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2,505,370

PIEZOELECTRIC CRYSTAL UNIT

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FIG. 1

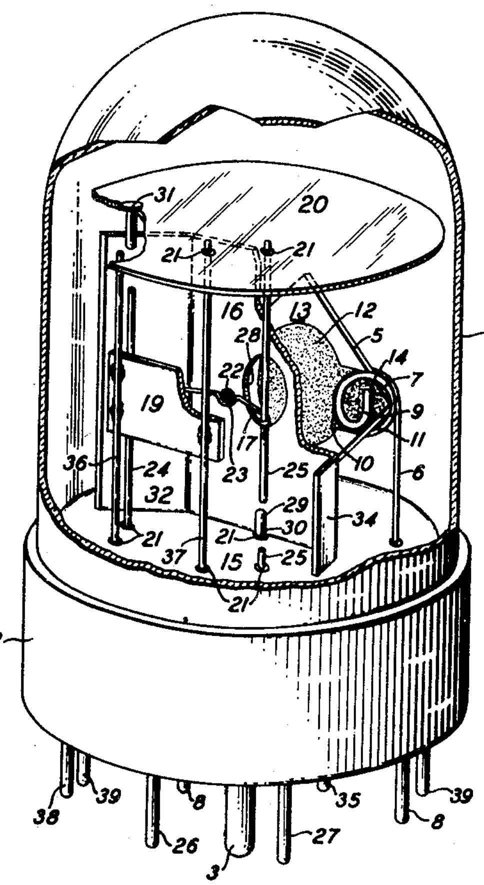
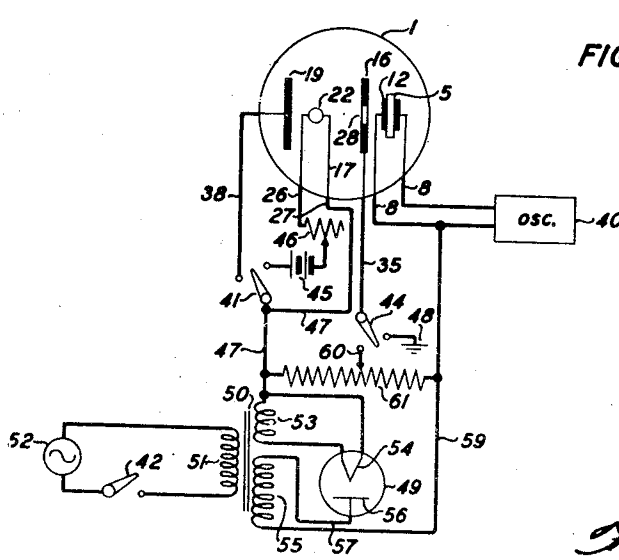


FIG. 2



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PIEZOELECTRIC CRYSTAL UNIT

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9 Claims. (Cl. 171—327)

1

This invention relates to piezoelectric crystal units, and particularly to a sealed crystal unit susceptible of frequency adjustment.

Crystal units mounted within small closed containers are well known in the art. Such units have been developed to insure greater frequency stability, to protect the mounted crystals from injury, and to make them easier to handle during the processes of supply, maintenance, and operation.

One of the best of the various types of containers for such crystal units utilizes an evacuated and sealed envelope of glass or metal similar to those employed in radio receiving tubes. The envelope is fixed for convenience in a base having projecting contact pins and arranged for removable mounting in a standard tube socket. Evacuated and sealed containers of this type are particularly advantageous for use in situations where extreme variations in temperature, humidity, and other climatic factors are encountered, which would normally cause changes in the frequency of the crystal. In contrast, the frequency of a crystal unit carefully manufactured and so mounted in a sealed envelope, may be depended upon to remain permanently fixed.

It may be necessary, however, to change the natural frequency during use, and often the change is desired under field conditions. In previously available crystal units an increase in frequency required dismantling the unit, and grinding or etching away some of the crystal or the plating, while to reduce the frequency it was necessary to add to the plating. Such operations require equipment not ordinarily available in the field, and necessitate removing the crystal unit from service for a considerable time.

It is an object of the present invention to enable decreasing or increasing the frequency of such a sealed crystal unit at will without requiring the disassembly of the crystal or its envelope, and without requiring the use of extensive auxiliary apparatus.

The invention contemplates, in brief, provision for mounting within a crystal-containing envelope a cathode from which metal may be evaporated onto the crystal to decrease its frequency, and means for removing metal from the crystal plating by sputtering when the frequency is to be increased. The sputtering process may

2

also be used instead of evaporation to apply metal to the crystal coating.

The invention has been illustrated in the drawings, in which:

Fig. 1 is a perspective view of the device, partially broken away to show the construction more clearly; and

Fig. 2 is a schematic circuit diagram illustrating the manner in which the invention is utilized.

A frequency-adjustable crystal unit, indicated generally as 1, is shown in Fig. 1 with the various elements broken away to reveal the construction more clearly. A base 2, similar to the well-known octal type of vacuum tube base with a keyed alining plug 3, has secured thereto an evacuated envelope 4 in which is disposed the crystal 5.

Crystal 5 may be held by any of the known means for making good contact while affording a resilient support. The support is here accomplished by a spaced pair of vertically disposed wires 6, only one of which is visible in the figure. Each of the wires 6 terminates upwardly in a helix 7, and external connection is provided thereto through contact pins 8. Helix 7 is spread axially to receive the corner 9 of the crystal between adjacent turns 10 and 11 thereof and retain it resiliently. Permanent connections may be obtained by soldering or cementing the helices to the metallic coatings of the crystal. For example, the coating 12 on the obverse face 13 of crystal 5 is joined by silver cement 14 to the helical turn 10. Similar connections, not visible in the figure, are provided to the coating on the reverse face of the crystal 5 at a point diagonally opposite corner 9. This type of mounting was disclosed and claimed in the United States Patent 2,392,429, issued January 8, 1946, to the present applicant.

Support wires 6 are held in alignment by virtue of their passage through a base plate 15 of mica or similar material. Base plate 15 is also bored to provide for the support and alignment of the shield 16, the filament 17, and the sputtering anode 19. A cooperatively bored mica top plate 20 completes the spacing structure. Suitable eyelets 21 may be used to protect the mica from chipping or fracture adjacent each of the borings.

The source of the metal to be evaporated onto the crystal coating 12 to decrease the frequency is a bead or globule 22 of gold or equivalent metal associated with filament 17. A loop 23 is formed in the filament, and the globule 22 is deposited therein prior to assembly. The sizes of the loop 23 and the globule 22 are so related that the surface tension of the globule will hold it in position when heated to a molten condition for evaporation. The heating is produced by the passage of current through filament 17. Rigid legs 24 and 25, to which the filament 17 is fixed, extend through top plate 20 and bottom plate 15, and terminate in the usual pin-type terminals 26 and 27 projecting from the base 2, as do terminals 8, for engagement with a conventional socket, not shown.

The portion of the obverse crystal face 13 on which the evaporated metal is deposited is limited by the conducting shield 16, through which a properly shaped bore 28 is formed. Shield 16 is positioned by a center pin 29 passing through a bore 30 in base plate 15, and by rivets 31 securing it to the top plate 20. The shield 16 may have side portions 32 and 34 extending at an obtuse angle thereto, to provide a partial enclosure of the bead 22 and prevent the evaporated metal from straying around the shield and depositing beyond the desired area on the crystal surface. Connection to the shield 16 is provided through center pin 29, which is linked to terminal pin 35.

The sputtering anode 19 is held by two legs 36 and 37 passing through top plate 20 and bottom plate 15. Leg 36 provides external connection to the sputtering anode through pin terminal 38. The two remaining terminals 39 of the standard octal base are not utilized in this embodiment. Sputtering anode 19 may be a flat or curved sheet of metal or other conductive material. It is aligned with the shield bore 28 and crystal coating 12, but its exact shape and position is not critical.

The circuit diagram is shown schematically in Fig. 2. In normal operation, the crystal 5 is connected through terminals 8 to the circuit in which it is acting as a frequency control, here shown as an oscillator 40. The filament control switch 41 is either open or else connected to the sputtering anode lead 38; sputtering power supply switch 42 is open, while the position of shield switch 44 is immaterial.

When it is desired to decrease the natural frequency of the crystal, the filament control switch 41 is thrown to close the filament circuit through battery 45, rheostat 46, filament terminal 26, the filament 17, filament terminal 27, and a lead 47. The filament current then heats the bead 22 to a molten state, and evaporation proceeds. The filament resistance is so chosen that the normally available battery supply voltage may be used, which may be, for example, 6 volts. The evaporating metal is dispersed substantially evenly in all directions. Those portions of the crystal face 13 on which it is not desired to deposit additional metal are masked by the shield 16, with bore 28 permitting passage toward the area to be plated. The shield 16 may be grounded at 48 by shield switch 44. The rate of evaporation is controlled by the filament rheostat 45, and the sputtering power supply switch 42 is opened, since no high potential is to be applied to the unit 1 from the rectifier tube 49. Depositing of the evaporating metal is continued until the frequency of oscillator 40 reaches the desired value. This point may be determined by conventional methods, such as feeding the oscillator output into a comparison circuit and observing the beat note produced therein against the output of an oscillator of known frequency. Switch 41 is opened when the beat note frequency reaches zero, and the operation is complete. A change of several kilocycles in the natural frequency of the crystal may thus be accomplished in a few seconds. In the factory production of crystals using this system, the output per operator in the final phase of frequency adjustment has been raised from less than a dozen crystals per hour to over two hundred.

When the crystal frequency is to be increased, a portion of the crystal plating is removed. In previously known plated crystal units, increasing the frequency required, as mentioned above, grinding or lapping the crystal or the plating, or the removal of the latter by means such as etching in acid. These processes are obviously unsuitable for use in correcting a crystal sealed into an evacuated envelope.

The crystal unit herein described permits adjustment by increasing the crystal frequencies under service conditions, without requiring any disassembly of the unit, and the adjustment may be completed in a short interval.

Removal of the required amount of plating is accomplished by sputtering, that is, by applying to a sputtering anode in the evacuated envelope a positive potential of sufficient magnitude to cause a glow discharge, in which minute particles of the metal are driven out of the plating, and then attracted toward a sputtering anode on which they are collected. For the plating metals commonly used, such as gold, an attracting potential of the order of 1500 to 2500 volts is adequate to accomplish this aim in a short time. While for efficient evaporation, evacuation should be carried as far as possible, a lesser degree of evacuation is required for most efficient sputtering, as well understood by those skilled in the art. It is dependent, among other factors, upon the material being sputtered and the rate at which it is desired to carry out the operation. For gold plated crystals, the optimum pressure to which evacuation must be carried is about .011 millimeter of mercury, with comparable pressures for platinum or silver. If the crystal is plated with copper, the sputtering should be carried on in an atmosphere of hydrogen. Other plating materials may operate best at different pressures and in other atmospheres.

During the sputtering process, the crystal will be heated to a temperature which may be from 200° to 250° C. by positive ion bombardment. In consequence the operator must, in adjusting the frequency, apply a correcting factor relating the observed frequency to that which will be experienced at the normal operating temperature of the crystal. In contrast, during the evaporation plating, the time required is so short that the crystal temperature is not increased significantly above normal operating temperature. It is, of course, necessary that those elements which receive the sputtering potentials should be adequately insulated, in accordance with standard practice.

Sputtering potential is obtained from a step-up transformer 50, primary 51 of which is connected to an alternating current source 52 through sputtering power switch 42. Transformer 50 is of a conventional type, with a low voltage secondary winding 53 supplying heating current to the rectifier tube filament 54, and a high voltage secondary winding 55 connected to the rectifier tube anode 56 by lead 57 and supplying negative potential to the plated face 12 of the crystal through lead 59. The plated face 12 is to act as the cathode during the sputtering process. The positive potential from the rectifier filament is applied through lead 47 to the crystal unit filament 23, and through switch 41 and terminal 38 to the sputtering anode 19.

The shield 16 may be used to control the rate at which the sputtering process is carried out. For this purpose, switch 44 is shifted from ground connection 48 to the adjustable arm 60 of a potentiometer 61 bridged across the leads 47 and 59, and hence between the sputtering anode and cathode. The potential of shield 16 may thus be set at any desired fraction of the potential difference between the plated face 12 and the sputtering anode.

In some cases it may be desirable to use a variant of the embodiment illustrated, eliminating the elements for plating by evaporation, and employing the sputtering process both for plating and deplating the crystal. The changes in the basic circuit of Fig. 2 required to accomplish this aim will be obvious to those skilled in the art; the crystal plating itself must be connected as the anode when plating is to be done by sputtering, and the sputtering anode 19 then acts as the cathode.

While the invention has been illustrated as applied to use with a crystal designed for vibration in the thickness shear mode, it is equally applicable to crystal vibrating in other modes, and particularly at the higher frequencies. In such cases, the location of the electrodes from which metal is to be applied to the crystals, the placing of the necessary shields, the sizes and shapes of the apertures in the shields, and the disposition of the sputtering electrodes, will be determined by the shape of the crystal, and the portions to which the plating is to be applied. It is to be understood that the embodiments shown and described herein are illustrative only of the invention, and that the invention includes all other equivalent forms within the scope of the appended claims.

What is claimed is:

1. In combination, a piezoelectric crystal, a metal coating on said crystal, means for oscillating said coated crystal at its natural frequency under low pressure, means comprising an anode electrode spaced from and having a positive potential with respect to said coating for removing metal from said coating on said crystal while said coated crystal is oscillating for thereby increasing the natural frequency of said coated crystal during said oscillating thereof, and means applicable to the indication of the natural frequency of said crystal during said oscillation.

2. In a crystal unit, comprising a plated piezoelectric crystal mounted in an envelope evacuated to an optimum sputtering pressure and arranged for frequency adjustment, means comprising a sputtering anode spaced from said plated crystal for removing plating material from said crystal, means for maintaining said plated crystal in oscillation at its natural frequency while removing therefrom plating material, and means for frequency-determining connections during said oscillation.

3. In a metal plated piezoelectric crystal mounted in an evacuated container, means for adjusting the natural frequency of said plated crystal, comprising means including an anode electrode disposed within said container for sputtering metal off said metal plated crystal, means for oscillating said metal plated crystal at its natural frequency of oscillation during said sputtering of said metal, and means for indicating the natural frequency of oscillation of said plated crystal during said sputtering of said metal.

4. An adjustable frequency piezoelectric crystal unit comprising a base, contact pins extending through said base, an evacuated and sealed envelope secured to said base, leads extending from said contact pins into said envelope, and elements disposed within said envelope and connected to said leads, comprising a coated crystal, means for masking a portion of said crystal, a source of material, means comprising said source constituting an anode electrode for receiving material transferred from said coated crystal, and means comprising said masking means for defining the coated portion of said crystal from which coated material on said crystal may be transferred to said source.

5. An adjustable frequency piezoelectric crystal unit comprising a base, contact pins extending through said base, an evacuated and sealed envelope secured to said base, leads extending from said contact pins into said envelope, and elements disposed within said envelope and connected to said leads, comprising a coated crystal, a source of metal, means for shielding all except a desired coating portion of said crystal from said source, and means including said source disposed adjacent said shielding means and constituting an anode electrode with respect to said coated crystal for collecting metal from said coated crystal and thereby increasing the value of said frequency characteristic for said coated crystal.

6. An adjustable frequency piezoelectric crystal unit comprising a base, contact pins extending through said base, an evacuated and sealed envelope secured to said base, leads extending from said contact pins into said envelope, and elements disposed within said envelope and connected to said leads, comprising a coated crystal, a source of metal, means for masking a portion of said coated crystal from said source, and means including said source and said last-mentioned means constituting anode electrodes with respect to said coated crystal for attracting metal from said coated crystal and thereby increasing the value of said frequency characteristic for said coated crystal.

7. An adjustable frequency piezoelectric crystal unit comprising a sealed envelope evacuated to a pressure of the order of .011 millimeters of mercury and elements disposed within said evacuated envelope comprising a coated crystal, a source of metal selected from the group including gold, platinum, and silver, a shield disposed between said coated crystal and said source and arranged to mask desired portions of said coated crystal from said source, means comprising said source and said shield adaptable to produce a removal of metal from a desired coated portion of said coated crystal for raising to a desired value said frequency characteristic thereof, and electrodes sealed through said envelope connecting individually to said coated crystal, to said source of metal, and to said shield.

8. A piezoelectric crystal unit, comprising a sealed envelope containing an atmosphere of hydrogen at optimum sputtering pressure, a copper-plated crystal, a separate source of additional copper, a shield disposed between said crystal and said source and apertured to mask certain portions of said crystal from said source; and electrodes sealed through said envelope arranged to

provide external individual connection to said crystal, said source, and said shield.

9. In a piezoelectric crystal unit, the combination of a sealed envelope, an atmosphere of hydrogen disposed within said envelope at optimum sputtering pressure; a copper-plated crystal, a source of additional copper, an apertured mask disposed between said source and said crystal; and electrodes sealed through said envelope arranged to provide individual external connection to said crystal, said source, and said mask.

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