May 25, 1943. S. C. HIGHT 2,320,131

PIEZOELECTRIC CRYSTAL APPARATUS

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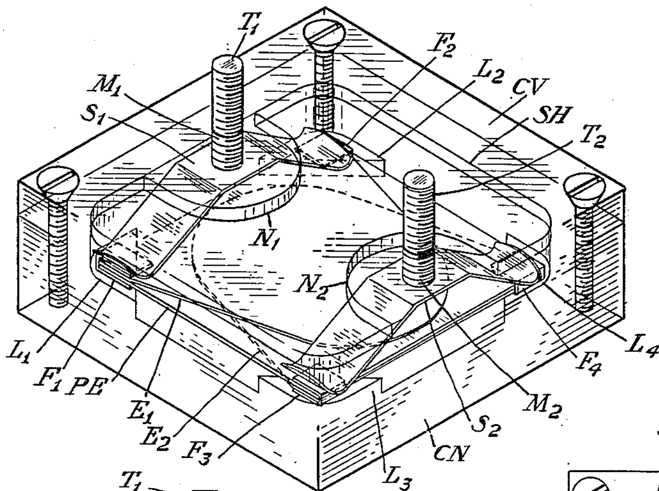

Fig. 1

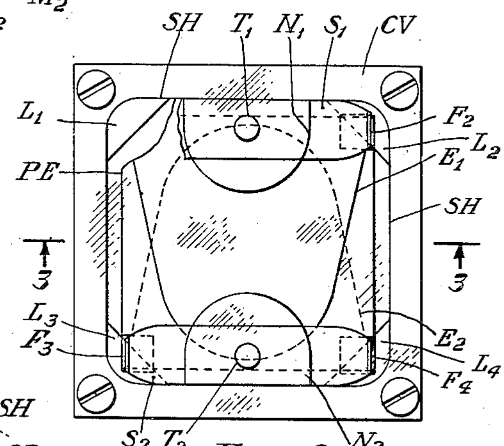

Fig. 2

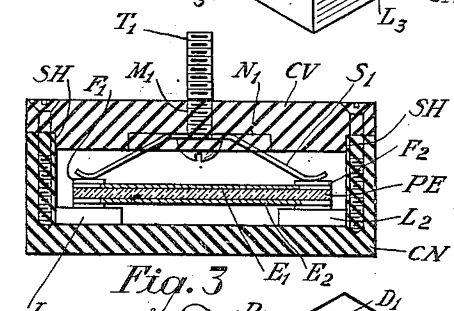

Fig. 3

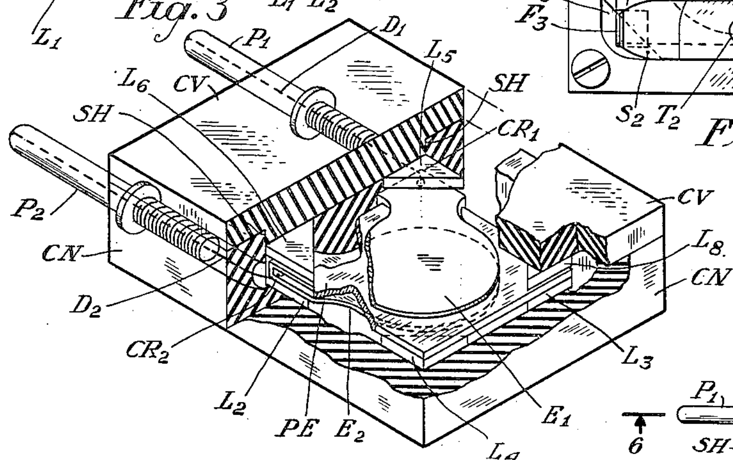

Fig. 4

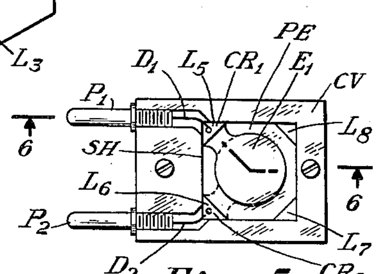

Fig. 5

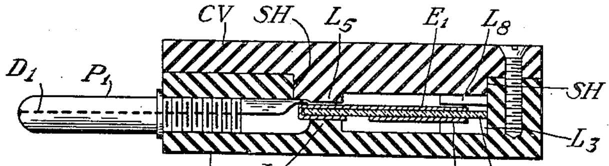

Fig. 6

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PIEZOELECTRIC CRYSTAL APPARATUS

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14 Claims. (Cl. 171—327)

This invention relates to piezoelectric crystal apparatus and particularly to electrodes, coatings and mountings for high frequency, thickness-mode piezoelectric crystal elements, such as quartz crystal elements, suitable for use as circuit elements in such systems as oscillations generator systems, electric wave filter systems, and so on.

In my earlier application, Serial No. 357,251, filed September 18, 1940, of which the present application is a continuation-in-part, there is described a crystal element provided with conductive metallic coatings formed integrally with one or more of the corner or marginal portions of its opposite major surfaces and extending around the edge thereof in order to provide inactive corner or marginal portions of no motion, where the crystal element may be electrically connected and mounted by clamping means, or by soldered supporting wires, or otherwise, without interfering with the desired vibratory motion in other parts of the crystal element. According to one aspect of the present invention, a holder is provided for the crystal element, the holder including a pair of springs for clamping the corners of the crystal element. The two springs may also be employed to establish electrical connections with opposite electrode faces of the crystal element. Moreover, the holder may provide a common support for the springs in order that the springs may be located on but one side of the common support, and hence lie adjacent but one face of the crystal element.

This invention will be better understood from the detailed description hereinafter following when read in connection with the accompanying drawing in which Fig. 1 represents a perspective view of one form of the invention, Fig. 2 is a plan or top view of the arrangement shown in Fig. 1, Fig. 3 illustrates a sectional view taken along the line 3—3 of Fig. 2, Fig. 4 illustrates a partly cutaway view in perspective of a different embodiment of the invention, Fig. 5 represents a plan or top view of the arrangement of Fig. 4, and Fig. 6 illustrates a sectional view along the line 6—6 of Fig. 5.

Referring to Figs. 1 to 3 of the drawing, there is shown a piezoelectric quartz element or plate PE provided with oppositely disposed partial or reduced-area plated electrodes E_1 and E_2 which are formed integrally with the major surfaces of plate PE. The crystal PE may be operated in thickness-mode vibrations at a fundamental frequency or at a harmonic frequency, the frequency being determined mainly by the thickness of the plate PE between the major surfaces thereof. The plate PE may be, for example, a thickness shear mode AT-cut quartz plate of the type referred to in my earlier application above designated.

Four metallic foils F_1, F_2, F_3 and F_4 may be bent around the corners of the crystal element PE, the foils F_1 and F_2 being in contact with electrode E_1, and the other foils F_3 and F_4 in contact with electrode E_2. These foils are strips of any soft metals, such as gold, silver, tin, lead, etc. Each foil is U-shaped so that it will contact the two major surfaces of the crystal element PE as well as the intervening edge of the crystal element PE. All the surfaces of the crystal element which contact the foils F_1, F_2, F_3 and F_4 are plated, as described in my prior application.

The crystal element PE may be inserted in a container CN having a cover CV which together provide a housing for the element PE. This housing may be made of any dielectric material, preferably of a molded plastic material, such as polystyrine, lucite, plexi-glass, etc. The container CN is provided with four lands or elevations L_1, L_2, and L_3 and L_4, these lands supporting the crystal element PE at the foils F_1, F_2, F_3 and F_4 as shown. These lands L_1, L_2, L_3 and L_4 elevate the crystal element PE so that during the vibration of the latter element its lower surface will clear the bottom of container CN at all times. The cover CV has a shoulder SH formed therein which is only slightly smaller than the opening in container CN so that the cover CV will closely fit the container. The shoulder SH of the cover CV may be cut away at N_1 and N_2 so as to accommodate the curved springs S_1 and S_2. The cover CV is preferably screw-threaded at M_1 and M_2 to receive the machine screws T_1 and T_2 which fasten the springs S_1 and S_2, respectively, to the cover CV. The screw members T_1 and T_2 at the same time act as terminals for the piezoelectric element PE. Four screws may be passed through corresponding openings in the cover CV and in the container CN, the latter being threaded to hold the cover CV in place.

When assembled the ends of each of the springs rest against two of the foils corresponding to one of the plated electrodes. That is, the ends of spring S_1 contact the foils F_1 and F_2, while the two ends of spring S_2 contact foils F_3 and F_4. The springs S_1 and S_2 are preferably made of a material such as phosphor-bronze.

The quartz element PE may be prepared, for example, by coating its surfaces with silver by Brassier's process. Those parts of the silver coatings that are to be removed may be etched with nitric acid. The remaining portion then constitutes the plated electrodes E_1 and E_2. The electrodes E_1 and E_2 may be applied by any suitable process, such as Brassier's process, evaporation in vacuum, sputtering, electroplating or otherwise. The electrodes E_1 and E_2 may consist of films of silver, gold, aluminum, platinum, or other conductive material. By adding to or partially removing the coated electrode material, the crystal may be brought to its required operating frequency.

The foils F_1, F_2, F_3 and F_4 act like gaskets in increasing the area over which the springs S_1 and S_2 contact the electrodes E_1 and E_2. The foils F_1, F_2, F_3 and F_4 yield under pressure and hence provide a firmer, more steady contact with the electrodes during the vibrations of the plate PE. The foils F_1, F_2, F_3 and F_4 may be omitted, if desired, but in that case there will be some likelihood of the coated electrodes being pierced or worn by the springs during mechanical vibration of the crystal or of the electrodes being burnt away when a large amount of power is controlled by or traverses the crystal.

The springs S_1 and S_2 are employed both to clamp the crystal PE within its housing and to contact the electrodes E_1 and E_2. This dual function of the springs is a feature of this invention. If desired, however, the springs need not be employed for contact purposes, but leads (not shown) may be soldered to the plated electrodes E_1 and E_2 to provide the contacting means.

It will be further observed that the springs S_1 and S_2 have a common support in the cover CV, and are disposed on but one side of the crystal element PE. This is another feature of this invention. No spring-like or tensioning member whatever is positioned on the other side of the crystal element.

Figs. 4 to 6 disclose a modified form of housing for a crystal element PE. The crystal element PE may be prepared by entirely coating the element with a film such as silver, for instance, parts of which may be removed by etching, the remaining portions constituting electrodes E_1 and E_2, as already explained. The silver coating is not removed from the adjacent corners CR_1 and CR_2. At these adjacent corners the silver coating is copperplated, and leads D_1 and D_2 are soldered to the copperplated portions of the crystal element. The electrodes E_1 and E_2 may then be reinforced by additional plating which also may serve to adjust the frequency of vibration. The electrode plating may be accomplished with a material similar to that described hereinabove in regard to the device of Figs. 1–3. For example, if gold is employed as the electrode film, the gold film will be extended to cover the copperplated portions. The final electrode plating will also fix the final vibratory frequency of the crystal element PE.

The crystal element PE also rests on four lands or elevations L_1, L_2, L_3 and L_4. The cover CV also embodies a shoulder SH which may also be provided with corresponding lands or elevations such as L_5, L_6, L_7 and L_8. The crystal element may be clamped between the two groups of lands L_1 to L_4 and L_5 to L_8, as shown. If desired, the two groups of lands need not be employed for clamping the crystal, but merely to restrict its overall freedom of motion within the holder.

The plugs P_1 and P_2 may be threaded or molded in container CN. These plugs are hollow so as to receive the leads D_1 and D_2, which may be soldered to the ends of plugs P_1 and P_2.

While this invention has been shown and described in certain particular embodiments merely for the purpose of illustration, it will be understood that the general principles of this invention may be applied to other and widely varied organizations without departing from the spirit of the invention and the scope of the appended claims.

What is claimed is:

1. A holder for a piezoelectric crystal element having means comprising a plurality of springs for clamping only the corners of said crystal element and establishing individual electrical connections with the opposite electrode faces of said crystal element, said plurality of springs having a common support and being disposed only on one side and adjacent only one face of said opposite electrode faces of said crystal element.

2. A holder for a piezoelectric crystal element including two curved spring strips, each spring strip having two ends to contact two corners of the piezoelectric crystal element, said spring strips having a common support and being disposed only on one side and adjacent only one face of said crystal element.

3. A holder for a piezoelectric crystal element including two curved spring strips mounted on a common support and disposed adjacent to but one face of said crystal element, each spring having two ends to contact two of the corners of the piezoelectric element, and a pair of terminals each of which is mounted in one of said spring strips.

4. A holder for a piezoelectric element having two coatings integral with the piezoelectric element, one of the coatings extending from two of the corners of the crystal element and extending over portions of the opposite faces of the crystal element, the other coating extending from the other two corners of the crystal element and extending over other portions of the opposite faces of the crystal element, said holder including two curved spring strips, each spring strip contacting two of the corners common to one of the coatings, and a support common to both spring strips, whereby the spring strips are disposed on only one side and are adjacent only one face of said crystal element.

5. A holder for a piezoelectric crystal element comprising four metal foils each of which is bent over one of the corners of the crystal element, two curved spring strips, the two ends of each spring strip contacting two of the metal foils, and a common support for said spring strips, said spring strips being disposed only on one side and adjacent only one face of said crystal element.

6. A holder for a piezoelectric crystal element, said holder including two curved spring strips and a common support for said spring strips, said spring strips being disposed only adjacent one face of the crystal element, the ends of each spring strip contacting two of the corners of the crystal element, said spring strips serving both to clamp the crystal element and as terminals through which traverse the currents that flow to and from the crystal element.

7. Piezoelectric crystal apparatus comprising a piezoelectric crystal element having a pair of conductive coverings thereon, each of said coverings partially covering two major and at least

one minor face of said crystal element, and means including a pair of springs individually contacting with said pair of coverings for applying a clamping force to said crystal element through said partially covered major faces adjacent the edges thereof, said pair of springs being disposed at one side only of one of said major faces of said crystal element.

8. Piezoelectric crystal apparatus comprising a rectangular-faced, piezoelectric crystal element having its thickness made of a value in accordance with the value of its desired thickness-mode frequency, said crystal element having a pair of electrode coverings thereon each partially covering the major faces and two of the four corners of said crystal element, said coverings including four U-shaped metallic foils bent around said four corners of said crystal element, a container for said crystal element, means including a pair of springs carried by said container for applying clamping force to said four corners of said crystal element in a direction substantially normal to said major faces of said crystal element, each of said springs contacting two of said foils corresponding to one of said electrode coverings, and a pair of terminal leads carried by said container at one side only thereof. said pair of terminal leads being individually connected with said pair of springs.

9. Piezoelectric crystal apparatus comprising a rectangular-faced piezoelectric crystal element having its thickness made of a value corresponding to the value of its desired thickness-mode frequency, said crystal element having a pair of electrode coverings each partially covering the major faces of said crystal element, a container for said crystal element, means including said container for applying clamping force to the four corners of said crystal element in a direction substantially normal to said major faces of said crystal element, and a pair of terminal leads carried by said container at one side only thereof, said terminal leads being individually secured to said pair of electrode coverings at points adjacent two of said four corners of said crystal element.

10. Piezoelectric crystal apparatus comprising a rectangular-faced piezoelectric crystal element having its thickness made of a value in accordance with the value of its desired thickness-mode frequency, said crystal element having a pair of conductive coverings thereon each partially covering the major faces and at least one of the four corners of said crystal element, a container for said crystal element, means including said container for applying clamping force to said four corners of said crystal element in a direction substantially normal to said major faces of said crystal element, and a pair of terminal leads carried by said container at one side only thereof, said terminal leads being individually connected with said pair of coverings at points adjacent said corners of said crystal element.

11. In combination, a rectangular piezoelectric crystal having major and minor faces, a pair of electrodes each partially covering two major and three minor faces of said crystal and means for applying a clamping force to said crystal through its partially covered major faces.

12. In combination, a piezoelectric crystal having major and minor faces, a pair of electrodes each partially covering two major and at least one minor face of said crystal, and means for applying a clamping force to said crystal in a direction substantially normal to the plane of its major faces and contiguous the areas on said major faces which are covered by the same electrode.

13. In combination, a rectangular piezoelectric element, a pair of electrodes each covering an end zone of two major faces of said crystal, and means for applying a clamping force to said crystal contiguous said end zones in a direction substantially normal to its said major faces.

14. In combination, a piezoelectric crystal, a pair of electrodes each partially covering two electrode faces of said crystal, the covered areas of said electrode faces embracing the opposite end zones of each of said crystal faces, and a pair of electrode leads each secured to said crystal contiguous said covered end zones.

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