July 28, 1936. M. G. CROSBY 2,048,782

CRYSTAL CONTROLLED CIRCUIT

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Fig. 1

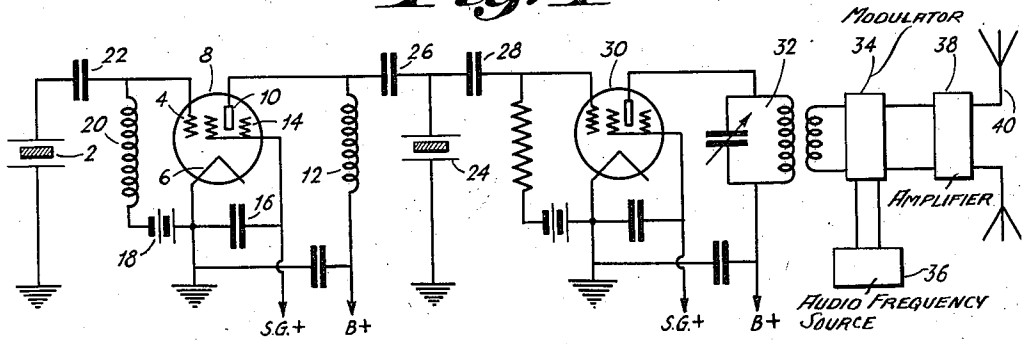


Fig. 2

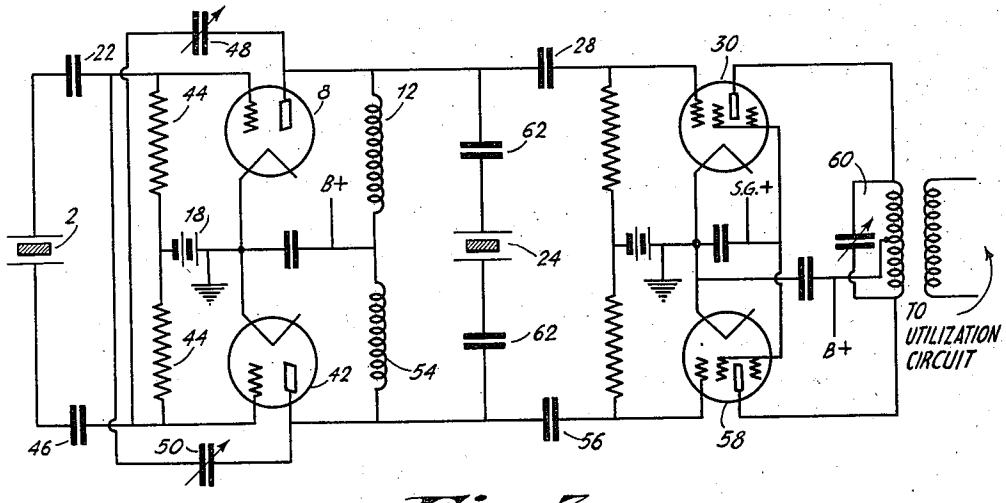
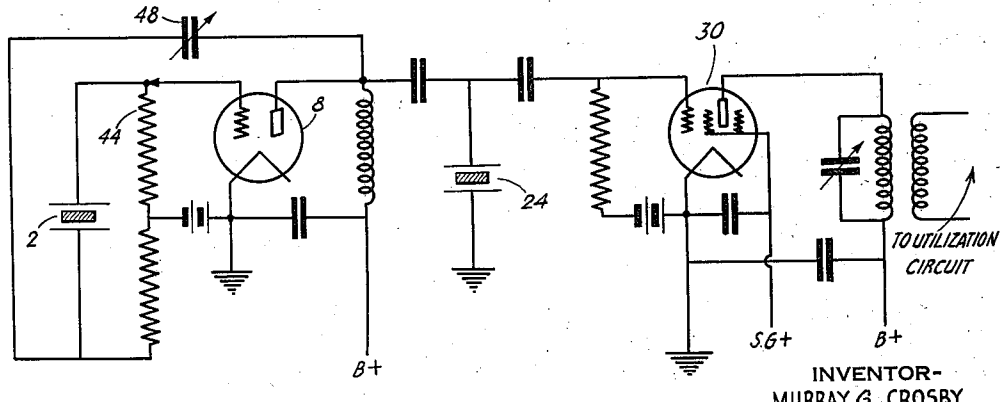


Fig. 3



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Fig. 4

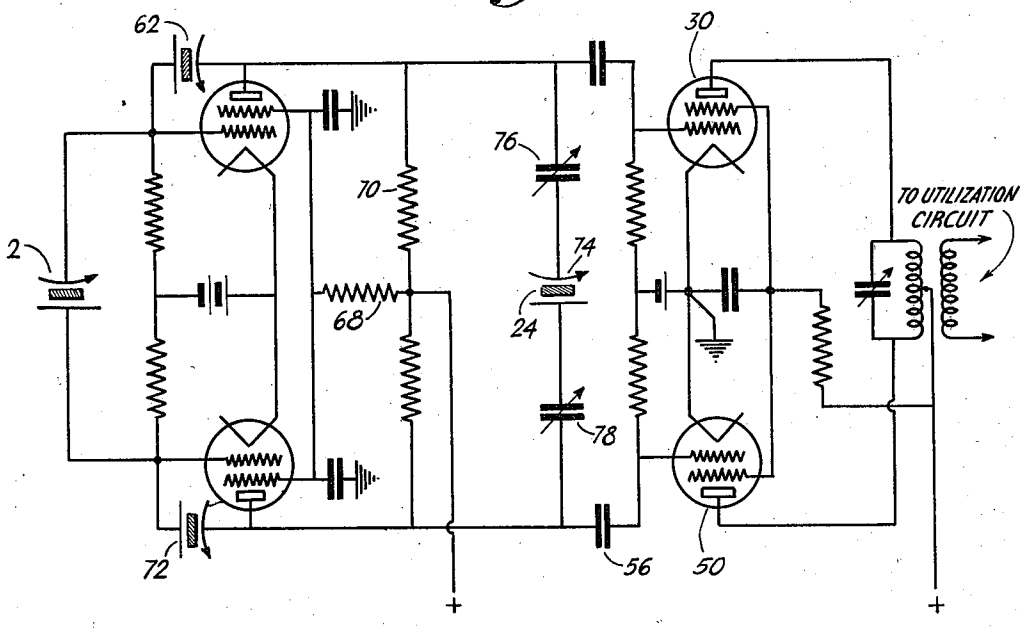
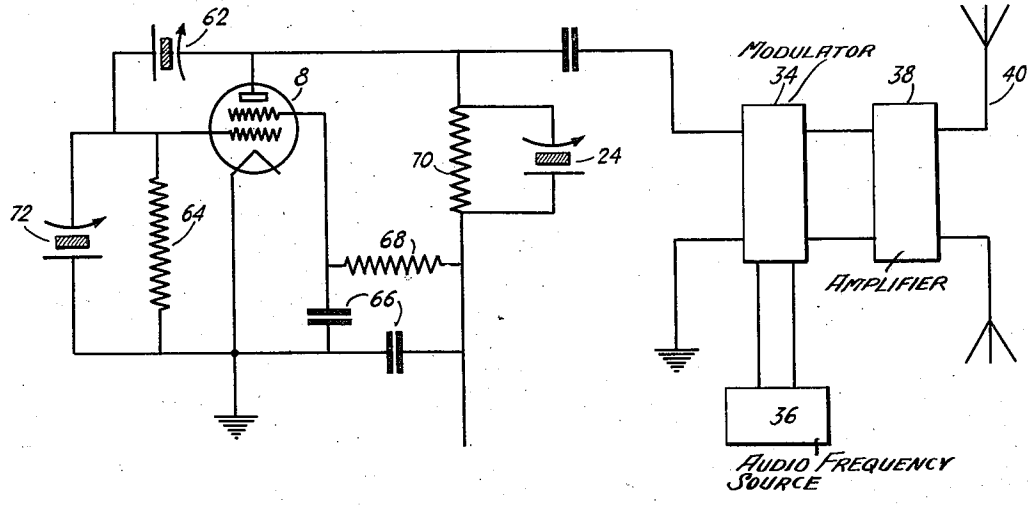


Fig. 5



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CRYSTAL CONTROLLED CIRCUIT

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Application October 4, 1932, Serial No. 636,107

5 Claims. (Cl. 250—36)

This invention relates to improved piezo-electric crystal controlled oscillation generator circuits.

Heretofore, crystal controlled oscillation generators have been subject to frequency variation because of circuits having inductance and capacity associated therewith. Consequently, because of variations in reactance of these circuits, and also to a limited extent because of variations in tube electrode voltages, frequency drifts have occurred. To overcome such frequency changes is the principal object of my present invention and to do so, I provide a crystal controlled oscillation generator in which normally reactive circuits are replaced with a piezo-electric crystal.

Because my invention involves the use of a plurality of crystals operating at substantially the same frequency, it should be apparent that frequency drift will rarely, if ever, occur, and if it does it will be in such amounts as to be practically negligible. Consequently, my improved form of crystal controlled oscillation generator will be very suitable for a standard frequency oscillation generator.

According to my invention further, crystals having different temperature coefficients may be simultaneously used whereby the frequency of oscillation may be rendered practically independent of ambient temperature changes.

My present invention may more readily be understood both as to its mode of operation and structural organization by referring to the accompanying drawings wherein,

Figure 1 illustrates a crystal controlled oscillation generator having crystals operating at like frequencies in the input and output or grid and plate circuits;

Figure 2 illustrates a pushpull crystal controlled oscillation generator incorporating the principles of my present invention;

Figure 3 illustrates a modification of Figure 1 wherein a neutralizing circuit is used in place of a screen grid in order to reduce interelement feed back;

Figure 4 is a modification of Figure 2 wherein crystals are used in the input and output circuits of a pushpull system and wherein further crystals are used for feed back purposes; and,

Figure 5 is a single tube modification of the oscillator shown in Figure 4.

Referring more specifically to Figure 1 of the drawings, a quartz piezo-electric crystal 2 is connected between the grid or cold electrode 4 and filament 6 of a vacuum tube or electron discharge device 8. Plate potential for plate or cold electrode 10 is fed through a radio frequency choke 12 and a screen grid 14 is maintained at radio frequency ground potential by the action of a suitable by-passing condenser 16. The cold electrodes 4, 10 and 14 are, of course, unequally spaced from the cathode 6 and are subjected to different unidirectional potentials. At the higher frequencies, the condenser 16 may be made of such a value as to series resonate with the inductance of the screen grid lead so as to positively maintain the screen grid substantially at radio frequency ground potential. Grid or control electrode bias is supplied by means of a battery 18 conductively connected to the grid 4 through a radio frequency choke 20. The crystal may be connected directly to the grid, but is preferably isolated therefrom for unidirectional potentials by means of a by-passing condenser 22 which obviously offers appreciably no impedance to high frequency or crystal currents. A crystal 24 is somewhat similarly connected in the anode or output circuit of tube 8, it being isolated from the plate potential by means of a condenser 26 and from the grid biasing potential from the next stage by means of another condenser 28. Both condensers 26, 28, however, offer little impedance to high frequency currents.

It is to be noted that crystal 24 is used to replace the heretofore customary parallel tuned circuit consisting of an inductance coil and a variable condenser connected in parallel between the plate and cathode of the oscillation generator tube 8.

The crystals 2 and 24 are ground to substantially the same desired operating frequency, care being taken that crystals 2 and 24 are ground to such frequencies as to offer effectively the correct reactance for the desired operating frequency. For example, with straight capacity feed back from the anode circuit to the control electrode or grid circuit, crystals 2 and 24 should be ground so as to offer inductive reactances to the desired operating frequency. Further, crystals 2 and 24 should be so cut from the natural crystal or so chosen as to have respectively positive and negative temperature coefficients or the reverse whereby changes in ambient temperature will become self compensating and produce no variation in operating frequency of the system as so far described.

Output energy may be taken through by-passing condenser 28 and fed to the control electrode of a vacuum tube amplifier 30 having a tunable output circuit 32. Energy from the circuit 32 may then be fed into amplifiers and/or frequency

multipliers and/or modulator 34 supplied with modulating potentials from a suitable source 36. The resultant modulated output may then be fed to a power amplifier 38 and then radiated by means of a radiating antenna 40.

The system shown in Figure 1 may also indicate a receiving system in which case the antenna 40 would indicate a receiving antenna, 38 a radio frequency amplifier, and 34 a first detector supplied with energy from the local oscillator tube 38. Rectangle 36 would then indicate a second detector followed by suitable low frequency amplifiers and a translating device such as a syphon recorder, ear phones or loudspeaker.

In Figure 2 the crystal 2 is shown connected between the control grids of tubes 8, 42 and the crystal 24 is illustrated as being connected between the plates or anodes of those tubes. The crystal 2 is isolated from the grid biasing potentials supplied to the grids through resistors 44 from source 18 by means of by-passing condensers 22, 46. Interelectrode feed back may be reduced if desired by means of the neutralizing condensers 48, 50 cross-connecting the anodes and control electrodes of tubes 8, 42. While the plate potential shown in Figure 2 has been shown as being fed through radio frequency chokes 12, 54, these chokes may obviously be replaced by a resistor such as resistors 44.

The output of crystal controlled oscillator tubes 8, 42 of Figure 2, is fed through by-passing condensers 28, 56 to the pushpull connected screen grid amplifiers 30, 58 having a tunable output circuit 60 from which energy may be taken inductively as shown and fed to any suitable utilization circuit.

As described in connection with Figure 1, the crystals of Figure 2 should be ground so that the feed back voltages will be of correct phase for oscillation generation. Also, the crystals 2, 24, if desired, may be made of such material or cut from the natural crystal in such a way as to have positive and negative temperature coefficients respectively, thereby preventing changes in frequency due to ambient temperature changes. Obviously, while the crystal 24 has been shown isolated from the D. C. circuits by means of by-passing condensers 62, these condensers, if desired, may be dispensed with without affecting the radio frequency operation of the system. They are preferred, however, to safeguard the crystal against application of undesired D. C. potentials.

In the arrangement shown in Figure 1 a screen grid has been illustrated in order to reduce feed back. The purpose of such a reduction is, of course, to reduce the load carried by the crystal as a result of which frequency stability is enhanced. In Figure 2 the feed back control has been accomplished by means of a cross neutralized arrangement of tubes. In Figure 2 adjustment of feed back may also be accomplished by variably tapping the grids of the tubes on resistors 44. Such an arrangement utilizing a variable tap and also reduced to a single tube stage is illustrated in Figure 3.

Referring to Figure 3, neutralizing condenser 48 serves the dual function of controlling feed back as well as preventing the application of plate potential to crystal 2. As a further feed back control, the control electrode or grid is shown variably tapped to input resistor 44. If desired, in the system shown in Figure 3, the resistor 44 may be replaced by a divided inductor and may be completely neutralized by means of the condenser 48 with the crystal 2 removed from circuit. Then, by replacing crystal 2 into circuit the capacity balance will be upset sufficiently to cause oscillation generation. The output of the oscillator shown in Figure 3 is fed to a suitable amplifier 30 somewhat similar to the one shown in Figure 1 whose output may be utilized as desired.

It is to be clearly understood that I am not to be limited in the placing of crystals ground approximately to the same frequency into circuit as shown in Figures 1 to 3 inclusive.

In the arrangement shown in Figure 5 the screen grid tube 8 has a screen grid so effectively grounded and its input and output circuits shielded so that insufficient feed back for oscillation generation occurs. Feed back is then accomplished by means of crystal 62 connected between the plate and grid of tube 8. Crystals 72 and 24 shown in Figure 5 correspond to crystals 2 and 24 of Figure 1. Grid and control electrode bias shown in Figure 5 is obtained by means of grid leak resistor 64, the screen grid is grounded for radio frequency currents by means of condensers 66 and polarized through the action of voltage dropping resistor 68. Anode potential is supplied to the plate of tube 8 through resistor 70 across which crystal 24 is connected in parallel. The crystals 2, 62 and 24 shown in Figure 5 are shown provided with electrodes which may be variably spaced from the crystal, or with variable condensers connected in series therewith for adjustment purposes.

Crystals 72, 62 and 24 of Figure 5 are ground approximately to the same operating frequency. By discreet choice of frequencies and also by correct variation of capacities in series with crystals 72, 62 and 24 the phase of the voltages fed back will be correct for oscillation generation at a frequency which is approximately the mean of the frequencies of crystals 72, 62 and 24.

The pushpull arrangement of the oscillation generator shown in Figure 5 is illustrated in Figure 4. Crystals 2 and 24 form the grid circuit and plate circuit, or respectively the input and output circuit frequency controlling crystals. Crystals 62 and 72 form the sole feed back circuits from the anode circuits to the control electrode or grid circuits. As an added adjustment and refinement, crystal 24 may not only be provided with an adjustable electrode 74, but also may be placed serially between the two variable coupling condensers 76, 78. As in Figure 2, output energy may be fed through by-passing condensers 78, 56 to the pushpull connected electron discharge devices 30, 50 whose output energy is fed to any suitable utilization circuit.

It is to be clearly understood that during operation, all of the crystals in each of the systems described oscillate at a common frequency which in general lies between the natural frequencies of the crystals included in circuit. That is to say, the frequency at which the crystals oscillate differs slightly from their natural resonant frequencies in any particular circuit such as described above.

Having thus described my invention, what I claim is:

1. An oscillation generator comprising an hermetically sealed container wherein are contained an electron emitting cathode and a plurality of relatively cold electrodes including an anode and a control grid unequally spaced from said cathode, a piezo-electric crystal connected between

said anode and said control grid, and a piezo-electric crystal connected between a cold electrode and said cathode, said crystals being mechanically isolated from each other and being ground to approximately the same frequency and to such specific frequencies that oscillations are generated by said device at a constant frequency substantially that of the common operating frequency of said crystals.

2. An oscillation generator comprising an electron discharge device having an anode a cathode and a control grid, a piezo-electric crystal connected between said control grid and anode, another piezo-electric crystal connected between said anode and cathode, said crystals being ground to substantially like frequency and being mechanically isolated from each other, and, means for reducing capacity feed back between said anode and control electrode.

3. Apparatus as claimed in the preceding claim characterized by the fact that said means for reducing interelectrode feed back is in the form of a screen grid maintained substantially at ground potential.

4. An oscillation generator comprising a closed container wherein are contained an electron emitting cathode and a plurality of cold electrodes unequally spaced from said cathode, a piezo-electric crystal connected between one of said cold electrodes and said cathode, a piezo-electric crystal connected between said other cold electrode and said cathode, and a third piezo-electric crystal connected between said pair of cold electrodes, said crystals being mechanically isolated from each other and being ground to approximately the same frequency and to such specific frequencies that oscillations are generated by said device at a constant frequency substantially that of the common operating frequency of said crystals.

5. In an oscillation generator an electron discharge tube net work having at least one electron discharge tube adapted to produce oscillations between its electrodes, means including a plurality of piezo-electric devices each connected across different pairs of said electrodes for maintaining constant the frequency of said oscillations, said piezo-electric devices being so ground as to obtain substantially the same frequency characteristics and being mechanically isolated one from another, and means for feeding back energy non-inductively from the output side to the input side of said network through one of said piezo-electric devices.

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