May 18, 1943 G. M. THURSTON 2,319,357

VARIABLE AIR-GAP CRYSTAL HOLDER

Filed Sept. 3, 1941 2 Sheets-Sheet 1

FIG. 1

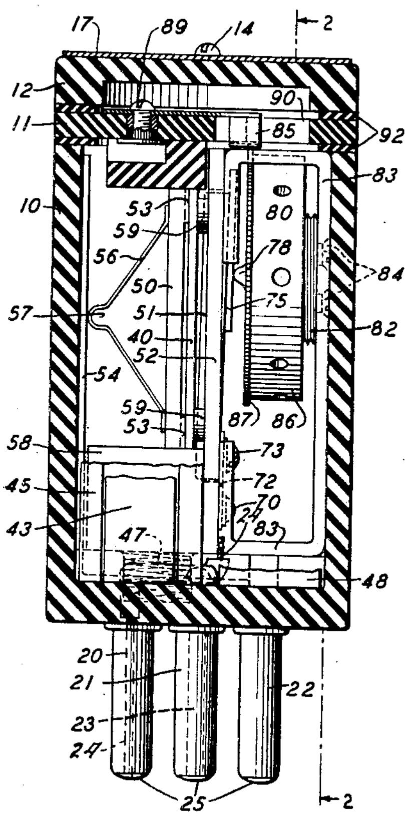
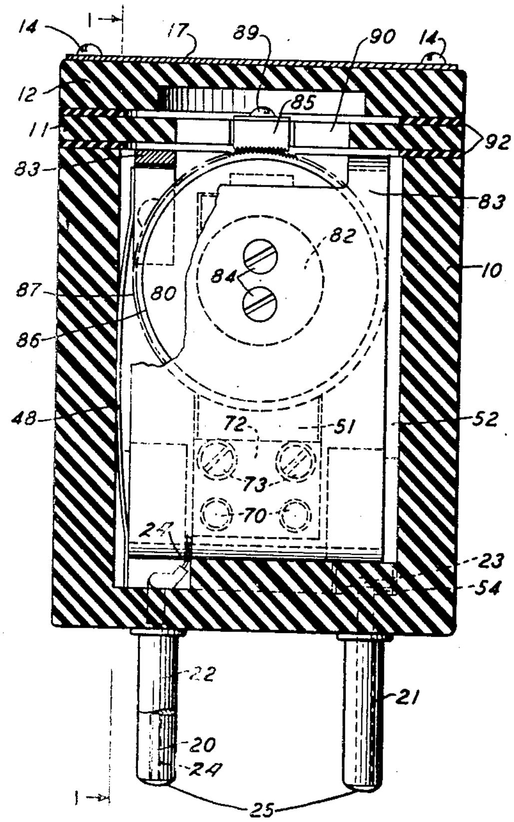


FIG. 2



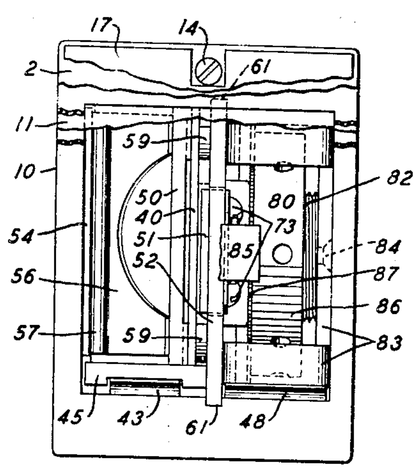


FIG. 3

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VARIABLE AIR-GAP CRYSTAL HOLDER

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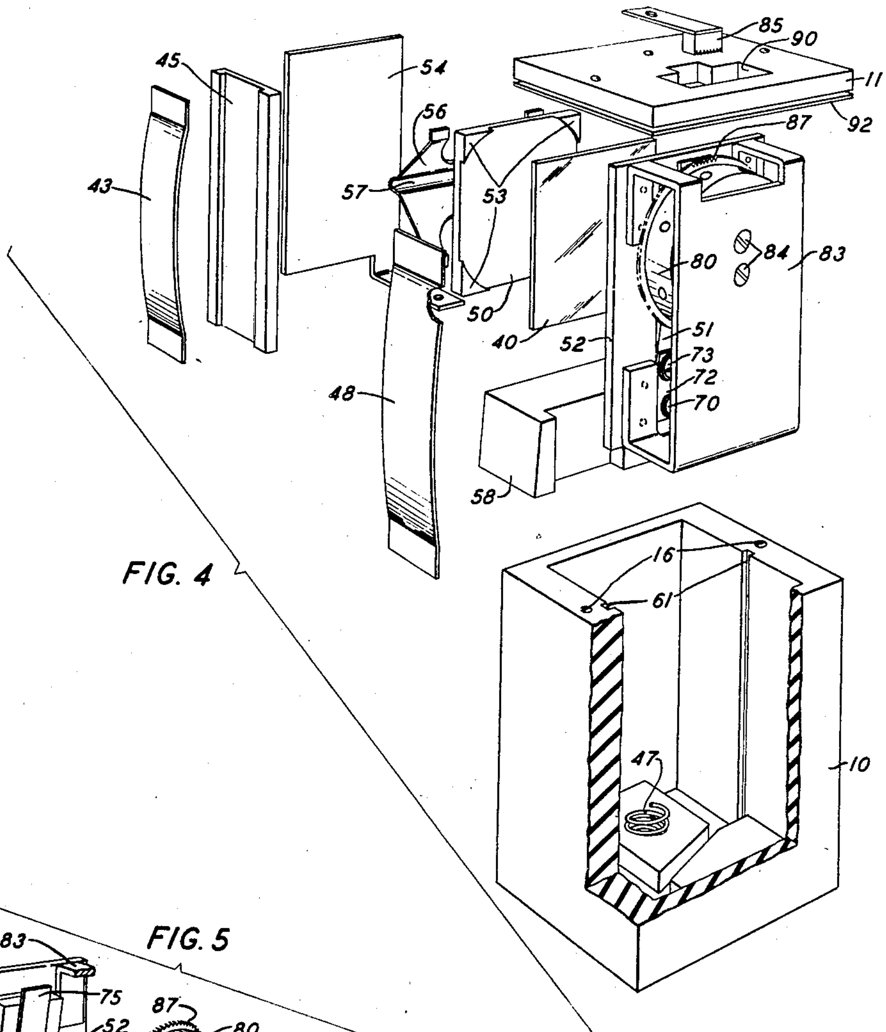
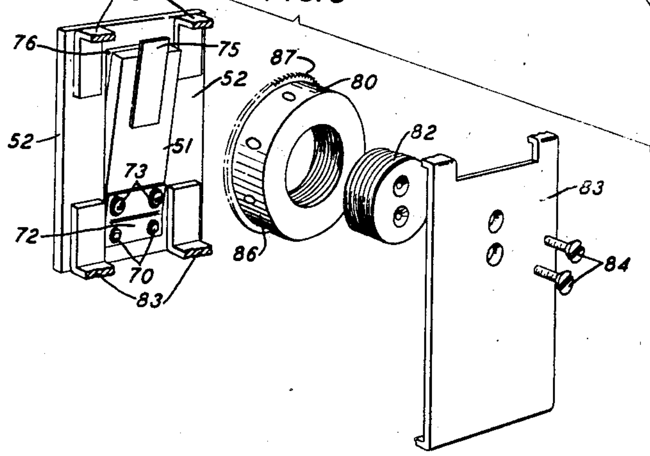


FIG. 4

FIG. 5



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UNITED STATES PATENT OFFICE

2,319,357

VARIABLE AIR-GAP CRYSTAL HOLDER

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Application September 3, 1941, Serial No. 409,370

15 Claims. (Cl. 171—327)

This invention relates to piezoelectric crystal apparatus and particularly to mounting and frequency adjustment arrangements for piezoelectric crystal elements such as thickness-mode quartz crystal elements useful in the control of oscillation generators in radio transmitters and receivers, for example.

One of the objects of this invention is to provide piezoelectric crystal apparatus, the circuit frequency of which may be varied within certain limits and adjusted to an exact value.

Another object of this invention is to provide improved means for resiliently clamping a piezoelectric crystal element to hold it rigidly against bodily movement out of a predetermined position with respect to its clamping means while independently providing therefor an angularly variable air-gap electrode to adjust the circuit frequency thereof to a desired value independently of the clamping means.

The frequency of a piezoelectric quartz crystal element in an oscillator circuit, for example, is a function of the spacing of its surfaces from its adjoining electrodes. In accordance with this invention, by varying the gap or spacing between one of the surfaces of the crystal element and its adjoining angularly movable electrode, the frequency of the circuit may be varied within limits and adjusted to a desired frequency.

To mechanically hold the crystal element in position at all times and to reduce undesired extraneous frequencies therein, the crystal element, which may be a thickness-mode crystal element of low or zero temperature-frequency coefficient, for example, may be rigidly and resiliently clamped at its peripheral portion only, and at all four corners thereof when the major surfaces thereof are rectangular or square in shape. The crystal element being adequately clamped is not adversely affected by mechanical shock or vibration, and being provided with an angularly adjustable air-gap electrode that is adjustable independently of the crystal clamping means, may be adjusted to an exact frequency value. The crystal unit is relatively inexpensive to manufacture, and may be made of a size that occupies a relatively small space.

In a particular embodiment, the crystal element may be provided with corner clamping only and with an independent angularly adjustable air-gap electrode which is spring-hinged to crystal clamping frame. Also, spring pressure may be applied to crystal electrode assembly in three mutually perpendicular directions to prevent bodily movement of the assembly out of a predetermined position within the enclosing container. In such an arrangement, there is no wear or disturbance of position of the crystal element as a result of adjustments in the air-gap, and the device is particularly useful in mobile applications or wherever small adjustments in frequency are desired.

For a clearer understanding of the nature of this invention and the additional advantages, features and objects thereof, reference is made to the following description taken in connection with the accompanying drawings, in which like reference characters represent like or similar parts and in which:

Figs. 1, 2 and 3 are respectively front, side and top views, in section, of a piezoelectric crystal holder unit in accordance with this invention, Fig. 1 being a view taken on the line 1—1 of Fig. 2, Fig. 2 being a view taken on the line 2—2 of Fig. 1, and Fig. 3 being a top view of Fig. 1;

Fig. 4 is an exploded perspective view of parts of the crystal holder unit illustrated in Figs. 1 to 3; and

Fig. 5 is another exploded perspective view of parts of the crystal holder unit illustrated in Figs. 1 to 4.

Referring to the drawings, the crystal holder device, as illustrated in Figs. 1 to 5, may comprise a housing composed of insulating material such as molded Bakelite and consisting of a container 10 of nearly cubical shape with covers 11 and 12 therefor composed of the same material. The cover 12 may be removably fastened to the container casing 10 by screws such as the screws 14 insertable through corresponding circular openings in the cover 12 and engaging corresponding internally-tapped brass inserts 16 embedded in the phenol product casing 10. A nameplate 17 may be removably secured to the cover 12 by screws insertable through openings in the nameplate 17 and engaging corresponding internally-tapped brass inserts embedded in the cover 12. The contents of the container 10 are made accessible upon removal of the screws that hold the nameplate 17 to the cover 12, and upon removal of the screws 14 that hold the cover 12 to the container body 10.

As illustrated in Figs. 1 and 2, three hollow tubular metal terminal pins or prongs 20, 21 and 22, each having rounded ends or tips 25, may be secured to the outside bottom surface of the container body 10 and utilized for mechanically supporting the device and also for establishing external electrical connections therewith. As illustrated in Figs. 1 and 2, wires or rods 23 and 24 may be soldered to the ends or tips 25 of the terminal pins 20 and 21 and disposed within the hollow pins 20 and 21 to individually establish the electrical connections with a piezo-electric crystal element 40 which is disposed between a stationary electrode 50 and an angularly movable electrode 51, the latter being spring-hinged to a fixed or stationary frame or plate 52. A wire 24 may be soldered at one end thereof to the fixed plate 52 and at its other end to the pin terminal 20, and a rigid rod 23 may be soldered at one end thereof to the pin terminal 21 and at its other end to the conductive connector plate 54 disposed in contact with a conductive V-shaped spring 56 which electrically interconnects the connector plate 54 with the stationary electrode plate 50. As illustrated in Figs. 1 to 4. the contact plate 54 may be placed against the side and bottom inner walls of the container 10 to electrically interconnect the external terminal pin 21 with the V-shaped spring 56 and the stationary electrode 50. The crystal clamping electrode plate 50 and the V-shaped spring 56 may be of the form described in United States Patent 2,115,145 to L. F. Koerner, dated April 26, 1938, Figs. 1 to 4.

Varnished tubing or other suitable insulated conductor wire may be utilized to interconnect the pin terminal 20 with the stationary frame or plate 52, the opposite ends of the wire 24 being soldered or otherwise conductively attached to the terminal pin 20 and to the plate 52. By means of the plug-in type terminals 20, 21 and 22 and corresponding sockets therefor (not shown), the entire unit may be removably inserted in the oscillator circuit of a radio transmitter or receiver, for example, to control the frequency of oscillations at a desired value in accordance with the adjusted frequency characteristic of the crystal element 40.

The crystal element 40 may be a thickness-mode quartz crystal plate of the type described, for example, in United States Patent 2,218,200, granted October 15, 1940, to F. R. Lack et al., which includes an AT cut quartz crystal element 40 of the low temperature-frequency coefficient type, the frequency of which may be varied within about ±.025 per cent of its nominal frequency by adjustment of a calibrated dial 80 which may be reset to a value of .001 per cent. The nominal frequency of the crystal element 40 may be a value within a range of the order from 1600 or less to 4500 or more kilocycles per second, for example.

The spring-pressed electrode plate 50 may have at each of the corners of its major surface that is adjacent the crystal element 40 four integral flat-surfaced corner projecting lands 53 which are adapted to make contact with one of the major surfaces of the crystal element 40 only at the four corners thereof, the central depressed portion between the corner projections 53 being a flat surface which may be uniformly spaced about .001 inch from the adjacent major surface of the crystal element 40, as described in the hereinbefore mentioned L. F. Korner United States Patent 2,115,145, dated April 26, 1938.

The stationary center plate 52 which may be removably slidable in two opposite grooves 61 cut or molded in the opposite interior walls of the container 10, mechanically divides the container 10 into two compartments, in one of which on one side of the center plate 52 is placed the crystal element 40, the crystal electrode plate 50, the V-shaped spring 56, the connector plate 54, and a removable insulating spacer 58, which is disposed in slidably fitting relation between the parallel plates 52 and 54 adjacent the lower edges of the crystal element 40 and its stationary electrode 50.

The container 10 may interchangeably hold a crystal element 40 and an electrode 50 of various corresponding sizes and shapes. For this purpose, a suitable removable insulating spacer 58 having external dimensions suited to the dimensions of the compartment between the parallel plates 52 and 54 and having internal configurations suitable for the edges of the electrode 50 and the crystal element 40 may be provided. Where the crystal element 40 and the electrode 50 are of rectangular shape, the insulating spacer 58 may be shaped as illustrated in Figs. 1 and 4.

The spring 56 may be in the form of a V-shaped spring and may have a central rib 57 to permit the spring 56 to be readily there bent and adjusted to exert a suitable clamping pressure on the four corners of the crystal element 40. The spring 56 is constructed and placed in contact with the electrode plate 50 in a manner to register with and exert pressure only on the four corner clamping projections 53 of the electrode plate 50. The V-shaped spring 56 may be adjusted to exert a pressure of approximately five pounds on the crystal element 40, or of other suitable value to suit the thickness of the crystal element 40 and to rigidly clamp the crystal element 40 so that the V-shaped spring 56 may at all times press the crystal element 40 against the fixed center plate 52.

A bow spring 43 which may be made of spring steel or of other suitable spring material may be placed in the groove of an insulating guide 45 of moulded Bakelite, for example, and utilized to apply spring pressure in edgewise direction to the electrode 50 assembly that is located at one side of the center plate 52. Also, a coil spring 47 may apply pressure thereto in another direction acting on the insulating spacer 58, the V-shaped spring 56 applying pressure thereto in a third direction. Accordingly, by means of the springs 43, 47 and 56, spring pressure may be applied to the electrode assembly 50 in three mutually perpendicular directions to prevent bodily movement of the assembly out of a predetermined position within the container 10. A bow spring 48 may apply spring pressure to the center plate and bracket assembly 52, 83 to prevent bodily movement thereof out of a predetermined position against a wall of the container 10. The crystal clamping spring 56 is adjusted so as to prevent its pressure on the crystal element 40 from being overcome by pressures of the component springs 47 and 56 used in the assembly.

As illustrated in Figs. 1, 3 and 4, the thickness-mode quartz crystal element 40 is resiliently clamped at its four corners only by and between the four integral clamping bosses 53 of the stationary metallic electrode plate 50 which is located on one side of the crystal element 40, and the four oppositely disposed clamped projections 59 attached to the marginal rectangular shaped frame 52 which is located on the other side of the crystal element 40 adjacent the peripheral margin thereof. The four clamping projections 59 may be in the form of studs pressed into place in suitable openings cut near the four corners of the plate frame 52.

Accordingly, the piezoelectric crystal element 40 is resiliently held in position between the four clamping projection 53 of electrode plate 50 and the four oppositely disposed clamping projections 59 which are secured to the center plate 52 adjacent the four corners of the crystal element 40.

Attached to the lower margin of the stationary center plate 52 is a flat spring 72 which is also attached by screws 73 to the lower edge of the angularly movable electrode 51, the latter freely passing through a rectangular opening 76 in the center of the plate 52 and being disposed closely adjacent but normally out of pressure contact with the central portion of the major surface of the crystal element 40 that faces the stationary plate 52, so as not to press on that portion of the crystal element 40 that is directly opposite the movable electrode 51. The spring 72 being sprung away from the fixed plate 52 constantly holds the extension plate 75, that is secured by welding or otherwise to angularly movable electrode 51, against the hump 78 on the flat face of an adjustable control knob 80 which is rotatable on the screw-threaded stud 82 attached by screws 84 to a bracket 83 carried by the center plate 52.

The spring 72 may be made of phosphor-bronze or other suitable spring material and may be riveted at two points 70 or otherwise secured to the bottom part of the fixed center plate 52 in such a manner that the spring 72 is normally biased or sprung away from the fixed plate 52 in a direction away from the crystal element 40. The control knob 80 engaging the stud screw 82 attached to bracket 83 carried by plate 52 may be rotated on the screw 82 and by contact of the hump 78 with the arm 75 of the angularly movable electrode 51 squeeze the electrode 51 angularly towards the crystal element 40.

The adjustable control knob 80, when rotated inwardly on the stud screw 82, works against the pressure of the spring 72 and causes the angularly movable electrode 51 to be moved towards the crystal element 40 thereby decreasing and varying the angular air-gap between the crystal element 40 and the movable electrode plate 51 and causing a frequency variation in the crystal unit. The pitch of the thread of the screw 82 may be made of such a value that the control knob 80 may make one complete rotation in order to move the electrode 51 through its entire adjustment distance, which may be, for example, roughly of the order of ⅛ inch or less at the upper edge thereof.

The pressure exerted by the spring 72 against the hump 78 of the control knob 80 may be such as to provide sufficient friction against a too easy turning of the control knob 80 from any desired setting. If desired, additional means such as a lock 85 extending through an opening in the cover 11 may be provided to securely lock the control knob 80 in position, the rotatable control knob 80 having a knurled periphery 87 cooperating with a similarly knurled portion of the lock 85. A dial 86 may be provided on the periphery of the rotatable adjustment knob 80, and a stationary pointer may be provided adjacent the dial 86 to indicate the setting thereof.

The stationary or fixed plate 52 consists of a flat-surfaced metal plate 52 having a central opening 75 to provide a marginal frame for clamping the crystal element 40 and to support the movable electrode 51. The spring 72 may be riveted or otherwise securely attached to the bottom region of the fixed plate 52, the opposite end of the spring 72 being secured to the movable electrode 51 which extends through the opening 75 in the center of the fixed plate 52.

The fixed plate 52, the bracket 83, and the stud 82 secured thereto may be composed of nickel-silver or other suitable material. The spring 72 may be made of phosphor-bronze, spring tempered. The control knob 80 may be made of nickel-silver provided with a knurled periphery 87.

The angularly adjustable electrode 51 is at all times out of contact with the crystal element 40 and at no time clamps the crystal element 40 or otherwise disturbs the position of crystal element 40 or its calibration. To prevent moving the electrode 51 into pressure contact with the crystal element 40, suitable stop and indicating means may be applied to the control knob 80 to confine its extreme motion within a limiting point beyond which it should not be moved.

The spacing between the outer edges of the movable electrode 51 and the edges of the frame 52 that form the rectangular opening 76 therein may be equal and of a value to permit free movement of the electrode 52 within the opening 76.

The inner major surface of the movable electrode 51 and that of the peripheral marginal frame plate 52 that face towards the crystal element 40 are non-aligned with respect to each other, the electrode 51 being disposed nearest to the crystal element 40 illustrated in Figs. 1 and 3.

The angularly adjustable rectangular-shaped electrode 51 being spring-hinged to one side of the marginal frame 52 is adjustably movable in the manner of a trap-door within the rectangular-shaped central opening 76 in the marginal frame 52, thereby to adjustably vary the wedge-shaped air-gap spacing between the crystal element 40 and the movable electrode 51 for adjusting the frequency of the crystal unit to a desired value.

The peripheral frame plate 52 and the four clamping projections 59 attached thereto may be constructed of metal or of any other material having suitable mechanical properties to function to support and rigidly clamp the crystal element 40 at its four corners only, and also to support the spring 72 that supports and supplies potential to the central field-producing movable electrode 51 attached thereto.

The rigidly clamped corners of the crystal element 40 are quiescent at all times, and the effective electric field for operatively driving the desired piezoelectric motion of the crystal element 40 is provided by the angularly movable electrode 51 which is disposed centrally of and relatively near to the crystal element 40 and accordingly provides a relatively strong electric field at the central portion only of the crystal element 40. While the peripheral clamping frame 52 may have electrode potential thereon, it does not function as a field-producing electrode for working any useful piezoelectric motion in the thickness-mode crystal element 40 at the periphery thereof, the useful motion therein to obtain the desired frequency being at the central portion thereof and resulting from the field applied thereto by the centrally located electrode 51.

If it be desired to take the electrode potential off the metallic marginal frame 52, insulators (not shown) may be provided and interposed between the spring 72 and the frame 52 in order to electrically insulate the metal frame 52; or alternatively the frame 52 itself may be made of insulating material of suitable mechanical properties.

With the control knob 80 rotated so that it holds the stop 75 just flush against the plate frame 52, the surfaces of the four clamping studs 59 that contact the crystal element 40 may be lapped flush with respect to each other and also with respect to the surface of the movable electrode 51 that faces the crystal element 40. After such surfaces have been so lapped, the control knob 80 may be backed off about $\frac{1}{32}$ of a turn and this position suitably marked to indicate the limit of travel of the dial 80.

Access to the interior of the unit may be had by unscrewing the two top screws 14 to remove the name plate 17 and unscrewing the screws to remove the cover 12 and the gasket 92. By loosening the screw 89 holding the dial locking device 85, the lock 85 may be swung around so as not to interfere with turning of the dial 80. The dial 80 then may be turned to the desired per cent deviation or frequency setting, and the lock 85 reset. The dial 80 should not be turned beyond its freely movable or adjustable limits in order to avoid any straining of the frame of the unit and displacement of the frequency calibration thereof.

The top plate 11 of phenol fibre may be secured to the container body 10 by screws and may be provided with a rectangular-shaped opening 90 therein to permit access to the rotatable control knob 80 when the cover 12 has been removed from the container body 10. Gaskets 92 of rubber, or artificial rubber, such as Neoprene or other suitable material, may hermetically seal the joints between the cover 12, the top plate 11 and the body 10 of the enclosing container to which the cover 12 is secured by means of the screws 14.

The clamping projections 53 of the electrode 50 and the clamping projections 59 of the center plate 52 rigidly clamp the crystal element 40 adjacent its four corners only, independently of adjustments in the angularly movable electrode 51. The V-shaped spring 56 tends at all times to hold the crystal element 40 against the fixed plate 52. The control knob 80 working against the pressure of the spring 72, independently adjusts the air-gap spacing between the crystal element 40 and the electrode plate 51.

The crystal element 40 is, by means of the V-shaped spring 56, held in contact with the clamping projections 53 and 59 of the plates 50 and 52 at all times, the movable electrode 51 moving with respect to the fixed plate 52 to form an angular or wedge-shaped air-gap, the hinge or pivot points of which are well within the projected major surface area of the crystal element 40 thus giving a relatively large change in angle for a relatively small movement of the air-gap adjustment, and also because of the wedge shape of the air-gap, reducing undesired resonances that might result from a parallel air-gap between the crystal surface and the electrode 51 spaced therefrom. The independent rigid and resilient clamping of the crystal element 40 at its four corners is provided at all times to mechanically hold the crystal element 40 in position and to reduce extraneous frequencies in the crystal element 40.

The arrangement illustrated in Figs. 1 to 5 provides a relatively inexpensive form of crystal mounting that provides not only a four-corner clamping of the crystal element 40 but also, independently of the clamping means, an adjustable air-gap for the crystal element 40 that is angular or wedge-shaped. The variation in the air-gap may be used to change the frequency to either side of a frequency assignment for the station in order to avoid beat-note interference for two stations operating on the same frequency assignment or to operate two stations on the same assignment without mutual interference. The frequency variation of the crystal element 40 may be made of the order of about ±.03 per cent when the wedge-shaped air-gap is varied within the range resulting from about one turn of the control knob 80. The dial 86 may be calibrated in terms of frequency or wavelength and any setting from minimum to maximum air-gap adjustment may be duplicated. Since the frequency of the crystal unit may be adjusted by movement of the hinged door electrode 51 to about ±.025 of the nominal frequency and with an accuracy of about .001 per cent, the allowable grinding tolerance in manufacture of the crystal element 40 may be reduced to a negligible amount. Accordingly, the unit is useful in many applications such as, for example, heterodyne oscillators, and where one transmitter is adjusted so as to avoid interference from another transmitter.

Although this invention has been described and illustrated in relation to specific arrangements, it is to be understood that it is capable of application in other organizations and is, therefore, not to be limited to the particular embodiments disclosed, but only by the scope of the appended claims and the state of the prior art.

What is claimed is:

1. A frequency-controlling piezoelectric crystal device comprising a pair of stationary metallic plates between which a thickness-mode rectangular-faced piezoelectric crystal element is disposed, means including a V-shaped spring disposed in contact with one of said plates for resiliently exerting pressure on one of said plates and rigidly clamping all four of the corners of the peripheral portion only of the crystal element between said plates, another spring secured to the other of said plates and sprung away therefrom in a direction away from the crystal element, a rectangular-shaped movable electrode carried by said another spring and angularly movable within a rectangular opening in said other of said plates, means including said another spring for pivotally establishing said angular relation between the crystal element and said movable electrode, and means including a screw-threaded rotatable member working against the pressure of said another spring for adjustably increasing and decreasing the angle between the crystal element and said movable electrode to control the value of said frequency.

2. A frequency-controlling piezoelectric crystal device comprising a pair of plates between which a thickness-mode rectangular-faced piezoelectric crystal element is disposed, one of said plates having an opening adjacent the central portion only of the major surfaces of the crystal element, means including a spring cooperating with one of said plates for resiliently exerting pressure on and rigidly clamping all four corners of the peripheral portion only of the crystal element between said plates, another spring secured to the other of said plates and sprung away therefrom in a direction away from the crystal element, means including a movable electrode carried by said another spring and movable within said opening for pivotally establishing an angular relation between the crystal element and said movable electrode, and means including a

rotatable member working against the pressure of said last-mentioned spring for adjustably increasing and decreasing the angle between the crystal element and said movable electrode to adjust the value of said frequency.

3. A frequency-controlling piezoelectric crystal device comprising a pair of plates between which a thickness-mode piezoelectric crystal element is disposed and clamped, means including a spring cooperating with one of said plates and with clamping projections on both of said plates for resiliently clamping the peripheral portion only of the crystal element, another spring secured to the other of said plates and sprung away therefrom in a direction away from the crystal element, means including an electrode carried by said another spring and movable within an opening in said other of said plates for pivotally establishing an angular relation between the crystal element and said movable electrode, and means including a rotatable member working against the pressure of said last-mentioned spring for adjustably increasing and decreasing the angle between the crystal element and said movable electrode to adjust the value of said frequency.

4. A frequency-controlling piezoelectric crystal device comprising electrode plates for a piezoelectric crystal element disposed therebetween, a marginal frame surrounding the periphery of one of said electrode plates, a pair of springs disposed on opposite sides of the crystal element, means including said frame and one of said electrode plates cooperating with one of said springs for resiliently clamping the peripheral portion only of the crystal element, means including the other of said springs carried by said frame for pivotally establishing an angular relation between the crystal element and the other of said electrode plates, and means including a rotatable member working against the pressure of said other of said springs for adjustably increasing and decreasing the angle between the crystal element and said other of said electrode plates to adjust the value of said frequency.

5. A frequency-controlling piezoelectric crystal device comprising a stationary electrode and a movable electrode for a piezoelectric crystal element disposed therebetween, means including a spring disposed on one side of the crystal element and secured to said movable electrode for pivotally mounting said movable electrode angularly with respect to the crystal element and said stationary electrode, means including another spring and said stationary electrode for exerting clamping pressure resiliently on the peripheral portion only of the major surfaces of the crystal element, said first-mentioned spring tending to increase the angle between the major surface of the crystal element and said movable electrode, and means including a rotatable member cooperating with said first-mentioned spring for adjustably increasing and decreasing said angle between the crystal element and said movable electrode to adjust the value of said frequency, said last-mentioned means being adjustable independently of said clamping pressure exerted on said crystal element.

6. A piezoelectric crystal device comprising a stationary electrode plate and a movable electrode plate for a crystal element disposed therebetween, a frame surrounding the periphery of said movable electrode, means including said stationary electrode plate pressed by a spring for clamping the crystal element with respect to said stationary frame, said clamping of the crystal element being adjacent the peripheral edges only thereof, another spring having its end portions secured to said frame and to said movable electrode adjacent a peripheral edge thereof, said last-mentioned spring being sprung away from said stationary frame in a direction away from the crystal, means including a rotatable member cooperating with said last-mentioned spring for adjustably increasing and decreasing the angle between the crystal surface and said movable electrode plate, said springs being disposed on opposite sides of the crystal element and one only of said springs exerting clamping pressure on the crystal element.

7. A frequency-controlling piezoelectric crystal device comprising a stationary plate having an opening therein containing a movable electrode plate disposed adjacent the center of the crystal element, means including a spring for pivotally moving said movable electrode plate angularly in a direction to increase the angle between the crystal element and said movable electrode plate, said movable electrode plate being pivoted at a region within the projection of the major surface area of the crystal element, said spring being secured at one of its ends to said stationary plate and having its opposite end secured to said movable electrode plate at that part thereof that is adjacent said pivoted region thereof, said spring being sprung away from said stationary plate in a direction away from the crystal element, and a rotatable adjustable member carried by said stationary plate and cooperating with said spring secured to said stationary plate for adjustably increasing and decreasing the angle between said major surface of the crystal element and said movable electrode plate to adjust the value of said frequency.

8. A frequency-controlling piezoelectric crystal device comprising a stationary electrode plate disposed on one side of the crystal element, a movable electrode plate disposed on the opposite side of the crystal element, a frame having an opening therein containing said movable electrode plate, means including a spring for clamping the periphery of the crystal element between said frame and said stationary electrode plate, said movable electrode plate being pivoted at a region within the projection of the major surface area of the crystal element by another spring secured to said frame, said movable electrode plate extending through said opening in said frame and being out of contact with the crystal element, said another spring being sprung away from said frame in a direction away from the crystal element, and a screw-threaded rotatable adjustable member carried by said frame and working against the pressure of said last-mentioned spring for adjustably increasing and decreasing the angle between said major surface of the crystal element and said movable electrode plate to adjust the value of said frequency.

9. A frequency-controlling piezoelectric crystal device comprising a stationary rectangular-shaped electrode plate of the same size as and disposed on one side of the crystal element, a movable electrode plate of smaller size than and disposed on the opposite side of the crystal element, said crystal element having a rectangular-shaped major surface, a stationary frame surrounding the peripheral edges of said movable electrode plate, means including a V-shaped spring engaging said stationary electrode plate for clamping the periphery of the crystal ele-

ment between said frame and said stationary electrode plate, said movable electrode plate being pivoted at a region within and not beyond the projection of the major surface area of the crystal element by a flat spring having one of its edges secured to said frame and having its opposite edge secured to said movable electrode plate and disposed out of contact with the crystal element, said flat spring being sprung away from said frame in a direction away from the crystal element, said V-shaped spring and said flat-shaped spring being disposed on opposite sides of the crystal element, said V-shaped spring resiliently exerting clamping pressure on the periphery only of the crystal element and on the four corners thereof, and a screw-threaded rotatable adjustable member carried by said stationary frame and acting against the pressure of said flat-shaped spring for adjustably increasing and decreasing the angle between said major surface of the crystal element and that of said movable electrode plate to adjust the value of said frequency.

10. A piezoelectric crystal holder for a thickness-mode crystal element comprising a container, a stationary electrode and a movable electrode between which a piezoelectric crystal element is disposed in said container, a frame having an opening in which said movable electrode is disposed, means including a V-shaped spring engaging said stationary electrode for clamping the periphery of said crystal element between said frame and said stationary electrode, said movable electrode being pivoted with respect to said frame at a region within the projection of the major surface area of said crystal element by means of a flat-shaped spring secured to said movable electrode and to said frame at said pivoted region thereof, said flat-shaped spring being sprung away from said frame in a direction away from said crystal element, said V-shaped spring and said flat-shaped spring being disposed on opposite sides of said crystal element, a screw-threaded rotatable adjustable member carried within said container and opposing the action of said flat-shaped spring for adjustably increasing and decreasing the angle between the major surface of said crystal element and that of said movable electrode, and means including said springs for individually establishing external electrical connections with said electrodes.

11. A piezoelectric crystal device comprising a spring-controlled movable electrode plate, a frame and a stationary electrode plate between and by which a piezoelectric crystal element having a rectangular major surface is resiliently clamped adjacent the four corners thereof, a spring secured to said movable electrode plate and pivoted to said frame, said spring being sprung away from said frame in a direction away from the crystal element, and a rotatable member carried by said frame and working against the pressure of said spring for adjustably increasing and decreasing the angle between the major surface of the crystal element and that of said movable electrode plate to vary the frequency of the crystal element positioned between said electrode plates.

12. An adjustable air-gap piezoelectric crystal holder including a pair of electrodes, a frame having an opening therein through which one of said electrodes is movable, means including a spring for clamping the periphery of a crystal element between said frame and one of said pair of electrodes, and means including a screw-controlled spring hinged to said frame and said movable electrode for angularly adjusting to a desired value the spacing of said crystal element with respect to said movable electrode.

13. Piezoelectric crystal apparatus comprising an electrode adjacent one major face of the crystal element, means including a frame disposed adjacent the margin of the opposite major face of the crystal element for resiliently clamping the corners of the crystal element between said frame and said electrode, and a movable electrode angularly hinged to said frame and disposed within an opening therein and forming with said opposite face of the crystal element an air-gap which is adjustable independently of said clamping means.

14. Piezoelectric crystal apparatus comprising an electrode disposed adjacent one major face of the crystal element, a marginal frame disposed adjacent the periphery only of the opposite major face of the crystal element, means for resiliently clamping the crystal element between said electrode and said frame, said frame having an opening therein, said opening being adjacent the center only of said major faces of the crystal element, a movable electrode spring-hinged to said frame and angularly movable within said opening, and means for adjustably varying the angular spacial relation of said movable electrode with respect to the crystal element.

15. A piezoelectric crystal holder comprising a plate having a central opening therein, a stationary electrode having clamping projections contacting the crystal element at its periphery only, a movable electrode disposed within said opening and being angularly movable with respect to said crystal element and normally out of contact therewith, means including a spring attached to said movable electrode and to a part of said plate for moving said electrode away from said crystal element, adjustable screw means for moving said movable electrode toward said crystal element against the pressure of said spring, and means including a plurality of springs for exerting pressure on said stationary electrode in three mutually perpendicular directions to resiliently fix the position of said stationary electrode and crystal element with respect to said plate.

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