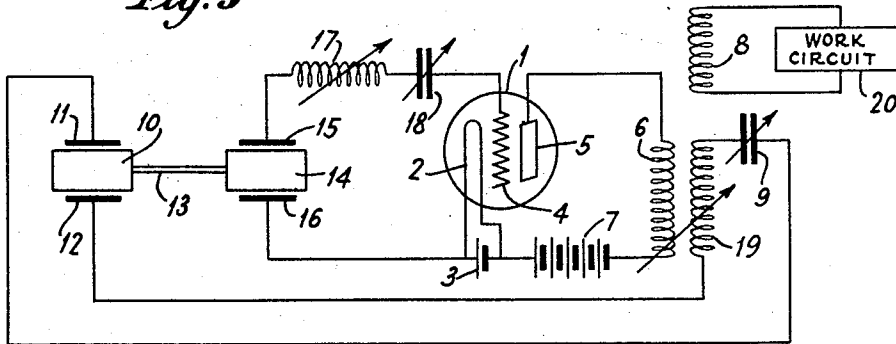


Fig. 6

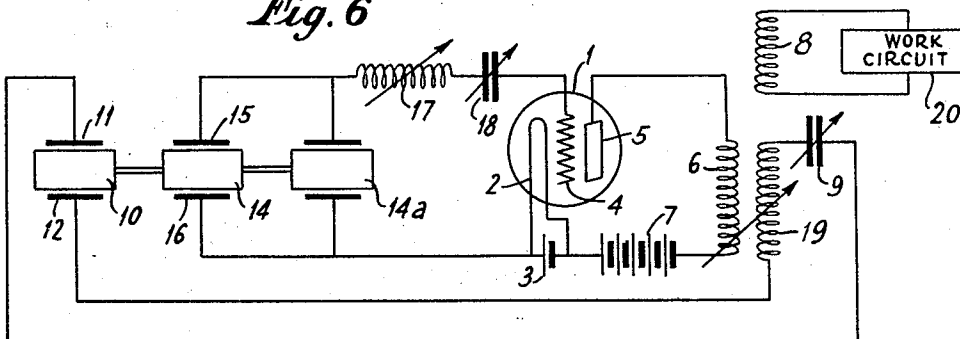
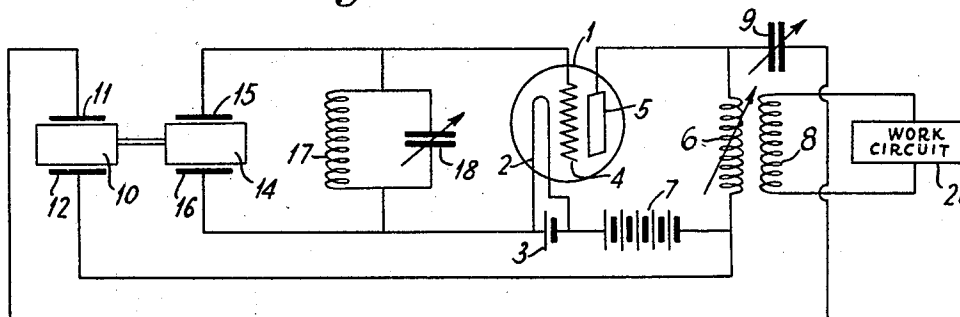


Fig. 7



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FREQUENCY CONTROL FOR OSCILLATION GENERATORS

Application filed August 23, 1927. Serial No. 214,888.

This invention relates to electrical oscillation generators, and more particularly to such generators utilizing one or more thermionic vacuum tubes, provided with a plurality of piezo-electric crystal devices, and one or more tuning elements, constructed and arranged to generate electrical oscillations, the frequency of which may be determined by the adjustment of the tuning controls in such manner that the apparatus will generate oscillations of one of a plurality of frequencies corresponding to the particular response characteristics of the crystals utilized.

It is an object of this invention to provide relatively simple and efficient apparatus of the class described, which is readily controllable to select the frequency of the oscillations desired, and which will oscillate at an extremely constant frequency at any one of the natural frequencies afforded by the apparatus. Still other objects and advantages of my invention will be apparent from the specification.

The features of novelty which I believe to be characteristic of my invention are set forth with particularity in the appended claims. My invention itself, however, both as to its fundamental principles and as to its particular embodiments will best be understood by reference to the specification and accompanying drawings, in which:

Figures 1, 2 and 3 are curves explaining the operation thereof.

Figures 4, 5, 6 and 7 are diagrammatic views of various forms of circuits in accordance with my invention.

It is well known that piezo-electric crystal devices such as slabs of quartz, tourmaline, Rochelle salt and the like, are capable of vibrating in response to electrical stresses impressed thereon and, conversely, if vibrated mechanically, produce electrical stresses.

Since the frequency characteristic of vibration of such devices is relatively constant, these devices are widely used for the stabilization and control of thermionic vacuum tube oscillators, and particularly so when the apparatus is used to generate oscillations of very high frequency such as are utilized in radio communication. It has been the custom in

the past in case it was desired to change the frequency of oscillations generated to remove the crystal device and substitute for it another crystal device so arranged as by choice of its material, dimensions and shape, that its natural frequency corresponded to that desired. Under certain conditions, particularly in case the oscillator is desired to operate at any one of a relatively large number of frequencies, the substitution of crystal devices is undesirable.

I have discovered that it is not necessary to change such devices when it is desired to change the frequency of oscillations to be generated. In accordance with my invention, I provide a plurality of such devices associated with the thermionic amplifier in a manner to feed back energy from the output circuit thereof to the input circuit, to sustain the oscillations produced. The crystal devices will preferably be so chosen that their natural frequencies of oscillation are different and that some one of the crystal devices has a natural frequency corresponding to each frequency desired. In addition, I provide one or more tuning devices for selecting the natural frequency of oscillations desired. The frequency selecting means may, and preferably will, be a series or parallel tuned circuit or circuits associated with the crystal device and with either the input or output circuit of the amplifier, or with both the input and output circuits; and operative to select approximately the frequency of oscillation desired, and the piezo-electric device or devices having a natural frequency of vibrations most closely corresponding to the tuning of the tuning means control and determine the frequency exactly. If the device is operating at one frequency, and it is desired to change over to another frequency, it is only necessary to vary the tuning means so that the tuning of the circuit is changed to correspond to another of the natural frequencies of vibration of the crystal device which will, in turn, set or control the frequency of the oscillations generated. By this means it is possible to provide an oscillator which will produce oscillations of any one of a number of frequencies covering a desired band and

separated, for example, by predetermined intervals.

Referring now more particularly to Figure 1, the curve therein shown may represent the response characteristic of a particular piezo-electric crystal, and as will be noted, this crystal may have response peaks at frequencies *a*, *c* and *e*, due to vibration in different modes, or other causes. If used alone in a circuit, without any frequency selecting means, the crystal might vibrate at any one of these frequencies, depending upon a number of conditions. If, however, some tuning control is provided, it is possible to cause the crystal to vibrate at any one of its natural frequencies *a*, *c* and *e*, as desired.

Referring now more particularly to Figure 2, I have shown a similar response characteristic for a different crystal, which may have response peaks at frequencies *b*, *d* and *f* and, if utilized alone, this crystal device would oscillate at one of said frequencies depending upon conditions. By the use of a tuning device, the frequency desired may be selected.

If now, two such devices be utilized in the same circuit, it will be understood that the response peaks of both of them may be utilized, and oscillations may be generated at any one of the frequencies *a*, *b*, *c*, *d*, *e* and *f*, an appropriate tuning means being provided for the purpose of selecting the particular frequency. It will be understood that while I have referred to the use of two devices, my invention is not limited thereto, but contemplates the use of three or more of such devices, having different frequency characteristics, by means of which a considerably greater number of frequencies may be generated than in the case of a single such device.

It is to be noted that the exact position of the response peaks may be displaced slightly when the crystals are associated together, due to the mutual effect of each crystal on the other, in a manner analogous to the effect of two resonant currents on each other when coupled.

Referring now more particularly to Figure 4, I designate a thermionic amplifier system, herein shown diagrammatically as a single vacuum tube amplifier of the type commonly used in the art, but actually comprising as many stages of preferably aperiodic amplification as may be necessary or desired, and comprising an evacuated vessel having therein a cathode 2 adapted to emit electrons, an anode 5 and a control electrode or grid 4. The cathode may be heated to electron-emitting temperature by any suitable means, such as battery 3. The output circuit, connected between the anode 5 and the cathode 2, comprises an inductance 6 shunted by variable capacity 9, and a suitable source of potential 7. Inductively coupled with the coil 6 is a secondary coil 8 which may supply the oscil-

lations generated to a suitable work circuit, such as a radio transmitter or the like. The inductance of the coil and its coupling with the coil 6, are preferably made variable to obtain optimum adjustment. The energy impressed upon the coil 6 is transferred to piezo-electric crystal device 10 provided with conducting metallic poles 10*a* and 10*b*, and having the usual electrodes 11 and 12, which are connected to the free terminals of condenser 9 and coil 8 and to the cathode 2 respectively. A choke 22 is provided connected in shunt with electrodes 11 and 12. Associated with the piezo-electric crystal device 10, I provide a second piezo-electric crystal device 14, having a pair of electrodes 15 and 16, and also having metal poles 14*a* and 14*b*. The electrode 16 may be connected to the cathode circuit and the electrode 15 is connected directly to the control electrode 4. The crystal devices 10 and 14 are mechanically associated or coupled by being, in this instance, laid one upon the other.

In operation, the energy impressed on crystal 10 causes vibrations thereof, which vibrations are transmitted mechanically to crystal 14, and cause the generation of potential differences corresponding thereto, which are impressed on the control circuit of the amplifier system, and thereby repeated in the output circuit setting up continuous oscillations, the frequency of which is determined by the tuning of the output circuit, as well as by other factors, such as the natural frequencies of both crystals.

Referring now more particularly to Figure 5, I have shown a slightly different arrangement, in which the crystal 10 is inductively coupled to the amplifier output coil 6, by means of a series tuned circuit comprising inductance 19 and variable capacity 9, and in which a series tuned input circuit comprising inductance 17 and variable capacity 18 is utilized for tuning the input circuit. The mechanical coupling or energy transfer connection is shown diagrammatically as an elastic link 13.

While I have shown the connection 13 diagrammatically as a link, it will be understood that in practice this connection may be obtained in a number of ways. For example, the crystals may be mounted on a common mounting plate having sufficient elasticity to transmit vibrations from the one to the other, or again, the crystals may be directly associated, as for example, being laid, as shown in Fig. 4, one against the other. Under certain conditions, also, the mechanical coupling may take the form of an actual link of elastic material connecting the crystal devices.

A pick-up coil 8 may be associated inductively with the coils 6 and 19, and may lead to a suitable work circuit 20, which may comprise an amplifier, modulator and radio transmitter or the like.

It will be seen, just as in Fig. 4, that by reason of the mechanical connection between the crystals 10 and 14, the vibrations occurring in the one are transmitted to the other, as if the crystal devices 10 and 14 were one and the same, having a frequency characteristic representing the sum of the individual characteristics of the two separate devices slightly modified by the mutual effect of each crystal on the other. In operation, energy is supplied to the output circuit of the amplifier 1 and impressed upon the coil 19, and thence to the crystal device 10 which is set into vibration at some one of its natural frequencies to which the output circuit is tuned. The electrical oscillations impressed upon the crystal device 10 cause mechanical vibrations thereof, which are in turn communicated to the crystal device 14, and the forced vibrations of this device cause the generation of corresponding oscillations upon the electrodes 15 and 16. By tuning the input circuit, comprising inductance 17 and capacity 18 to this frequency, the impedance of the circuit is made a minimum to this particular frequency, and the system will operate to generate oscillations of selected frequency. In case it is desired to change the frequency, the tuning of the circuits will be correspondingly changed, so that the impedance of the system is a minimum at the particular desired frequency, which may be a natural frequency of crystal device 10, or of crystal device 14.

Referring now more particularly to Figure 6, I have shown an additional crystal device 14a in parallel with crystal device 14, giving additional frequencies of operation.

It may be pointed out in this connection that if any two piezo-electric crystal devices be selected at random, their natural frequencies will not ordinarily correspond, since in order to obtain crystal devices whose natural frequencies are the same, it is necessary that the dimensions, shapes and materials of the crystals be very carefully chosen, so that the crystals are matched. In case of a slight deviation, even in one dimension of the crystals from each other, the response characteristics will be different.

In this connection, it should also be noted, that it is preferable to use crystals which have sufficiently different response characteristics, so that the system will not oscillate on the two frequencies simultaneously, which would result in the production of beats, which might interfere with the desired operation.

Referring now more particularly to Figure 7, I have shown a system in general similar to that of Figure 5, but utilizing a parallel tuned circuit in the input instead of a series tuned circuit, and also utilizing conductive coupling of the crystal device 10 to the output circuit of the amplifier 1, similar to Fig. 4. In this arrangement, inductance

6 is included in the plate circuit of the amplifier 1, and is also connected in series with variable condenser 9 to electrodes of the piezo-electric crystal device 10.

While I have shown and described certain preferred embodiments of my invention, it will be understood that modifications and changes may be made without departing from the spirit and scope of my invention, as will be understood by those skilled in the art.

I claim:—

1. An electrical oscillatory system, the combination of an electron tube having grid, filament and plate electrodes, an input circuit interconnecting said grid and filament electrodes, an output circuit interconnecting said plate and filament electrodes, and a plurality of piezo electric crystals mechanically associated each having selected constant frequency oscillatory characteristics one of said crystals being connected in said input circuit and another of said crystals being connected in said output circuit for controlling the generation of oscillations in accordance with the frequency of a selected one of said piezo electric crystals.

2. In an electrical oscillatory system, the combination of an electron tube having grid, filament and plate electrodes, an input circuit interconnecting said grid and filament electrodes, an output circuit interconnecting said plate and filament electrodes, and a plurality of piezo-electric crystals each having selected constant frequency oscillatory characteristics one of said crystals being connected in said input circuit and another of said crystals in said output circuit for controlling the generation of oscillations in accordance with the frequency of a selected one of said piezo-electric crystals.

3. In a frequency control or stabilizing system a multiplicity of piezo-electric crystals of different frequency characteristics mechanically associated and separated one from another, an electron tube circuit having an input circuit connected to one of said crystals and an output circuit connected to another of said crystals, and means connected with said electron tube circuit for selectively sustaining the oscillations of any one of said crystals at its characteristic frequency.

Signed at New York city in the county of New York and State of New York this 11th day of August, A. D. 1927.

ALEXANDER McLEAN NICOLSON.