July 5, 1932. R. H. WORRALL ET AL 1,866,441

UNIVERSAL CRYSTAL CONTROLLED CALIBRATOR

Filed June 11, 1928 2 Sheets-Sheet 1

FIG. 1

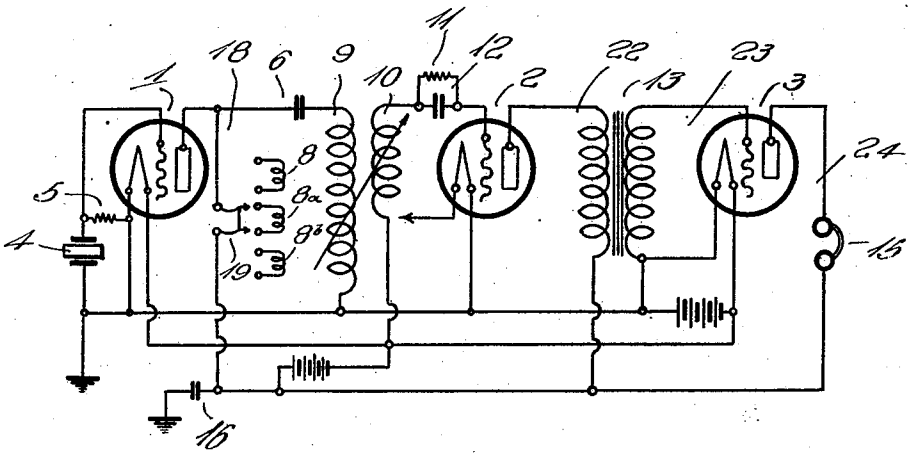
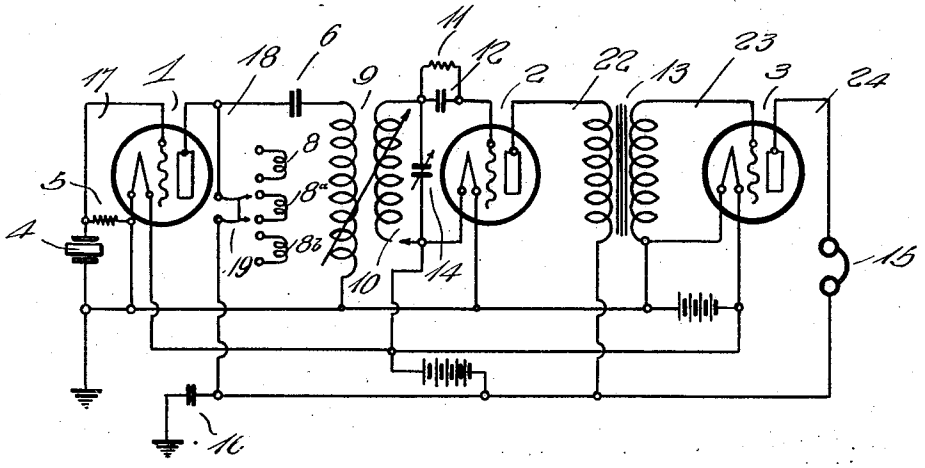


FIG. 2



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UNIVERSAL CRYSTAL CONTROLLED CALIBRATOR

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Fig. 3

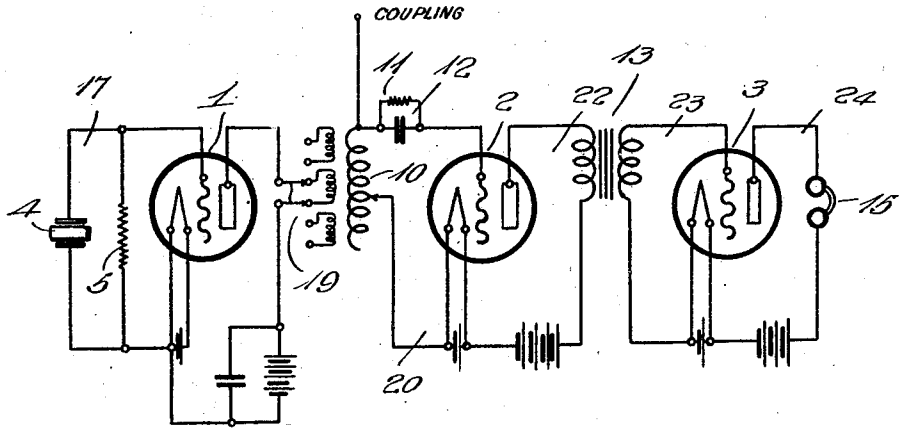
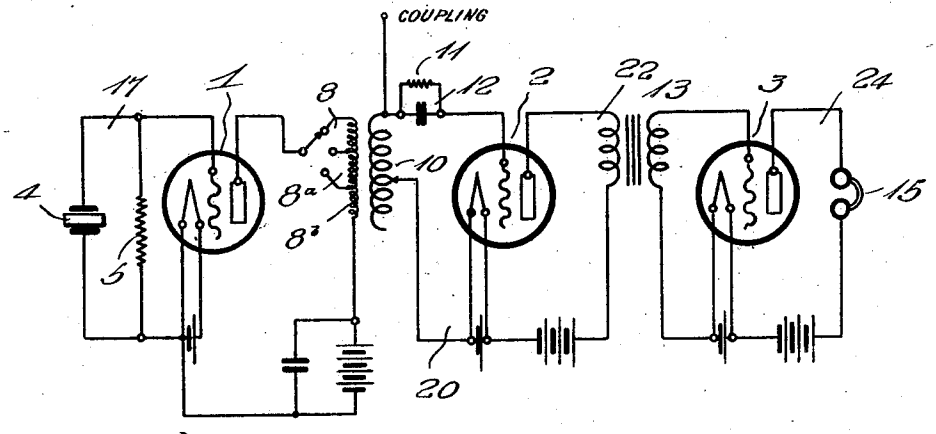


Fig. 4



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Patented July 5, 1932 1,866,441

UNITED STATES PATENT OFFICE

ROBERT H. WORRALL AND RAYMOND B. OWENS, OF WASHINGTON, DISTRICT OF COLUMBIA, ASSIGNORS, BY MESNE ASSIGNMENTS, TO WIRED RADIO, INC., OF NEW YORK, N. Y., A CORPORATION OF DELAWARE

UNIVERSAL CRYSTAL CONTROLLED CALIBRATOR

Application filed June 11, 1928. Serial No. 284,594.

Our invention relates broadly to oscillators wherein is employed a crystal having piezo-electric properties.

An object of our invention is to provide an efficient oscillation generator which will generate predetermined constant frequencies.

Another object of our invention is to provide a system wherein a piezo-electric crystal is employed to maintain the generation of constant frequencies which would be suitable for calibration purposes.

A further object of our invention is to provide a circuit arrangement employing a single piezo-electric crystal and means for obtaining a plurality of standard frequencies from said crystal.

The embodiments of our invention will be more fully understood by referring to the specification following and to the accompanying drawings wherein:

Fig. 1 is a schematic circuit diagram showing the embodiments of our invention and Figs. 2, 3 and 4 are schematic circuit diagrams showing modifications in the circuit and coupling arrangements employed in accordance with our invention.

Figure 1 is a diagrammatic drawing of one circuit arrangement embodying our invention, in which 4 is a means for controlling the frequency of the system and may be any crystal or crystals having the property to sustain oscillations, such as quartz, for instance. 1 is a thermionic vacuum tube having grid, filament and plate electrodes, a grid circuit and a plate circuit 18. 8, 8*a* and 8*b* are inductances in the plate circuit 18, whereby switch 19 may connect to either of inductances 8, 8*a* or 8*b* and tune the plate circuit 18 to the frequency desired. Energy generated in the plate circuit 18 of thermionic tube 1 is transferred to the grid circuit of the thermionic tube 2 by means of coupling condenser 6 and inductances 9 and 10. In the grid circuit of detector and amplifier 2 is connected a grid leak 11 and condenser 12. The output circuit 22 of detector and amplifier 2 is coupled to the input circuit 23 of amplifier 3 by means of transformer 13. In the output circuit 24 of amplifier 3 is connected reproducing means 15.

This circuit arrangement provides a means by which a piezo-electric crystal can be made to oscillate on any one of three frequencies; i. e. the "X axis frequency", the "Y axis frequency" or the "coupling frequency".

In some circuits the crystal oscillates on only one axis; namely, the "Y" axis. This gives harmonics for calibration purposes spaced from each other by the crystal "Y" frequency which might be 50 Kcs. and intended chiefly for work below 5000 Kcs. In other circuits the crystal operates only on the "X" axis of a crystal which might have a fundamental of 500 Kcs., and furnish harmonic points every 500 Kcs. to the limit of the radio frequency band now in use.

With the new type of calibrator it is possible to obtain three fundamental frequencies from a single crystal. For example, assume a crystal should be made with a "Y" fundamental of 50 Kcs., and an "X" fundamental of 500 Kcs. the coupling frequency will be between these two, but much closer to the "Y" than the "X" frequency. For low and intermediate frequency work the crystal could be operated on the "Y" or the "coupling" frequency while for the high frequency band the "X" axis frequency can be used, with harmonics every 500 Kcs.

Fig. 1 shows one method of operating the quartz crystals on either of its three axes. In a parallel feed circuit, such as this, the radio frequency current which is in the inductance 9 and condenser 6, is of the same frequency as that at which the crystal is oscillating. The fundamental frequency at which the crystal will oscillate is determined by the constants of coils 8, 8*a* and 8*b*. If coil 8 were properly designed the crystal could be made to oscillate on its "X" axis. Similarly, coil 8*a* could be designed to make the crystal oscillate on its "Y" axis, and coil 8*b* make its fundamental frequency the coupling frequency.

Therefore by varying coils in the plate supply lead, the crystal through the medium of switch 19 may be made to oscillate on any one of its three fundamental frequencies. Coil 10 is the coupling coil through the medium of

which harmonics are transferred to the detector amplifier circuit.

Fig. 1 consists of three circuits; the crystal circuit 4–5, the detector circuit 2 and the amplifier circuit 3. The crystal circuit consists of three circuits; i. e., the grid circuit which contains the quartz crystal 4 and the grid leak 5 connected as shown to the grid and filament of the crystals circuit tube 1; the parallel feed circuit which consists of a double pole triple throw switch 19 and three coils of widely different inductance 8, 8*a*, 8*b* connected to the plate of the crystal circuit tube as shown; and the plate circuit 18 which consists of the plate of the crystal circuit tube, a stopping condenser 6 and the inductance 9, connected as shown.

The detector circuit consists of the leak 11, grid condenser 12, inductance 10 and a transformer 13 connected in the proper manner to the detector tube as shown. The audio amplifier circuit may consist of any type of audio amplifier 13 connected in the proper manner. In Fig. 2 the nomenclature is exactly the same as in Fig. 1 with this additional: 14 is a variable condenser connected as shown to inductance 10; 16 is a bypass condenser; the detector and amplifier circuits are the same as in Fig. 1.

Figs. 3 and 4 show the application of the same principle to a series feed type of circuit. In the circuit shown in Fig. 3, the change from one fundamental crystal frequency to another is effected by switching from one properly chosen inductance to another in the plate circuit of the crystal oscillator tube; while in Fig. 4, a single coil is used with taps at selected points.

There are many types of coupling (conductive, inductive, capacitive, etc.) by means of which the harmonics in coil 9 may be transferred to the detector circuit coil 10. Fig. 2 shows the application, with certain modifications, of a harmonic selector circuit as described in United States Patent No. 1,696,933, dated January 1, 1929.

While it has been known for some time that three fundamental modes of oscillation could be obtained from an oscillating crystal through the medium of tuned circuits, we have provided a system whereby it is possible to use more than one mode of crystal oscillation through the use of a substantially untuned inductance employed in the plate circuit of the crystal tube in the crystal controlled calibrator. The inductance so employed depends for its frequency characteristics largely upon the value of inductance, the capacity between the adjacent turns being sufficient to give it the proper oscillation constant.

One of the advantages of this type of circuit, as compared with other types of circuits wherein the crystal calibrator circuit harmonics are obtainable only from one fundamental oscillation of the crystal circuit, is that with this circuit of our invention it is possible to obtain any one of three modes of fundamental oscillation.

A further advantage is that it is possible to calibrate any radio frequency circuit at very high frequencies, using the high frequency fundamental oscillation, or calibrate the intermediate range using the coupling frequency fundamental and the real low frequency range with harmonics of the low frequency fundamental.

It is clear that there are other advantages, for instance instead of using two or possibly three crystals to cover a given calibration range, one crystal may be used with a consequent saving of quartz and labor in grinding. With this type circuit one calibrator takes the place of two or possibly three, depending upon the range it is desired to cover. This means a great saving in materials as well as manufacturing costs.

Both parallel and series feed circuits may be used embodying our invention and although there are many other types of circuits applicable to the crystal controlled calibrator by the medium of which these modes of oscillation may be produced individually, we have endeavored to show that one crystal can be utilized through the medium of special circuits, and made to accomplish the same results as three separate crystals with their associated crystal calibrator circuits.

It is to be understood that we do not limit our invention to the circuits shown in the accompanying drawings, or that the crystal must be placed in the arrangement shown. It will also be obvious that the general principles herein disclosed may be embodied in many other circuit arrangements widely different from those illustrated, without departing from the spirit of the invention as defined in the following claims.

What we claim and desire to secure by Letters Patent of the United States is as follows:

1. In a system wherein a piezo-electric crystal is associated with a thermionic vacuum tube having grid, filament and plate circuits, rectifying means associated with said piezo-electric crystal and thermionic vacuum tube, amplifying means associated with said rectifying means, a plurality of means associated with said piezo-electric crystal and thermionic vacuum tube for causing said piezo-electric crystal to sustain oscillations at a frequency corresponding to one of its several operational axes, and means for selectively connecting said associated means to produce the frequency desired.

2. A system for calibrating radio frequencies throughout a wide range comprising an electron tube having grid, filament and plate electrodes, a grid circuit including a piezo-electric crystal, a plate circuit including any one of a plurality of selectable inductances of

frequency values corresponding to the different natural frequency characteristics of said crystal, means for selecting said inductances for inclusion in said plate circuit, a rectifier network coupled to said plate circuit and including an input circuit both for oscillations of a frequency to be calibrated and for oscillations of a known frequency, and means to amplify and audibly reproduce the beat note resulting from the two frequencies.

In testimony whereof we affix our signatures.

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RAYMOND B. OWENS.