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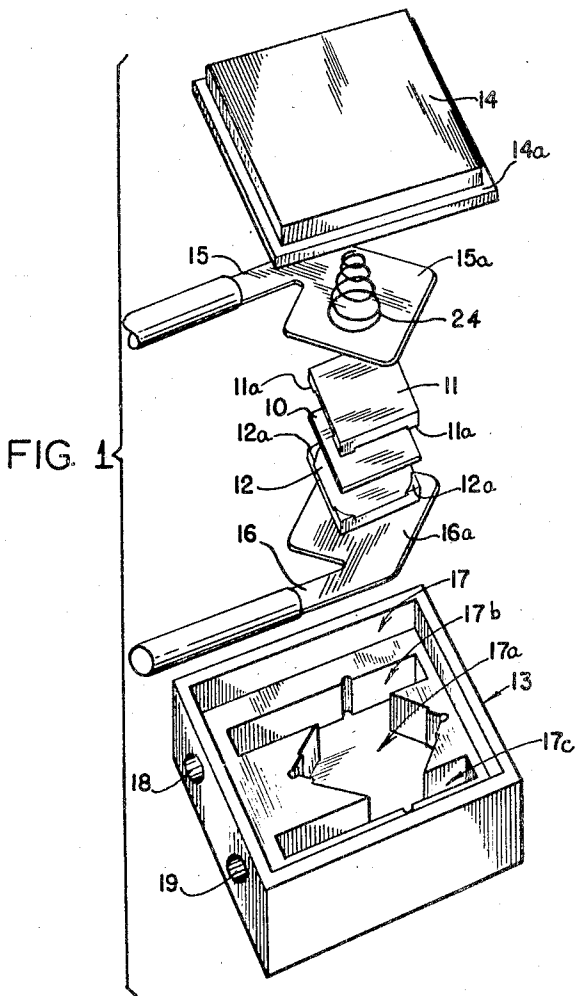
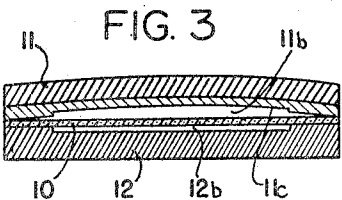
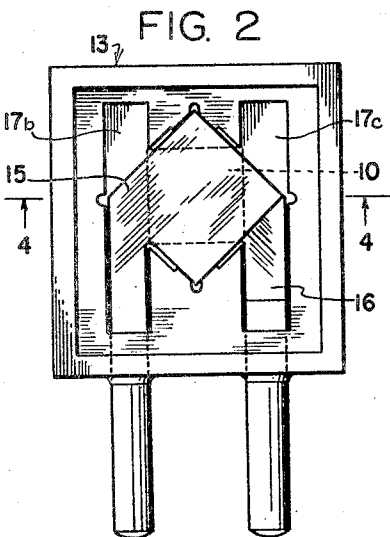
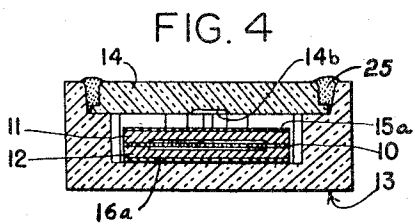
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2,434,265

HOLDER FOR PIEZOELECTRIC CRYSTAL UNITS

Filed July 18, 1945

2 Sheets-Sheet 1



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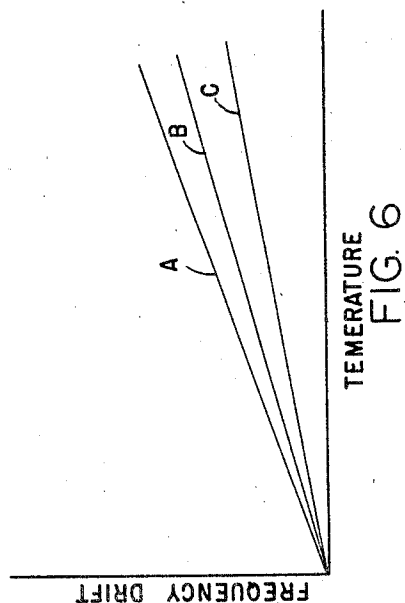
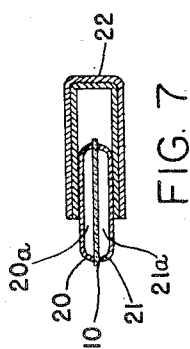
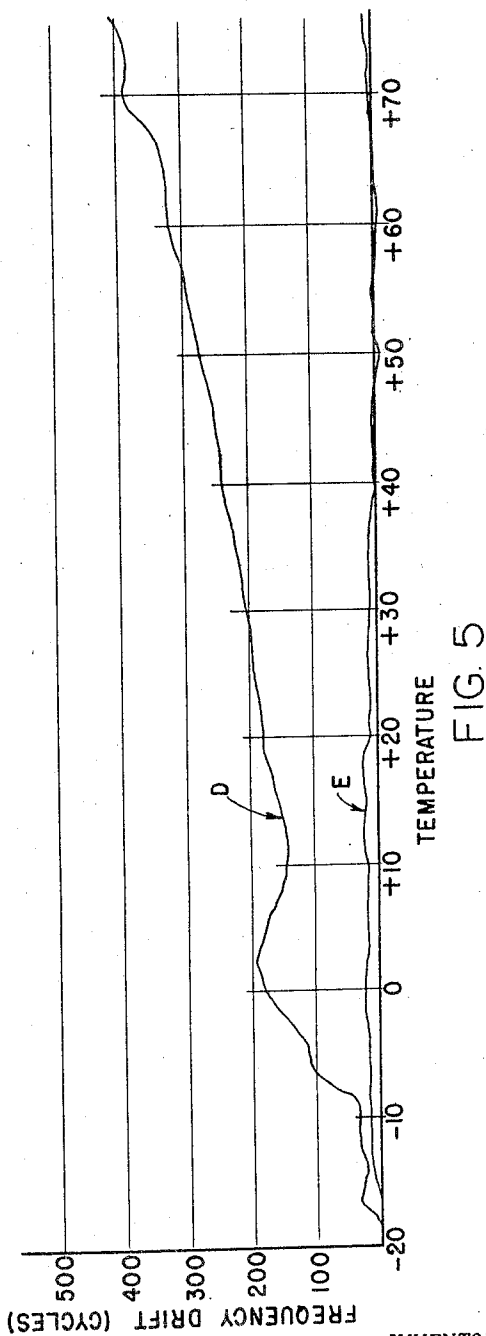
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HOLDER FOR PIEZOELECTRIC CRYSTAL UNITS

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2 Sheets-Sheet 2



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HOLDER FOR PIEZOELECTRIC
CRYSTAL UNITSHal F. Fruth, Chicago, Ill., assignor to Motorola,
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Application July 18, 1945, Serial No. 605,763

12 Claims. (Cl. 171—327)

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The present invention relates to piezoelectric crystal units of the character employed for frequency control purposes in high frequency circuits and more particularly to an improved holder for a piezoelectric crystal.

It is well known that the frequency of oscillation of a piezoelectric crystal changes with variations in the temperature of the crystal, occasioned by ambient temperature changes. It is also well known that the output frequency of a crystal varies with variations in the air gap spacing between the crystal faces and the associated electrodes. Various arrangements have been proposed and employed for producing a temperature controlled variation in the crystal face-crystal electrode air gap spacing in order to minimize variations in the output frequency of the crystal with ambient temperature changes. For the most part such arrangements have been used in crystal units of the so-called floating crystal type, as exemplified by Marrison Patent No. 1,785 036, granted December 16, 1930, wherein the crystal is mechanically divorced from one electrode and hence is free of vibrational restraint through the thickness thereof. This form of crystal unit, while providing for maximum activity of the crystal response, is usually somewhat unstable in operation due to the difficulty involved in maintaining the crystal properly oriented relative to its associated electrodes. On the other hand, when pressure mounting of the crystal is employed to obviate the problem of frequency instability, conventional expedients for compensating the crystal against frequency drift occasioned by ambient temperature changes can no longer be used.

It is an object of the present invention, therefore, to provide an improved holder for pressure mounting a piezoelectric crystal and for minimizing variations in the output frequency of the crystal with ambient temperature changes.

According to another object of the invention, an improved piezoelectric crystal holder is provided in which at least one of the electrodes acts to maintain the crystal under pressure and yet is thermally deformable to change the air gap spacing between itself and one face of the crystal and thus prevent ambient temperature changes from appreciably changing the crystal output frequency.

The invention, both as to its organization and method of operation, together with further objects and advantages thereof, will best be understood by reference to the following specification taken in connection with the accompanying drawings, in which:

Fig. 1 is an explosion view illustrating the components of an improved piezoelectric crystal holder characterized by the features of the present invention;

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Fig. 2 is a top view of the holder with the cover removed therefrom;

Fig. 3 is a detail view in section illustrating the mode of obtaining temperature compensation of the crystal output frequency;

Fig. 4 is a sectional view taken on line 4—4 of Fig. 2, assuming Fig. 2 shows a completely assembled device with the cover in position thereon;

Fig. 5 is a graph illustrating the accuracy of the compensation obtained with the structure shown in Fig. 1;

Fig. 6 is a graph illustrating the method of classifying piezoelectric crystals for matching with electrodes having different temperature response characteristics; and

Fig. 7 is a side view, partially in section, illustrating a modified embodiment of the invention.

Referring now to the drawings and more particularly to Fig. 1 thereof, the present improved crystal holder is there illustrated in its use to support under pressure a piezoelectric quartz crystal 10 of rectangular configuration and having a thickness determined by the particular frequency at which the crystal is designed to oscillate. Along its lower face the crystal 10 is adapted to be supported by an electrode 12 having raised corner parts or feet 12a which bear against the corner portions of the lower crystal face. This electrode, together with the crystal 10, is adapted to be received within the portion 17a of an open cavity 17 formed within an insulating housing member 13 which is preferably comprised of a suitable ceramic material. Along one edge thereof, this housing member is provided with a pair of holes 18 and 19 communicating with elongated recesses 17b and 17c within which conductive terminals 15 and 16 are respectively disposed. At their inner ends these conductors terminate in rectangular plates 15a and 16a between which the crystal and electrode assembly are insertable. Preferably, the conductors 15 and 16 are stamped out of flat conductive stock and have sufficient flexibility to permit insertion of the crystal and electrode assembly therebetween.

In accordance with the present invention a thermally deformable bi-metallic electrode 11 is provided for supporting the crystal 10 along its upper face. Specifically, this electrode is provided with downwardly depending corner parts or feet 11a which are coextensive with the corner parts 12a of the lower electrode 12 and bear against the corner portions of the upper crystal face. In order to urge the electrodes 11 and 12 toward each other, thereby to clamp the corner portions of the crystal 10 between the corner parts of the electrodes, a helical coil spring 24 is provided which, during the assembly of the holder, is compressed between the upper terminal plate 15a and a ceramic cover 14 which is utilized

to close the open side of the housing member 13. The upper end of this spring seats in a depression 14b provided at the underside of the cover in the center thereof (see Fig. 4). Thus, with the cover 14 sealed in place within the cover receiving portion of the recess 17, the spring 24 reacts between this cover and the electrode 11 to clamp the corner portions of the crystal 10 between the two electrodes.

In the assembly of the described components of the holder, the terminal conductors 15 and 16 are first inserted through the openings 18 and 19, respectively, following which the space between the conductors and the side walls of the identified holes is sealed. To this end, the inner surfaces of the holes are preferably metalized by employing a conventional silver and copper plating technique, following which the metalized surfaces are tinned to permit a soldered connection to be formed between the conductors 15 and 16 and the prepared metalized surfaces of the hole walls. With the terminal conductors 15 and 16 thus assembled with the housing member 13, the crystal 10 is matched with a set of electrodes 11 and 12 in the manner more fully described below, following which the matched crystal and electrode set is inserted between the conductor plates 15a and 16a. The spring 24 is next placed in position over the terminal plate 15a and compressed by positioning the cover 14 within the cover receiving portion of the recess 17. Here also, a sealed connection is provided between the housing member 13 and the cover 14 in order to completely seal the crystal assembly against exposure to moisture, dirt and other foreign matter. To this end the cover 14 is cut back along the top edge thereof as indicated at 14a, and the adjacent surfaces of the cover edge and housing member are metalized and tinned in the manner explained above, thereby to permit a soldered connection indicated at 25 in Fig. 4 of the drawings to be made at all points around the periphery of the cover between the cover edges and the adjacent metalized surfaces of the housing member.

From the preceding explanation, it will be apparent that the crystal 10 is positively restrained against lateral motion relative to the electrodes 10 and 11 by virtue of the spring developed clamping pressure exerted upon the corner portions thereof by the corner parts 11a and 12a of the two electrodes. Further, the configuration of the cavity portion 17a is such as to preclude any appreciable lateral movement of the crystal and electrode assembly. In this regard it will be noted that only a very small portion of the crystal face area is held under compression between the two electrodes, thus minimizing the decrease in crystal activity resulting from the restraining forces exerted through the thickness of the crystal. With this structure, and as best shown in Fig. 3 of the drawings, an air gap 12b is provided between the major portion of the upper surface of the lower electrode 12 and the lower face of the crystal. A similar air gap 11b is provided between the major portion of the lower surface of the upper electrode 11 and the upper face of the crystal, which air gap, due to the thermally deformable characteristic of the electrode 11, is variable in accordance with variations in the ambient temperature to which the holder is subjected.

In production, quartz crystals may be so cut that the output frequency of each crystal varies directly with temperature, i. e., as the crystal

temperature decreases the frequency of vibration decreases and vice versa. Another important and well known factor which appreciably affects the output frequency of a crystal unit is the mass, density and elasticity of the air between the crystal and the electrodes associated with the two faces thereof. This factor is, of course, determined by the dimensions of the air gaps 11b and 12b between the crystal faces and the two electrodes, and varies with temperature. To a lesser extent, the interelectrode capacitance between the electrodes 11 and 12 affects the output frequency of the crystal, which capacitance is varied in response to expansion and contraction of the crystal through the thickness thereof in response to changing temperature of the crystal. Specifically, as the air gap dimensions are increased, the two last-mentioned variable factors are changed to produce an increase in the output frequency of the crystal unit. Conversely as the air gap dimensions are decreased, a decrease in the crystal unit output frequency is produced.

In order to reduce the variations in crystal output frequency which are produced in the above-described manner in response to ambient temperature changes, the bi-metallic thermally deformable electrode 11 is assigned the function of varying the length of the air gap 11b in the correct sense to compensate for the frequency drift which would otherwise be produced. To this end the high coefficient of expansion side 11c of the electrode 11 is disposed adjacent the upper crystal face so that as the ambient temperature rises to produce a corresponding rise in the temperature of the crystal 10, the center region of the electrode 11 is cupped toward the upper crystal face effectively to reduce the average length of the air gap 11b. Conversely, as the temperature decreases, the central region of the deformable electrode 11 is cupped away from the upper crystal face, thereby effectively to increase the average length of the air gap 11b. Preferably, the electrode 11 is so designed that it is perfectly flat and unstressed at a normal temperature of approximately 72 degrees Fahrenheit, such that departure from this temperature value in opposite senses produces corresponding opposite cupping of the electrode. It will thus be apparent that as the temperature of the crystal is increased from a normal value in response to a corresponding increase in the ambient temperature, the electrode 11 is deformed to produce a corresponding decrease in the length of the air gap 11b which counteracts the frequency change which would otherwise occur. Conversely as the crystal temperature is decreased from a normal value, the electrode 11 is deformed to change the length of the air gap 11b in the correct sense to counteract the crystal output frequency change which would otherwise occur.

By appropriate design of the electrode 11, in the matter of the choice of metals from which this electrode is made and the relative thicknesses thereof, substantially exact temperature compensation of the crystal unit against frequency drift may be obtained. This fact will be evident from a consideration of the curves D and E illustrated in Fig. 5 of the drawings which are quantitatively accurate frequency drift-temperature characteristics of a typical crystal unit before and after the described improved compensating facilities are provided. Specifically, the curve D illustrates the frequency drift-temperature characteristic of a typical uncompensated crystal unit,

as measured over a temperature range extending from minus 20 degrees centigrade to plus 70 degrees centigrade. This curve indicates a maximum frequency increase of approximately 400 cycles over the temperature range indicated. After the crystal of the unit was embodied in the present improved holder having a matched thermally deformable electrode 11 of appropriate design, the frequency drift-temperature characteristic E was obtained. From an inspection of this curve it will be observed that a maximum departure of 25 cycles was obtained over the entire temperature range.

It has been found that in the production of piezo-electric quartz crystals on a volume basis, crystals ground to the same frequency exhibit different frequency drift-temperature characteristics. Accordingly, in the manufacture of crystal units embodying the present invention on a production basis, it is preferable to classify the crystals according to their frequency drift-temperature characteristics and employ correspondingly classified electrode pairs in matching the crystals and electrodes for assembly with the other components of the holder. Specifically, and as best shown in Fig. 6 of the drawings, the crystals of a given group may have individual frequency drift-temperature characteristics conforming with greatest accuracy to any one of three empirical characteristics A, B and C. Accordingly, they may be classified and separated on this empirical basis. For ease in matching the crystals with the thermally deformable electrodes 11, these electrodes are designed to fall in three classes which provide exact compensation for crystals having the empirical frequency drift-temperature characteristics A, B and C. Thus, in order to match a thermally deformable electrode 11 with a given crystal, it is only necessary to know the particular frequency drift-temperature class in which the particular crystal belongs in order to make a proper selection of the electrode 11 which will most nearly provide exact temperature compensation. By this method of crystal and electrode classification, matching of the crystals and electrodes to produce units having the desired constancy of frequency output under varying temperature conditions may be easily and rapidly accomplished.

Although the present improved holder has been described as employing only one thermally deformable bi-metallic electrode 11, it will be understood that if desirable or necessary both of the electrodes 11 and 12 may be formed of bi-metallic thermally deformable material in the manner of the electrode 11 shown in Fig. 3 of the drawings. In such case, the compensating action of the two electrodes may be additive or subtractive as desired, i. e., the two electrodes may be arranged to change the lengths of the air gaps 11b and 12b in the same sense in response to the same temperature change or to change the gap lengths in opposite senses. In the latter case, in particular, the magnitude of change in the air gap lengths produced in response to any given increment of temperature change should be different for the two electrodes, so that the degree of compensation is determined by the differential between the responses of the two electrodes to the temperature change. In the case where the action of the two electrodes 11 and 12 is cumulative, the responses of the two electrodes to given temperature changes may be the same or different, as desired.

In the modified embodiment of the invention

shown in Fig. 7 of the drawings, the crystal 10 is shown as being pressure mounted between the rims of two resilient deformable electrodes 20 and 21 which are of dished or cupped cross-sectional configuration, and are held between the leg ends of a thermally deformable bi-metallic clamp 22 of U-shaped configuration. With this structure, the leg ends of the clamp 22 move toward and away from each other in response to temperature changes to correspondingly move the cupped electrode surfaces toward and away from the faces of the crystal 20 and thus correspondingly change the air gaps 20a and 21a. Thus by appropriate design of the clamp 22, the air gap change required to effect substantially complete temperature compensation of the crystal against frequency drift may be obtained.

While there have been described what are at present considered to be the preferred embodiments of the invention, it will be understood that various modifications may be made therein which are within the true spirit and scope of the invention as defined in the appended claims.

I claim:

1. In combination with a piezoelectric crystal, a holder therefor comprising temperature responsive electrode means for holding said crystal under compression transversely of the crystal faces and responsive to temperature variations to develop a variable air gap between at least a portion thereof and at least one of the crystal faces which varies in the correct sense to reduce variations in the output frequency of the crystal with ambient temperature changes.
2. In combination with a piezoelectric crystal, a holder therefor comprising means including a pair of electrodes for holding said crystal under compression transversely of the crystal faces, at least one of said electrodes being at least in part thermally deformable to change the output frequency of the crystal in the correct sense to reduce variations in said output frequency with ambient temperature changes.
3. In combination with a piezoelectric crystal, a holder therefor comprising means including a pair of electrodes for holding said crystal under compression transversely of the crystal faces, at least one of said electrodes being deformable to change the output frequency of the crystal, and thermally responsive means for deforming said one electrode in the correct sense to reduce variations in said output frequency with ambient temperature changes.
4. In combination with a piezoelectric crystal, a holder therefor comprising an electrode adapted to support one face of said crystal, a thermally deformable electrode adapted to support the other face of the crystal, said thermally deformable electrode being effective to develop a variable air gap between said other crystal face and at least a portion thereof in the correct sense to reduce variations in the output frequency of the crystal with ambient temperature changes, and means urging said electrodes toward each other, thereby to clamp the crystal between said electrodes.
5. In combination with a piezoelectric crystal, a holder therefor comprising an electrode adapted to bear against one face of said crystal, a thermally deformable bi-metallic electrode having spaced portions adapted to bear against the other face of said crystal, said thermally deformable electrode being effective to develop a variable air gap between said other crystal face and at least a portion thereof in the correct sense to reduce variations in the output frequency of

the crystal with ambient temperature changes, and means urging said electrodes toward each other, thereby to clamp the crystal between said electrodes.

6. In combination with a piezoelectric crystal, a holder therefor comprising an electrode adapted to bear against one face of said crystal, a thermally deformable bi-metallic electrode having spaced portions adapted to bear against the other face of said crystal, said thermally deformable electrode being variably cupped to develop a variable air gap between said other crystal face and the cupped portion thereof in response to ambient temperature changes, said cupping being in the correct sense to reduce variations in the output frequency of the crystal with ambient temperature changes, and means urging said electrodes toward each other, thereby to clamp the crystal between said electrodes.

7. A holder for a piezoelectric crystal of rectangular configuration comprising a pair of electrodes at least one of which is thermally deformable, said electrodes being of the same configuration as a crystal inserted therebetween and being provided with corner parts adapted to bear against the corner portions of said crystal and to space the remaining parts of the electrodes from the crystal, said thermally deformable electrode being movable transversely of the crystal faces in response to ambient temperature changes to vary the air gap between itself and the adjacent crystal face in the correct sense to reduce variations in the output frequency of the crystal with said ambient temperature changes, and means urging said electrodes toward each other, thereby to clamp the corner portions of the crystal between said corner parts of said electrodes.

8. A holder for a piezoelectric crystal of rectangular configuration comprising a pair of electrodes at least one of which is thermally deformable, said electrodes being of the same configuration as a crystal inserted therebetween and being provided with corner parts adapted to bear against the corner portions of said crystal and to space the remaining parts of the electrodes from the crystal, said thermally deformable electrode being variably cupped in its center region in response to ambient temperature changes to vary the air gap between itself and the adjacent face of the crystal in the correct sense to reduce variations in the output frequency of the crystal with said ambient temperature changes, and means urging said electrodes toward each other, thereby to clamp the corner portions of the crystal between said corner parts of said electrodes.

9. In combination with a piezo electric crystal, a holder therefor comprising a housing member of insulating material having an open cavity therein, an electrode disposed in said cavity and adapted to support one face of said crystal, a thermally deformable electrode disposed in said cavity and adapted to support the other face of said crystal, said thermally deformable electrode being effective to develop a variable air gap between said other crystal face and at least a portion thereof in the correct sense to reduce variations in the output frequency of the crystal with ambient temperature changes, a cover for closing the cavity opening, and a spring reacting between said cover and one of said electrodes to clamp the crystal between said electrodes.

10. In combination with a piezoelectric crystal,

a holder therefor comprising a housing member of insulating material having an open cavity therein, an electrode disposed in said cavity and adapted to bear against one face of said crystal, a thermally deformable bi-metallic electrode having spaced portions adapted to bear against the other face of said crystal, said thermally deformable electrode being variably cupped to develop a variable air gap between said other crystal face and the cupped portion thereof in response to ambient temperature changes, said cupping being in the correct sense to reduce variations in the output frequency of the crystal with ambient temperature changes, a cover for closing the cavity opening, and spring means reacting between said cover and one of said electrodes to clamp the crystal between said electrodes.

11. A holder for a piezoelectric crystal of rectangular configuration comprising a housing member of insulating material having an open cavity therein, a pair of electrodes disposed in said cavity and at least one of which is thermally deformable, said electrodes being of the same configuration as a crystal inserted therebetween and being provided with corner parts adapted to bear against the corner portions of said crystal to space the remaining parts of the electrodes from the crystal, said thermally deformable electrode being variably cupped in its center region in response to ambient temperature changes to vary the air gap between itself and the adjacent face of the crystal in the correct sense to reduce variations in the output frequency of the crystal with said ambient temperature changes, a cover for closing the cavity opening, and spring means reacting between said cover and one of said electrodes to clamp the corner portions of the crystal between said corner parts of said electrodes.

12. In combination with a piezoelectric crystal, a holder therefor comprising a housing member of insulating material having a cavity opening on one side thereof and having a pair of holes extending into said cavity from an edge thereof, an electrode disposed in said cavity and adapted to bear against one face of said crystal, a thermally deformable electrode disposed in said cavity and adapted to support the other face of said crystal, said thermally deformable electrode being effective to develop a variable air gap between at least a portion of itself and said other crystal face in the correct sense to reduce variations in the output frequency of the crystal with ambient temperature changes, terminal conductors extending through said holes and provided with plates between which said electrodes and crystal are assembled, a cover for closing the cavity opening, and a spring reacting between said cover and one of said plates to clamp the crystal between said electrodes.

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