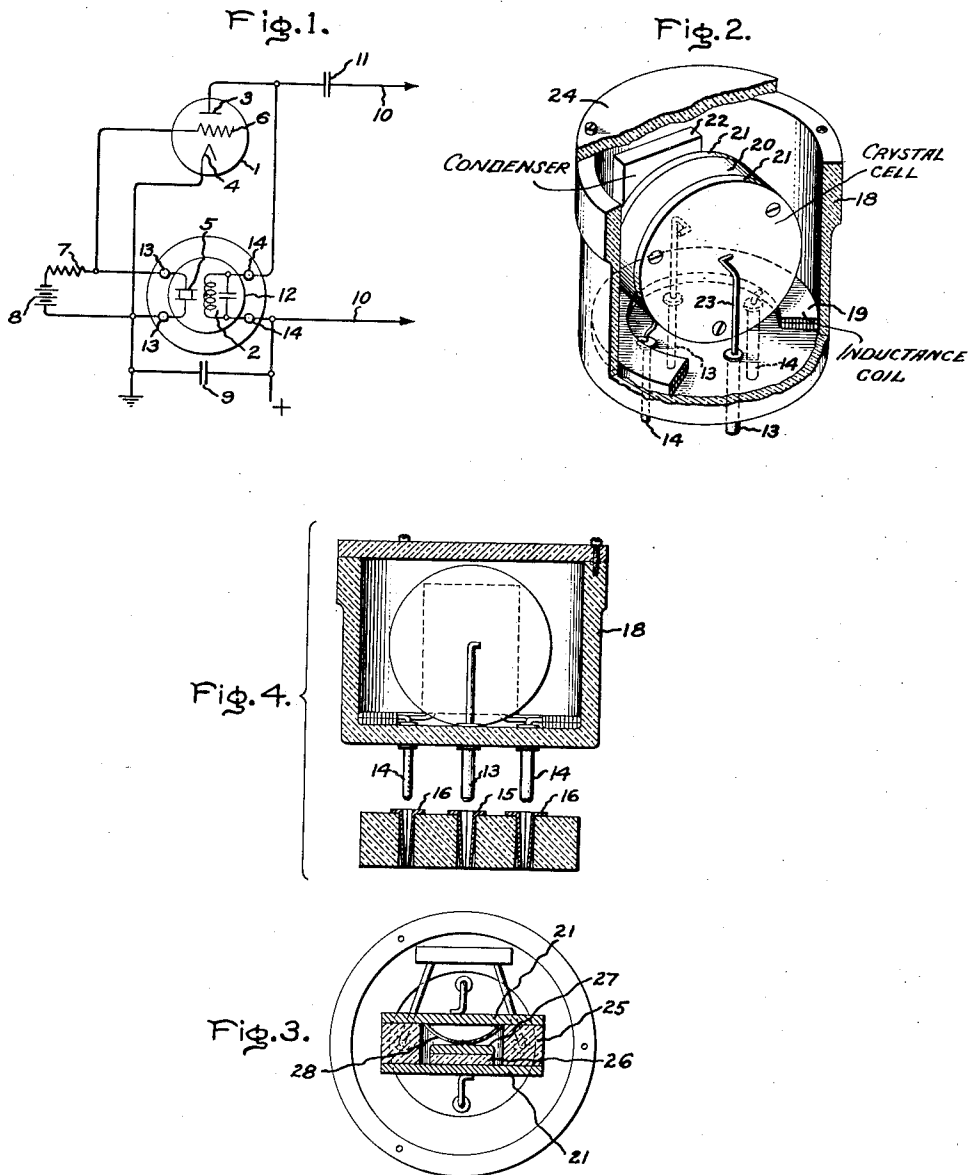


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FREQUENCY DETERMINING UNIT FOR PIEZOELECTRIC
CRYSTAL CONTROLLING OSCILLATORS
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FREQUENCY DETERMINING UNIT FOR
PIEZOELECTRIC CRYSTAL CONTROLLING
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My invention relates to oscillators, and more particularly to oscillators of the electron discharge type which include a piezoelectric crystal as the frequency determining means.

Piezoelectric crystal controlled oscillators of conventional design usually include an output circuit which is tuned to a resonant frequency slightly above the natural frequency of mechanical vibration of the frequency determining crystal.

In using such an oscillator for certain purposes such, for example, as a frequency monitoring unit for checking the carrier frequencies of radio transmitters, it is at times necessary to change the output frequency of the oscillator from one predetermined value to another predetermined value. This is usually accomplished by inserting in the oscillator circuit a new piezoelectric frequency determining crystal having the desired natural frequency and then adjusting the tuned output circuit of the oscillator until its resonant frequency is slightly above the frequency of the newly inserted crystal. Such a method of adjusting the output frequency is somewhat laborious and requires considerable skill on the part of the operator if the exact desired output frequency is to be secured.

One of the objects of my invention is to provide a piezoelectric crystal controlled oscillator which includes means whereby the output frequency may be easily and quickly changed from one predetermined value to another predetermined value without adjustment of the tuning elements of the oscillator circuit.

In accordance with my invention the above-stated object is attained by assembling the frequency determining crystal cell and the elements of the output circuit in a self-contained unit which may be plugged into or removed from the oscillator circuit at will; the output circuit being adjusted and calibrated during the manufacture of the unit, so that its resonant frequency is slightly above the natural frequency of vibration of the piezoelectric crystal. In accordance with a further feature of my invention a suitable connector socket is included in the oscillator assembly which is provided with plug-receiving sockets connected in the oscillator circuit to receive the terminals of the crystal cell and the terminals of the oscillator output circuit. The frequency determining units are each assembled in a plug body which is equipped with plug connectors suitably arranged to engage the correct socket of the connector receptacle. By using a plurality of units pre-calibrated to different desired predetermined values the output frequency of the oscillator may

be changed at will by simply interchanging the frequency determining units.

It is a further and more specific object of my invention to provide a detachable self-contained frequency determining unit for an electron discharge oscillator which comprises a piezoelectric crystal and a tuned oscillator output circuit assembled in a container provided with plug outlet connectors for engaging the connector sockets of a receptacle having its respective terminals connected in the oscillator circuit at the proper points.

In constructing detachable frequency determining units as described above, it is desirable to adjust and calibrate during the manufacture and assembly thereof the tuning of the output circuit contained in the unit to a desired predetermined frequency slightly above the natural period of vibration of the frequency determining crystal. In accordance with my invention such a calibration is effected during the assembly of the unit by moving the crystal cell with respect to the inductance coil forming a part of the output circuit thereby to change the inductive coupling between the turns of the coil and the electrodes of the crystal cell and alter the over-all inductance of the coil. When the crystal cell is properly located in its correct position within the container such that the output circuit has the desired resonant frequency, the cell may be fixed in place within the container in a suitable fashion as by pouring a sealing compound around the cell. In this manner the self-contained unit may be calibrated to the desired frequency in the course of its manufacture and following such calibration is ready for use in the manner described above.

It is an additional object of my invention to provide a self-contained unit of the above-described type in which means are provided for calibrating during assembly of the unit the frequency of the tuned output circuit to a selected predetermined value.

The novel features 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 organization and the method of operation together with further objects and advantages thereof will best be understood by reference to the specification taken in connection with the accompanying drawing, in which Fig. 1 illustrates an electron discharge oscillator having my invention embodied therein; Fig. 2 is a perspective view partially in section of my improved self-contained detachable frequency determining unit, and Figs. 3 and 4 are respectively

top and side views, partially in section, of the device shown in Fig. 2.

Referring to Fig. 1 of the drawing, I have illustrated my invention as applied to a piezoelectric crystal controlled oscillator of conventional circuit arrangement. As shown, the oscillator comprises an electron discharge device 1 having a tuned output circuit 2 connected between the anode 3 and the cathode 4; and a frequency determining piezoelectric crystal 5 connected between the control grid 6 and the cathode 4 of the discharge device 1. A resistance 7 and a source of unidirectional potential 8 are connected in series between the control grid 6 and the cathode 4 for biasing the grid 6 negative with respect to the cathode 4 and a suitable source of high voltage (not shown) is included in the output circuit for supplying the energy necessary to maintain the oscillator in stable operation. The source of high voltage anode potential is shunted by a condenser 9 for by-passing the high frequency current flowing in the output circuit of the oscillator. The alternating potential generated across the output circuit may be impressed on a utilizing circuit (not shown) by the circuit leads indicated at 10. A direct current blocking condenser 11 is included in the upper circuit lead 10 which functions to pass the high frequency output current of the oscillator to the input of the utilizing circuit and to isolate the utilizing circuit from the operating voltage of the anode 3.

The operation of the above-described circuit is well known in the art and only a brief description thereof is deemed to be necessary to an understanding of my invention. During normal operation of the device the piezoelectric crystal 5 vibrates mechanically at its natural frequency and produces voltage pulsations which are impressed on the control grid of the discharge device 1. Such voltage pulsations control the flow of current in the output circuit thereby to produce an oscillatory current therein having a frequency determined by the frequency of vibration of the crystal 5. A portion of the oscillatory energy generated in the output circuit is fed back through the grid-plate tube capacity coupling and is supplied to the crystal in the proper phase to maintain the crystal in vibration at its frequency of mechanical resonance. The oscillatory energy developed in the output circuit is of course supplied to the utilizing circuit by the circuit leads 10.

In accordance with my invention the crystal cell and the elements of the output circuit are assembled in a single self-contained unit which is calibrated during its manufacture to a desired frequency and which may be readily connected in, or disconnected from, the oscillator circuit. This self-contained unit is shown diagrammatically by the circle indicated at 12 and may be conveniently plugged into the oscillator circuit by the plug connectors indicated at 13 and 14.

Referring to Fig. 2 of the drawing, I have illustrated the preferred embodiment of the self-contained frequency determining unit. As shown, the unit comprises a separable plug body or container 18 within which is mounted the elements of the tuned output circuit and the piezoelectric crystal cell. Preferably, the output circuit tuning coil 19 is made in the form of a flat toroid and is positioned in the bottom of the hollow interior of the plug body 18. A piezoelectric crystal cell 20 is disposed within the container in such a position that the planes of its two electrodes 21 are substantially at right angles to the plane of the flat side of the inductance coil 19. A condenser

22 for tuning the oscillator output circuit may be placed alongside the crystal cell 20 in case such a condenser is required. The container 18 is provided with plug connectors 13 and 14 which are respectively connected to the electrodes 21 of the crystal cell 20 and the terminals of the output circuit comprising the parallel connected condenser 22 and inductance 19. Preferably the connectors 13 are hollow, the bores thereof being of sufficient diameter to accommodate connecting wires 23, each of which terminates in a fabricated connection to one of the crystal cell electrodes 21. A suitable cover plate 24 is provided for closing the open end of the container 18.

The details of the crystal cell 20 and the complete electrical circuit of the cell are illustrated in Fig. 3 wherein the cell is shown as comprising a toroidal member 25 constructed of insulating material such as porcelain which member is closed by the stationary electrodes 21. Within the member 25 is mounted a piezoelectric crystal 26, a floating electrode 27, and a spring 28 for maintaining the crystal under pressure between one of the electrodes 21 and the floating electrode 25. Preferably, the spring 28 is of crow-foot design and is provided with a plurality of legs which rest against one electrode 21 and an aperture in the central portion which engages a projection extending from the floating electrode 27 thereby to maintain the crystal in a fixed position within the cell.

In the manufacture and assembly of the above-described frequency determining unit the inductance coil 19 is first placed in the bottom of the hollow interior of the plug body 18, and its terminals are soldered or otherwise connected to the connectors 14. If a condenser 22 be required to tune the inductance 19 to a desired frequency, it may be placed within the plug 18 along the internal circumference thereof and its terminals soldered to the connectors 14 thereby to connect the condenser and inductance in parallel.

Following the above assembly operations, the assembled crystal cell having the wires 23 soldered to the electrodes thereof may be inserted within the plug and the wires 23 projected through the hollow connectors 13. The wires 23 should be made considerably longer than the expected required length for soldering to the lower ends of the connectors.

At this stage of the assembly the unit may be adjusted and calibrated to obtain the exact desired resonant frequency of the output circuit formed by the parallel connected inductance 19 and condenser 22. This may be accomplished by properly connecting the elements in an oscillator circuit and moving the crystal cell 21 with respect to the coil 19 thereby to change the coupling between the electrodes 21 and the turns of the coil 19 and change the overall inductance value of the coil. A convenient method of making such an adjustment is that of pushing or pulling the wires 23 extending from the connectors 13 thereby to alter the position of the cell within the container 18 and vary the coupling between the electrodes 21 and the inductance 19 in the above-described manner. When the correct position is obtained the excess of wire extending from the connectors 13 may be cut off and the ends of the wires 23 soldered to the ends of the connectors 13. It will be understood that during the above-described adjusting step the cell 20 is entirely supported by the wires 23.

In order to secure the tuning elements 19 and

22 and the crystal cell 20 in position within the plug 18, the interior of the plug may be filled with a suitable filler after the elements are correctly positioned within the plug. It has been found that if the frequency determining unit be calibrated to an ultra-frequency as, for example, 10 megacycles, it is desirable to use rock wool as the filler medium. However, if the unit is calibrated to operate at a lower frequency any form of sealing compound may be used with success.

Referring to Fig. 4 of the drawing, I have illustrated a side view partially in section of the unit shown in Fig. 2, together with a suitable socket type of receptacle for accommodating the plug connectors 13 and 14 which project from the lower wall of the plug 18. As shown, the receptacle is provided with socket contacts 15 and 16 for accommodating the connectors 13 and 14. Preferably one of each of the pairs of connectors 13 and 14 should be of a diameter smaller than the diameter of the remaining connectors in order to prevent any possibility of the plug being plugged into the socket with the wrong connections.

By using rock wool or an equivalent material as the filler media when the unit is to be operated at ultra high frequencies certain undesired effects of the filler on the resonant frequency of the coil 19 are reduced or avoided. It has been found that if a sealing compound or similar material is used in a unit designed to operate at a very high frequency as, for example, from 10 megacycles upward, the resonant frequency of the coil is changed considerably from its previous calibrated value, and in certain instances the change has been found to be sufficient to prevent operation of the oscillator when the unit is plugged into the circuit. This change in the natural resonant frequency of the coil 19 is probably brought about by the change in the effective capacity of the coil caused by the introduction of the filler media in the electrostatic field of the coil. Whatever the cause for the change may be, the use of rock wool prevents such an undesired alteration in the resonant frequency of the coil 19 and, accordingly should be used as the filler media if the unit is designed to operate in the above-specified frequency range. In the lower frequency ranges, however, the use of rock wool has been found to be unnecessary since no such undesired shift in the natural resonant frequency of the coil is produced by the introduction of ordinary sealing compounds in the region surrounding the coil. Accordingly, if a unit is designed to operate at a frequency in the low frequency ranges as, for example, in the commercial broadcasting carrier frequency range, ordinary sealing compounds may be used as the filler media with good success.

Although I have described the frequency determining unit as including a tuning condenser 22, it will be apparent that in certain frequency ranges such a condenser may be dispensed with. Thus, at ultra high frequencies as, for example, in the range from 10 megacycles upward the distributed capacity of the inductance coil 19 may be sufficient to tune the coil to the required resonant frequency. It will therefore be understood that in such frequency ranges the condenser 22 need not be used.

While I have shown the crystal cell 20 as being mounted at right angles with respect to the flat plane of the coil 19, it may be found to be desirable in the lower frequency ranges to position

the cell within the plug body 18 in a manner such that the electrodes 21 are parallel with the side of the coil 19. The purpose of mounting the cell at right angles with respect to the coil in the manner illustrated is to provide a means for varying the effective inductance of the coil through a small range for a comparatively large displacement of the cell electrodes 21 with respect to the coil. Thus, with the cell mounted as shown, a comparatively small amount of the metal of the electrodes 21 is included in the effective magnetic circuit of the coil and a relatively large shift in the position of the cell with respect to the coil produces only a small change in the constants of the magnetic circuit of the coil. While small changes in the effective inductance of the coil 19 have been found to be sufficient to calibrate the output circuit of which the coil forms an element to the desired value at exceedingly high frequencies they may be entirely insufficient for calibrating purposes when the unit is designed to operate at a lower frequency. Although theoretically in the latter case the required change in inductance could be obtained by moving the perpendicularly mounted cell through a greater range of movement, limitations as to the size and cost of the plug body 18 reduce the practicability of such a method of adjustment.

In order to retain the desired small physical dimensions of the plug body 18 and at the same time obtain the required range in change of inductance of the coil 19 for the limited range of movement of the cell 20 when the unit is to be calibrated to operate at a relatively low frequency, it is desirable to mount the cell with the electrodes 21 parallel to the flat coil 19. With the cell in the last-named position the lower electrode 21 will be adjacent the upper side of the coil 19 and a considerable amount of metal is thereby included in the magnetic circuit of the coil. Accordingly, when the cell is moved a small distance with respect to the coil a relatively large change in the inductance of the latter will be produced. It follows that the range of inductance change for a given movement of the cell 20 is considerably increased by positioning the cell with its flat electrodes parallel to the flat side of the coil 19. In this connection it may be found to be desirable to form the electrodes 21 from iron or a similar highly permeable metal in order further to increase the range of inductance change for a given range of movement of the cell 20.

From the foregoing description it will be apparent that I have devised an arrangement wherein the frequency determining unit may readily be connected in or disconnected from an associated oscillator circuit with a minimum of effort on the part of the operator. Since the unit is self-contained it may be exactly calibrated during its manufacture to produce the desired oscillator output frequency and, further, it may easily be removed from the circuit for recalibration in the event such recalibration is necessary.

The above-described circuit and self-contained frequency determining unit is particularly useful in certain types of work requiring an oscillator carefully adjusted to produce a predetermined frequency. Thus, in transmitter monitoring work wherein it is desired to ascertain the carrier frequency of a particular transmitter, an oscillator having a definite predetermined output frequency is necessary to an intelligent determination of the carrier frequency being checked. By providing a calibrated self-contained frequency determining unit of the type described above an

oscillator output frequency may be obtained which corresponds exactly to the desired frequency. In addition, by providing a number of units calibrated to different frequencies the same oscillator
 5 may be employed to check a plurality of carrier frequencies practically without adjustment of the oscillator circuit, the only necessary operation required being that of interchanging one frequency determining unit having the desired value for the
 10 frequency determining unit previously employed.

While I have described what I consider to be the preferred embodiment of my invention, it will of course be understood that I do not wish to be limited thereto since many modifications in
 15 the structure may be made and I contemplate by the appended claims to cover all such modifications as fall within the true spirit and scope of my invention.

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

1. A piezoelectric crystal controlled oscillator circuit including an electron discharge device, a piezoelectric crystal and a tuned output circuit arranged to be connected therein, said crystal being
 25 mounted in a crystal cell having metallic electrode members, said output circuit including an inductance coil, socket contact terminals connected in said oscillator circuit for receiving the terminals of said output circuit and said piezo-
 30 electric crystal, a separable attachment plug including a body provided with connectors for engaging said contact terminals, said inductance coil and said crystal cell being mounted on said attachment plug, means utilizing said metallic
 35 electrode members to tune said coil to a frequency suitable for operation of said crystal, and means connecting the terminals of said inductance coil and the terminals of said piezoelectric crystal to said connectors.

2. A frequency determining unit for an electron discharge oscillator comprising in combination, a body, a plurality of connectors projecting from a wall of said body, a piezo-
 45 electric crystal cell having a pair of electrodes, said cell being mounted on said body, said electrodes being connected to a pair of said connectors, a tuned circuit comprising an inductance coil and capacitor connected in parallel, said coil and capacitor being mounted on said body, said
 50 coil being mounted in such position that its inductance is materially affected by the position of said electrodes relative thereto and in such position that said coil and capacitor resonate at a frequency suitable for operation of said crystal and means for connecting the terminals of said
 55 tuned circuit to a pair of said connectors.

3. A frequency determining unit for an electric discharge oscillator comprising in combination,

a body, a tuned output circuit including an inductance coil, a piezoelectric crystal cell including a pair of electrodes, said inductance coil being of flat toroidal form and being positioned on said
 5 body, said cell being positioned on said body to influence materially the inductance of said coil, said electrodes lying in such planes relative to the plane of the flat side of said coil that said inductance is varied to a desired extent upon move-
 10 ment of said crystal cell relative to said coil, means supporting said crystal cell in proper position with respect to said coil for operation of said oscillator, and connecting means extending from said body for connecting said coil and said crystal cell in an oscillator circuit.

4. A frequency determining unit for a crystal controlled electron discharge oscillation generator, said unit comprising a mounting carrying both an inductance coil, and a crystal cell having a crystal mounted therein, connections whereby
 20 the frequency produced by said oscillation generator is determined by said coil, crystal and cell, said cell being arranged within the field of said coil thereby to affect materially the frequency produced by said oscillation generator.

5. A frequency determining unit for an electron discharge oscillator comprising in combination a body, a tuned output circuit including an inductance coil, a piezoelectric crystal cell including a pair of conducting electrodes, a crystal within
 30 said cell, said inductance coil and said cell being mounted on said body, said cell being positioned in the field of said coil and in sufficiently close proximity to said coil that the natural frequency of said tuned circuit is dependent upon the posi-
 35 tion of said cell in said field, means to connect said tuned circuit and crystal cell in said oscillator to determine the frequency thereof, said cell and coil being so positioned relative to each other that said natural frequency of said tuned circuit corresponds to the operating frequency of said crystal.

6. A frequency determining unit for an electron discharge oscillator comprising in combination, a hollow body, a tuned output circuit including an inductance, a piezoelectric crystal cell including a pair of electrodes, said inductance and said cell being mounted within said body, means for adjusting the natural frequency of said tuned circuit during the assembly of said unit, said means including means for moving said piezoelectric cell relative to said inductance thereby to vary the coupling between said electrodes and said inductance, and means for securing said cell in position within said body after said adjusted position is
 55 determined.

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