Dec. 3, 1946. C. F. BALDWIN 2,412,030

PIEZOELECTRIC CRYSTAL MOUNTING

Filed Oct. 27, 1938

Fig. 1.

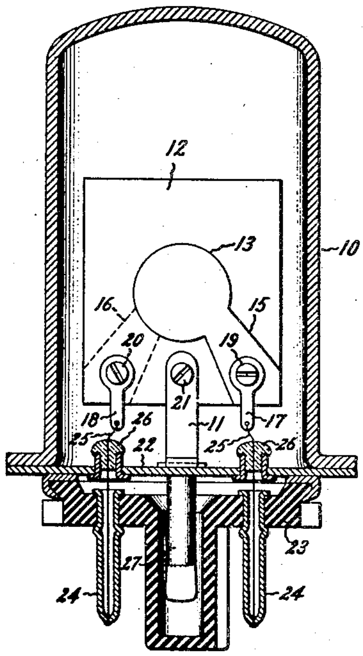


Fig. 3.

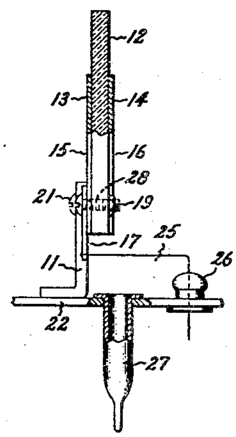


Fig. 2.

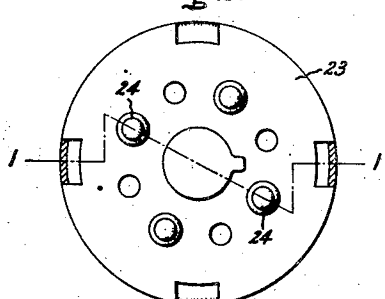


Fig. 4.

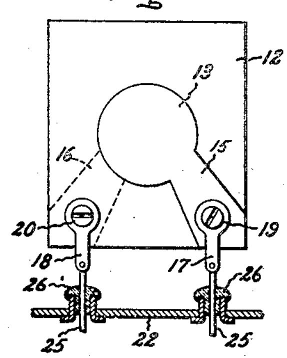
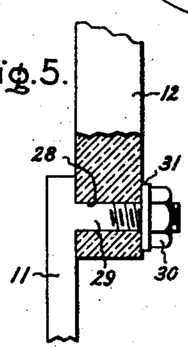


Fig. 5.



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UNITED STATES PATENT OFFICE

2,412,030

PIEZOELECTRIC CRYSTAL MOUNTING

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Application October 27, 1938, Serial No. 237,237

28 Claims. (Cl. 171—327)

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My invention relates to piezo-electric devices and more particularly to supporting means for a piezo-electric device. While not limited thereto, my invention is particularly useful for supporting a high frequency piezo-electric device which normally is operated at one of its harmonic frequencies. By harmonic frequency, I mean a frequency which is substantially a harmonic of the crystal fundamental frequency, sometimes referred to as a "mechanical" harmonic frequency of the crystal.

An object of my invention is to provide a new and improved method of supporting a piezo-electric crystal with the active parts of its oscillating surfaces out of physical contact with fixed physical objects.

A further object of my invention is to provide a greatly simplified and inexpensive supporting arrangement for a piezo-electric crystal and one having the advantages of extreme compactness, sturdiness and a high degree of reliability.

Another object of my invention is to provide a crystal mounting in which the crystal is freely supported in, and has each of its surfaces in close heat transfer relation with, a fluid cooling medium such as helium, argon or the like.

A further object of my invention is to provide a new and improved piezo-electric crystal of the high frequency type. By high frequency, I mean any frequency from about one megacycle to the highest frequency at which crystals may be used. My invention contemplates that the electrical circuit terminals and physical supporting means for the crystal are fixedly secured to the crystal by securing devices which extend through apertures provided in the body of the crystal.

The novel features which I believe to be characteristic of my invention are pointed out with particularity in the appended claims. My invention itself, however, will be better understood by reference to the following description taken in connection with the accompanying drawing in which Fig. 1 represents an embodiment of my invention; Fig. 2 is a bottom view of a crystal holder constructed according to my invention; Fig. 3 illustrates an additional view of the crystal at a right angle to the view in Fig. 1 and Figs. 4 and 5 show certain modifications of my invention.

Referring particularly to Fig. 1 of the drawing, my invention is illustrated as embodied in a crystal holder having an outer housing 10 of metal, glass, or the like in the interior of which is supported, as by a bracket 11, a piezo-electric crystal 12. The crystal 12 is here shown merely

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for purposes of illustration as greatly exaggerated in size. In practice, a crystal which is ground for fundamental operation has a definite relation between the length of its principal frequency determining dimension, measured in thousandths of an inch, and its operating frequency, measured in megacycles, which relation is a product between about 70 and about 113, depending on the particular manner in which the crystal is cut. Crystals operated at "mechanical" harmonics, as referred to above, also have such a product which is usually over 200. A particular type of such an harmonically operated crystal, which is especially useful, operates at its third mechanical harmonic, and has a product of about 300 of its operating frequency in megacycles and length of its principal frequency determining dimension in thousandths of an inch.

The piezo-electric crystal, here shown as of the harmonically operated type, is provided with flexible metallic electrodes 13, 14 (Figs. 1 and 3) fixedly secured in opposing relation over the central portion of each of the crystal faces. The electrodes 13, 14, as shown in Fig. 1, are very small relative to the size of the crystal, thereby to have small mass and minimum interelectrode capacity to enhance operation of the crystal at a harmonic frequency. The electrodes are preferably evaporated upon the faces of the crystal to assure minimum mass and are placed only on the central portion of each face to assure minimum capacity. In the present embodiment, each of the electrodes 13, 14 has an extended portion 15, 16, respectively, which extends to opposite corners of the crystal body.

Such a crystal of the harmonically operated type as described has certain relatively mechanically inactive surface portions lying between the central portion of the crystal and its periphery. These inactive portions may extend inward from the periphery of the crystal by substantial distances, and may be clamped with forces of several hundred pounds without interfering with the operation of the crystal. It is highly advantageous to clamp crystal supports or electric circuit terminals for the electrodes to such mechanically inactive surface portions by suitable means.

Electrical circuit connecting terminals 17, 18, are fixedly secured by small machine screws 19, 20 to the body of the crystal in electrical connection with the respective extended portions 15, 16 of the crystal electrodes. In the preferred embodiment of my invention, the machine screws 19, 20 extend through holes 28 (Fig. 3) drilled through the body of the crystal. These holes through which the machine screws are passed lie near the periphery of the crystal as shown in Fig. 3, where the inactive surface portions are located.

The supporting bracket 11 is in similar manner fixedly secured to the crystal 12 by a small machine screw 21 which extends through the bracket 11 and through a hole drilled in the lower edge of the crystal near the periphery thereof where, as explained above, the inactive surface portions are located. The bracket 11 may be shouldered, if desired, at the point where it contacts the edge of the crystal, the shoulder extending under the lower edge of the crystal to prevent the crystal turning about the screw 21. The bracket 11 is welded to or otherwise fastened in position on a base plate or header 22 which forms an end wall of the housing 10.

The housing 10 is provided at its lower end with a base 23 similar to those used on vacuum tubes, the base having electrical connecting prongs 24 suitably arranged for insertion into a standard vacuum tube socket. The use of a tube base and a tube socket in this manner greatly facilitates the replacement of one crystal unit with another having the same or different operating characteristics. Electrical connection is made between the several terminals 24 and the electrical terminals 17, 18 by electrical conductors 25, 25, which extend through insulating beads 26, 26, provided in the header 22.

The interior of the housing 10 may be evacuated through the sealing-off stem 27 which extends through and is hermetically sealed to the header 22. After evacuation, the housing may be refilled to a desired pressure, usually slightly less than atmospheric, with a dry gaseous fluid medium as air or, if greater heat conductivity is required, with helium, argon, or the like. After the refilling operation, the housing 10 is hermetically sealed by closing the end of the stem 27. It will, of course, be understood that the header 22 is hermetically sealed to the housing 10. The use of a dry gas in the interior of the housing is desirable in that it protects the crystal from dirt and moisture. Helium, argon, or the like gas, additionally aids in the rapid transfer of heat from the crystal to the atmosphere surrounding the crystal housing. It should be noted, in this connection, that the gaseous medium is in intimate heat transfer relation with all surfaces of the crystal and therefore provides the maximum possible cooling of the crystal during its normal operation. It is evident, therefore, that a crystal supported in the manner of my invention reaches its operating temperature rapidly and in a minimum of time.

Fig. 2 is a bottom view of the base 23 and shows the arrangement of the base prongs 24, 24 and the manner in which the cross-sectional view of Fig. 1 was made along the plane 1—1.

Fig. 3 is another view which shows more clearly the arrangement of the crystal 12, the electrodes 13 and 14, the securing screws 19, 20, and the supporting bracket 11.

A modification of my invention is shown in Fig. 4 in which elements corresponding to like elements of Fig. 1 are designated by like reference characters. The supporting bracket 11 of the Fig. 1 arrangement is eliminated in this modification and the crystal 12 is supported directly by the electrical conductors 25, 25. The electrical conductors 25, 25 are of larger cross-section than are the same conductors of the Fig. 1 arrangement for purposes of mechanical strength since it is apparent that the conductors must support the weight of the crystal, crystal electrodes and the electrical terminals. This modification has the important advantage that the conductors 25, which have a certain amount of resiliency, support the crystal in resilient manner from the header 22.

A modified support arrangement is illustrated in Fig. 5. The support 11 is here provided with an integrally formed stud 29 which extends through the aperture 28 provided in the crystal 12 and is threaded at its end to receive a nut 30. A washer 31, preferably formed of a soft metal, as Woods metal, prevents damage to the surface of the crystal when the nut 30 is tightened rigidly to secure the support 11 to the crystal.

It will now be apparent that I have provided a small, compact, crystal unit of sturdy construction in which the crystal is enclosed in a hermetically sealed housing. The housing when constructed of metal provides an electrostatic shielding of the crystal in addition to protecting the crystal from the deleterious effects of dirt and moisture. It will be evident that a crystal and its holder constructed in accordance with my invention has the added advantage that the crystal is supported in the best possible heat transfer relation to the surrounding cooling medium.

Thus, while I have illustrated a particular embodiment of my invention, I do not wish to be limited thereto since many modifications may be made in the several elements employed and in their arrangement and I, therefore, contemplate by the appended claims to cover any such modifications as fall within the true spirit and scope of my invention.

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

1. A piezo-electric crystal whose operating frequency is higher than its fundamental frequency and greater than a megacycle, said crystal having an aperture formed therethrough near the periphery thereof, and supporting means extending through said aperture and secured to said crystal in rigid supporting relation therewith.

2. A piezo-electric crystal of the harmonically operated type having a relatively active central face portion and a relatively inactive peripheral face portion, electrodes fixedly secured in opposing relation to each other over said active portions, electrical circuit terminals, and means extending through apertures formed in said peripheral portions for fixedly securing said terminals to said crystal each in electrical connection with a respective one of said electrodes.

3. A piezo-electric crystal having flexible electrode coatings in opposing relation over the central portion of opposite faces thereof, said coatings being electrically conductive and each having a current conducting portion extending to respective spaced apart points near the periphery of said crystal, apertures through said crystal at said spaced apart points, and means extending through said apertures for securing electrical circuit terminals each in electrical contact with a respective one of said electrode extending portions.

4. In a support for a piezo-electric device, the combination with a piezo-electric crystal whose operating frequency is higher than its fundamental frequency and is also greater than a megacycle, of means extending through apertures formed through said crystal for securing electrical circuit terminals to said crystal, electrodes evaporated on opposite faces of said crystal, means for electrically connecting each of said

electrodes with a respective terminal, and means utilizing said terminals for supporting said crystal suspended free of physical objects.

5. In a piezo-electric crystal mounting, the combination of a housing having an interior chamber filled with a thermally conductive fluid, a piezo-electric crystal, and means for supporting said crystal within said chamber with all of the exterior surfaces of said crystal in close heat transfer relation to said fluid, said last named means including a supporting bracket, and means extending through an aperture formed in the peripheral edge of said crystal for fixedly securing said bracket to said crystal.

6. A piezo-electric crystal whose operating frequency is higher than its fundamental frequency and higher than a megacycle, said crystal having electrodes positioned adjacent opposite faces thereof, and means passing through a hole through said crystal for pressing an electrical terminal against said crystal, said means being arranged to maintain electrical connection between said terminal and one of said electrodes.

7. In a support for a piezo-electric device, the combination with a piezo-electric crystal whose operating frequency is higher than its fundamental frequency and higher than a megacycle, of means passing through an aperture formed through the periphery of said crystal for pressing an electric circuit terminal with substantial force against said crystal, electrodes on opposite faces of said crystal, said means maintaining electrical connection between said terminal and one of said electrodes, and means utilizing said terminal for supporting said crystal free of surrounding objects.

8. A piezo-electric crystal whose operating frequency is a mechanical harmonic frequency of said crystal higher than its fundamental frequency, conducting material evaporated in a thin film upon the central portions of opposite faces of said crystal to form electrodes therefor, said thin films extending to respective spaced apart points near the periphery of said crystal, and means passing through a hole through said crystal at each of said spaced points for pressing an electric circuit terminal against the respective thin film to maintain electric connection between said terminal and the respective one of said electrodes.

9. In a piezo-electric device, a piezo-electric crystal having an operating frequency higher than its fundamental frequency, said crystal having relatively mechanically inactive surface portions, an electrode positioned adjacent said crystal, an electric circuit terminal, means for clamping said terminal to one of said inactive surface portions of said crystal with force sufficient to maintain said terminal in fixed relation to said crystal, and means for connecting said terminal to said electrode.

10. In a piezo-electric device, a piezo-electric crystal having an operating frequency which is a mechanical harmonic frequency of said crystal higher than its fundamental frequency, a thin film of conducting material evaporated only upon the central portions of opposite faces of said crystal to form electrodes therefor, said thin films extending to respective spaced apart points near the periphery of said crystal, a pair of electric circuit terminals, and means for clamping said electric circuit terminals to the respective thin film portions at each of said spaced points to maintain electric connections between said terminals and the respective electrodes.

11. In a piezo-electric device, a piezo-electric crystal having an operating frequency which is a mechanical harmonic frequency of said crystal higher than its fundamental frequency, said crystal having relatively mechanically inactive surface portions, a thin film of conducting material evaporated on a surface of said crystal forming an electrode and having a portion extending over one of said inactive portions, an electric circuit terminal, and means for clamping said terminal to said thin film over said inactive surface portion to maintain electric connection between said terminal and film.

12. In a piezo-electric device, a piezo-electric crystal having an operating frequency higher than its fundamental frequency, said crystal having relatively mechanically inactive surface portions at a substantial distance from its periphery, a support for said crystal, and means for clamping said support to one of said inactive surface portions with sufficient force to support said crystal during use of said device.

13. In a piezo-electric device, a piezo-electric crystal having an operating frequency which is a mechanical harmonic frequency of said crystal higher than its fundamental frequency, said crystal having relatively mechanically inactive surface portions, a thin film of conducting material evaporated on a surface of said crystal and forming an electrode thereon, said thin film having a portion extending over one of said inactive surface portions, an electric circuit terminal, means for clamping said terminal to said thin film over said inactive surface portion to maintain electric connection between said terminal and film, and means for supporting said crystal from at least one of said inactive portions.

14. In a piezo-electric device, a piezo-electric crystal having an operating frequency which is a mechanical harmonic frequency of said crystal higher than its fundamental frequency, said crystal having relatively mechanically inactive surface portions, a thin film of conducting material evaporated on a surface of said crystal and forming an electrode, said thin film having a portion extending over one of said inactive surface portions, an electric circuit terminal, means for clamping said terminal to said thin film over said inactive surface portion to maintain electric connection between said terminal and film, and means utilizing said terminal for supporting said crystal.

15. In a piezo-electric device, a piezo-electric crystal having an operating frequency which is a mechanical harmonic frequency of said crystal higher than its fundamental frequency, said crystal having relatively mechanically inactive surface portions, a thin film of conducting material evaporated on a surface of said crystal and forming an electrode, said thin film having a portion extending over one of said inactive surface portions, an electric circuit terminal, means for clamping said terminal to said thin film over said inactive surface portion to maintain electric connection between said terminal and film, and means for supporting said crystal from another of said inactive portions.

16. In combination, a piezoelectric crystal, a pair of electrodes each partially covering an electrode face of said crystal, an uncovered area of each of said crystal faces being in register, respectively, with a covered area of the other of said crystal faces.

17. The invention as set forth in claim 16 and

wherein said electrodes are integral with the electrode faces of said crystal.

18. In combination, a piezoelectric crystal, a pair of electrodes each partially covering an electrode face of said crystal, said electrode faces having non-covered areas adjacent opposite edge portions of said crystal, and a pair of supporting members secured to said crystal adjacent the said non-covered areas of its said electrode faces, each of said supports contacting one of said electrodes and comprising an electrical connection thereto.

19. In combination, a piezoelectric crystal, a pair of electrodes secured respectively to the opposite electrode faces of said crystal, said electrode faces having non-covered areas adjacent diagonally opposite edge portions of said crystal, and means for supporting said crystal at its said diagonally opposite non-covered areas.

20. In combination, a piezoelectric crystal, a pair of evaporated-metal electrodes partially covering the electrode faces of said crystal, non-covered areas of said electrode faces being adjacent opposite ends of said crystal, and a pair of supporting members secured to said crystal adjacent the said non-covered areas of its electrode faces, each of said supports contacting one of said electrodes and comprising an electrical connection thereto.

21. In combination, a piezoelectric crystal having opposite faces each partly covered with a metal film, the metal covered areas of said crystal faces comprising electrode areas, non-covered areas of said faces being at opposite ends of said crystal, and a clamp adjacent each of the said crystal ends, each clamp contacting the non-covered area of one face and the metal covered area of the other face.

22. A thickness-mode piezoelectric crystal element having substantially rectangular opposite major faces, the thickness of said crystal element between said opposite major faces being made of a value corresponding to the value of said thickness-mode frequency thereof, a pair of conductive coatings formed integral with said opposite major faces, said conductive coatings being disposed opposite each other at the central portions only of said major faces and forming electric field-producing electrodes spaced entirely inwardly of all of the peripheral edges of said major faces, one of said coatings on one of said major faces extending to one corner of said crystal element and the other of said coatings on the other of said major faces extending to another corner of said crystal element, conductive supporting means mounting said crystal element at said corners and establishing individual electrical connections with said coatings at said corners, said means comprising conductive spring wires.

23. A thickness-mode piezoelectric crystal element having substantially rectangular opposite major faces, the thickness of said crystal element between said opposite major faces being made of a value corresponding to the value of said thickness-mode frequency thereof, a pair of conductive coatings formed integral with said opposite major faces, said conductive coatings being disposed opposite each other at the central portions only of said major faces and forming electric field-producing electrodes spaced entirely inwardly of all of the peripheral edges of said major faces, one of said coatings on one of said major faces extending to one corner of said crystal element and the other of said coatings on the other of said major faces extending to another corner of said crystal element, conductive supporting means mounting said crystal element at said corners and establishing individual electrical connections with said coatings at said corners, said means comprising conductive spring wires.

24. A thickness-mode piezoelectric crystal element having substantially rectangular opposite major faces, the thickness of said crystal element between said opposite major faces being made of a value corresponding to the value of said thickness-mode frequency thereof, a pair of conductive coatings formed integral with said opposite major faces, said conductive coatings being disposed opposite each other at the central portions only of said major faces and forming electric field-producing electrodes spaced entirely inwardly of all of the peripheral edges of said major faces, one of said coatings on one of said major faces extending to one corner of said crystal element and the other of said coatings on the other of said major faces extending to another corner of said crystal element, conductive supporting means mounting said crystal element at said corners and establishing individual electrical connections with said coatings at said corners.

25. A thickness-mode piezoelectric quartz crystal element having substantially rectangular opposite major faces, the thickness of said element between said opposite major faces being made of a value corresponding to the value of the thickness-mode frequency of said crystal element, a pair of substantially equal size and oppositely disposed field-producing conductive coatings formed integral with the central portions of said opposite major faces and spaced entirely inwardly of all of the peripheral edges of said major faces, and a pair of relatively narrow connective conductive coatings formed integral with said opposite major faces and extending from said field-producing conductive coatings to two different corners of said crystal element.

26. In combination, a thickness-mode piezoelectric crystal element having its thickness made of a value corresponding to the value of its thickness-mode frequency, and a pair of conductive coatings each partially covering an electrode surface of said crystal element, the uncovered area of each of said crystal electrode surfaces being opposite a covered area of the other of said crystal electrode surfaces, and the covered areas of each of said crystal electrode surfaces being disposed opposite each other only at the central portions of said crystal electrode surfaces said oppositely disposed covered areas forming opposite field-producing electrodes having an effective field area covering less than 80 per cent of the area of one of said crystal electrode surfaces, said field area being spaced entirely away from all of the peripheral or marginal edges of said crystal electrode surfaces.

27. In combination, a thickness-mode piezoelectric crystal element having its thickness made of a value corresponding to the value of its thickness-mode frequency, and a pair of conductive coatings each partially covering an electrode surface of said crystal element, the uncovered area of each of said crystal electrode surfaces being opposite a covered area of the other of said crystal electrode surfaces, and the covered areas of each of said crystal electrode surfaces being disposed opposite each other only at the central portions of said crystal electrode surfaces said op-

positely disposed covered areas forming opposite field-producing electrodes spaced entirely away from all of the peripheral or marginal edges of said crystal electrode surfaces, said oppositely disposed covered areas forming opposite field-producing electrodes of substantially circular shape having an effective field area less than 80 per cent of the area of one of said crystal electrode surfaces.

28. In combination, a piezoelectric crystal element having its thickness made of a value corresponding to the value of its thickness-mode frequency, and a pair of conductive coatings each partially covering an opposite major surface of

said crystal element, each of said coatings covering a marginal edge portion of one of said major surfaces and tapering in width from said marginal edge portion thereof towards the central portion of each of said major surfaces, said pair of coatings being disposed opposite each other only at said central portions and forming opposite field-producing electrodes having an effective field area covering less than 80 per cent of the area of one of said major surfaces, said field area being spaced entirely inwardly of all of the marginal edges of said major surfaces.

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