Feb. 2, 1932. A. CROSSLEY 1,843,415

CRYSTAL CONTROLLED CALIBRATOR OR TRANSMITTER

Filed Dec. 23, 1927 3 Sheets-Sheet 1

FIG. I

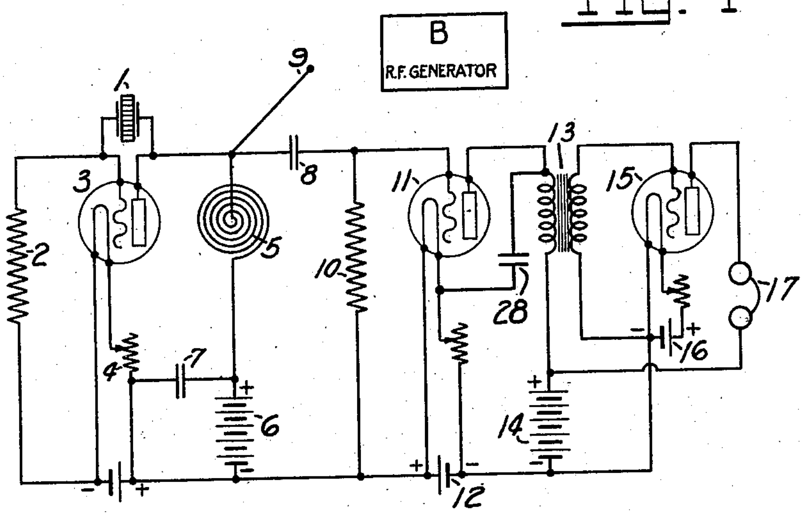
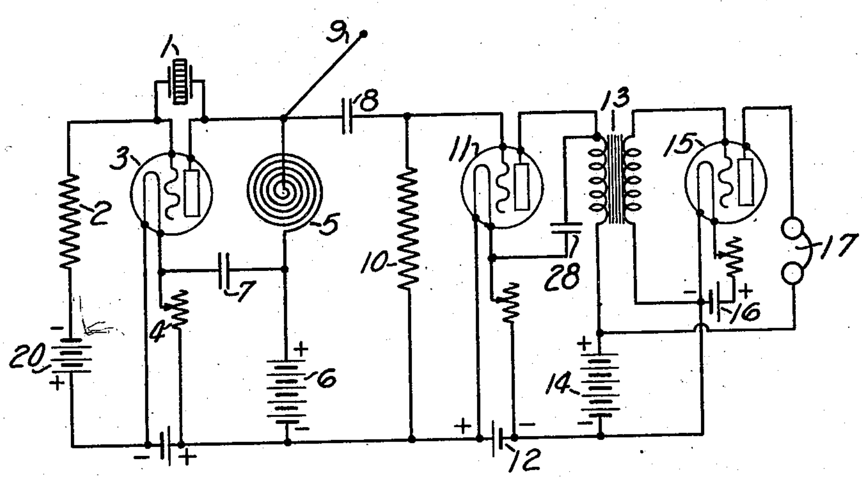


FIG. 2



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Filed Dec. 23, 1927 3 Sheets-Sheet 2

FIG. 3

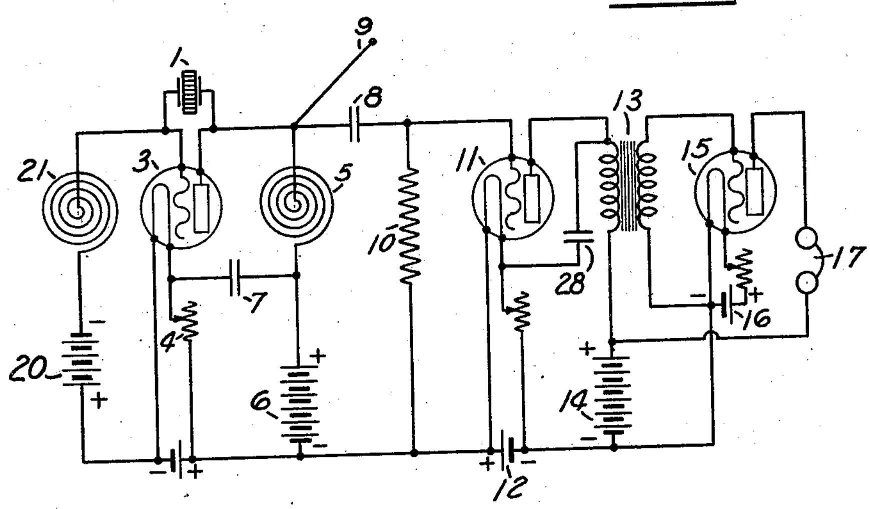
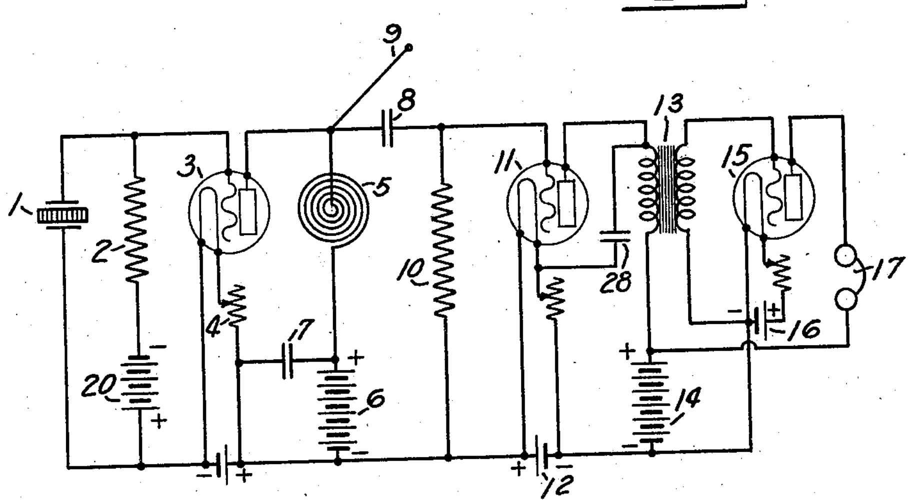


FIG. 4



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Filed Dec. 23, 1927 3 Sheets-Sheet 3

Fig. 5

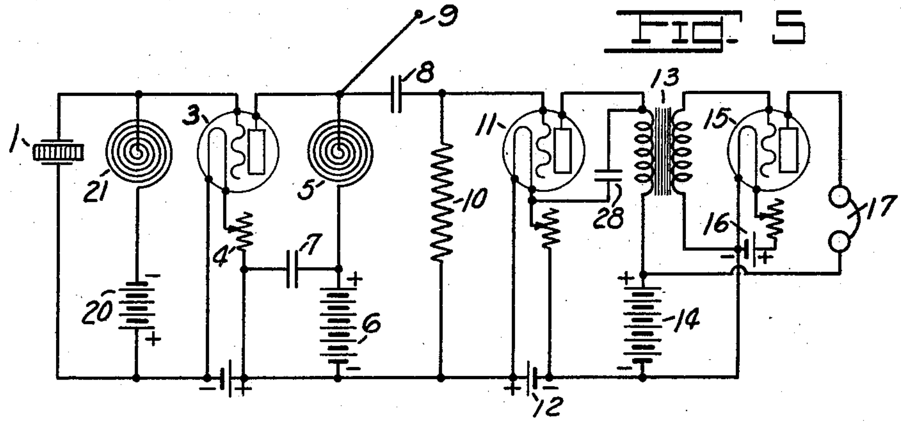


Fig. 6

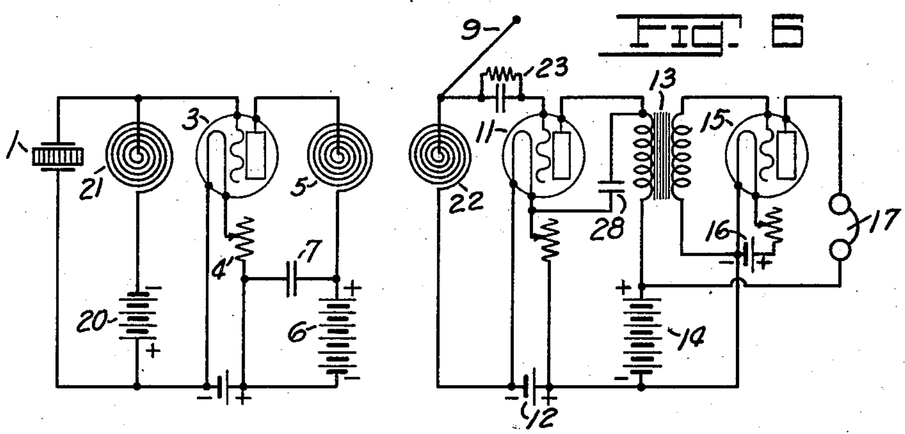
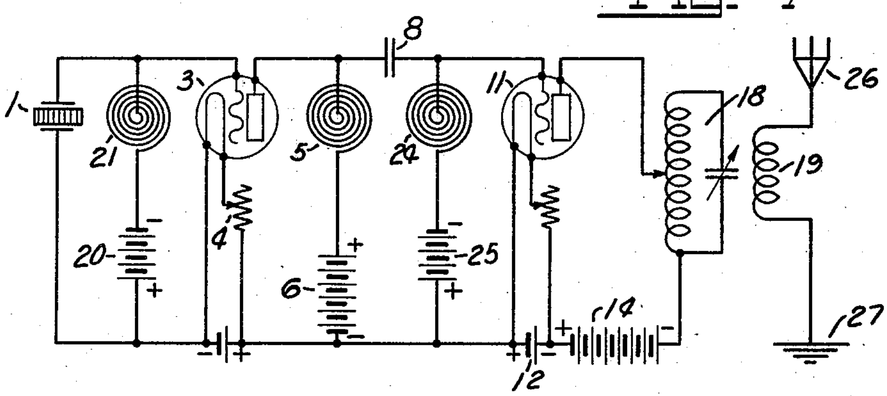


Fig. 7



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UNITED STATES PATENT OFFICE

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CRYSTAL CONTROLLED CALIBRATOR OR TRANSMITTER

Application filed December 23, 1927. Serial No. 242,264.

My invention relates broadly to crystal controlled systems and more particularly to a circuit arrangement for the production of harmonic frequencies in crystal controlled systems.

One of the objects of my invention is to provide circuit arrangements for an electron tube transmitter for deriving a harmonic frequency from the fundamental frequency of the oscillator and effecting transmission at relatively high frequencies.

Another object of my invention is to provide a circuit system for an electron tube oscillator in which the plate circuit is broadly tuned and has a flat impedance characteristic for a broad band of frequencies for the development of harmonic frequencies of relatively large amplitude.

Still another object of my invention is to provide a piezo electric crystal controlled calibrator system for the development and utilization of selected harmonic frequencies, wherein both a distorted plate current wave form and a flat impedance characteristic in the plate circuit for the development of frequencies which are harmonics of the fundamental frequency of the crystal are produced.

I have discovered a number of systems which will produce harmonic frequencies up to the 150th of the fundamental frequency of a piezo electric crystal used as a control element in a signal transmission system.

A study of the subject of harmonic frequency generation in vacuum tube circuits, whether crystal controlled or self-controlled, shows that two factors have a vital relation to the strength and number of these harmonic frequencies. These factors are the current wave form present in the plate circuit of the tube circuit and the sharpness of tuning or the impedance characteristics of the plate load circuit. If the current wave form is truly sinusoidal no harmonic frequencies will be obtained, but if it departs from this form to a square or other form, then harmonic frequencies will be produced. Assuming that the proper wave form for the generation of harmonics is obtained and a load is employed in the plate circuit that tunes sharply to a given frequency, then the strength of the harmonic currents will be reduced to a minimum and it will be very difficult to observe harmonic frequencies in excess of the fifth harmonic. On the other hand, if a plate circuit load is employed which tunes broadly and has a flat impedance characteristic for a broad band of frequencies, then the maximum number of harmonics will be obtained with a great increase in the strength of the individual harmonic currents.

By the biasing of the grid of an electron tube oscillator system a distorted plate current wave form may be obtained. This may be accomplished by introducing a radio frequency choke coil and a negative "C" battery in the grid-filament circuit. With this combination an initial voltage may be placed on the grid of the tube which will permit equal plate current change for any positive or negative alternation of grid voltage, thus obtaining a pure sine wave, or the biasing voltage can be increased either in a negative or positive direction and maximum plate current obtained for one alternation of grid potential and minimum current for the succeeding alternation, which condition represents the maximum wave distortion. A grid leak can be employed in place of the choke coil and battery and a distorted wave form obtained, due to the fact that the original positive grid excitation voltage is reduced in amplitude by virtue of the grid leak action. In the grid leak action the negative grid excitation voltage is not changed in amplitude or wave form, while the positive voltage causes a current flow across the electron path between grid and filament and back to the grid by way of the grid leak resistance. This current flow through the grid leak resistance produces an additional voltage on the grid which is in opposition to the initial positive alternation voltage and the combined effect results in a distorted plate current wave form.

A comparatively flat plate circuit impedance characteristic over a broad band of frequencies can be obtained by use of pancake wound coils or any other type of inductance coil which has large inductance and a small distributed capacity. In practice a coil having an inductance of 100 millihenries and a distributed capacity of 7 micro microfarads is employed to provide the required plate circuit load impedance for a 25 kc. crystal calibrator. For use with higher frequency crystals the coils will, of course, be smaller in order to provide the correct phase relationship for optimum oscillating condition.

My invention will be more fully understood from the specification hereinafter following by reference to the accompanying drawings wherein:

Figure 1 illustrates a crystal calibrator circuit embodying the principles of my invention; Fig. 2 shows an arrangement of grid biasing circuit for the crystal controlled oscillator system of my invention; Fig. 3 shows a modified arrangement of grid biasing circuit; Figs. 4 and 5 show crystal calibrator circuits embodying my invention wherein the piezo electric crystal element is connected in a position between the grid and filament electrodes; Fig. 6 illustrates a modified circuit arrangement for coupling the detector to the oscillator circuit; and Fig. 7 shows the application of the circuit arrangement of my invention to a signal transmission system.

In the figures two types of crystal oscillating circuits are shown; one in which the crystal is connected between grid and filament of the vacuum tube (see Figs. 4, 5, 6 and 7), and the other where the crystal is connected between grid and plate as in Figs. 1, 2 and 3. In all figures means are shown for distorting the wave form such as the grid leak method and the biasing battery method with the plate circuit inductance coil which has the broad impedance characteristic.

In Fig. 1 a crystal calibrator system is shown consisting of a crystal and mounting 1, grid leak 2, vacuum tube 3, filament rheostat 4, plate circuit inductance 5, plate battery 6 and by-pass condenser 7. Coupled to this first circuit by means of a small condenser 8 is a detector circuit which detects the difference in beat note between an unknown frequency B picked up by coupling lead 9, and either the fundamental or a harmonic frequency of the crystal circuit. The unknown frequency voltage at the detector tube 11 is obtained by coupling between B and the coupling lead 9. B designates a radio frequency generator, the energy from which is transferred to the crystal controlled system. The detector circuit comprises the grid leak 10, vacuum tube 11, filament battery 12, transformer 13, plate battery 14 and the amplifier stage shown by vacuum tube 15, filament battery 16 and telephone or responsive device 17.

This figure shows the wave distortion means in the form of the grid leak 2, and also the special inductance 5 in the plate circuit together with the capacitative coupling 8 between the oscillating circuit and the detector system. The size of the condenser 8 employed for coupling is, of course, dependent on the frequency range of the calibrator, but for best results should be of a minimum value in order that it will not materially affect the broadness of the impedance characteristic of the plate circuit. In practice a 50 micromicrofarad condenser produces best harmonic response with crystal calibrators whose fundamental frequency lies between 50 and 200 kcs.

The circuit illustrated in Fig. 1 is highly desirable for use with high frequency crystal calibrators because a larger coil system 5 is required to produce the oscillation condition than is necessary with circuits shown in Figs. 4, 5, 6 and 7. The capacitative reactance of the coil system 5, in the circuit shown in Fig. 1, must predominate at the fundamental crystal frequency before this circuit will oscillate. In the coil system 5 of Fig. 1 a large inductance to capacity ratio, which gives a substantially flat plate impedance curve and represents the best condition for generation of harmonics is required.

Fig. 2 is similar to Fig. 1, with the exception of the addition of the biasing battery 20 which is placed between one filament terminal of tube 3 and the low potential side of the resistance 2. This battery as previously stated, can bias the grid to a particular value, which produces maximum wave distortion. The resistance 2 prevents the short circuiting of the piezo electric controlling voltage from the crystal.

Fig. 3 is identical to Fig. 2, with the exception of the radio frequency choke coil 21, which is employed in place of the resistance 2 in the input circuit of the oscillator.

Figs. 4 and 5 are similar to Figs. 2 and 3 respectively, with the exception of the change in position of the crystal 1 from between the grid-plate electrodes to a position across the filament-grid electrodes of the oscillator tube 3.

Fig. 6 shows another method of coupling the detector to the oscillating circuits for the detection of harmonics. This method of coupling can be applied to circuits shown in Figs. 1 to 5, inclusive. The coil 5 is inductively related to a similar coil 22 each of which are designed for a large inductance to capacity ratio. A grid leak and grid condenser 23 are shown disposed in the grid circuit of the detector tube 11.

Fig. 7 shows a crystal controlled transmitter. In this transmitter I show one form of harmonic generating crystal controlled oscillator 3 which is coupled to a stage of amplification through the coupling condenser 8. The tuned plate circuit 18 of the amplifier 11 can be tuned to the desired harmonic frequency. Although I have shown only one type of harmonic generating circuit with this transmitter, it can be readily seen that any of the circuits shown in Figs. 1 to 5 can be employed.

The several circuits which have been illustrated for the purpose of explaining my invention have been found to be highly efficient in operation, and while I have described preferred embodiments, I desire that it be understood that modifications may be made and that no limitations are intended other than are imposed by the scope of the appended claims.

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

1. A system for generating harmonic frequencies of the fundamental frequency of a piezo electric crystal, comprising an electron tube having grid, cathode and plate electrodes, input and output circuits interconnecting said electrodes, a piezo electric crystal element connected to establish a feedback path from the output to the input circuit, a high resistance connected to the grid electrode of said electron tube, a source of potential connected to said resistance for impressing a negative potential upon said grid electrode through said resistance for distorting the wave form of the high frequency oscillations generated by said electron tube the frequency of which is sustained by said piezo electric crystal, and means disposed in the output circuit of said electron tube for producing a substantially flat plate circuit impedance characteristic whereby all of the harmonic frequencies which are included in the complex wave high frequency oscillations generated by said electron tube will be substantially equally attenuated.

2. A system for generating harmonic frequencies of the fundamental frequency of a piezo electric crystal comprising an electron tube having grid, cathode and plate electrodes, input and output circuits interconnecting said electrodes, a piezo electric crystal element connected to establish a feedback path from said output to said input circuit, means comprising a source of potential connected in series with a resistance for impressing a negative potential upon the grid electrode of said electron tube, and means in said output circuit for producing a substantially flat plate impedance characteristic whereby all of the harmonic frequencies which comprise the complex wave form high frequency oscillations in the output circuit will be substantially equally attenuated.

3. In a system for generating oscillations, the combination of an electron tube having grid, cathode and plate electrodes, an input circuit interconnecting said grid and cathode electrodes, an output circuit interconnecting said plate and cathode electrodes, a piezo electric crystal element connected between said grid and plate eletrodes, a high resistance connected into said input circuit, a source of potential disposed in series with said resistance and connected across said input circuit for impressing a negative potential upon the grid electrode of said electron tube, a source of potential in said output circuit and means connected in series with said source of potential comprising a relatively large inductance having a relatively small capacity for deriving harmonic frequencies of the fundamental frequency of said piezo electric crystal element.

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