

May 11, 1948.

I. E. FAIR

2,441,139

PIEZOELECTRIC CRYSTAL MOUNTING

Filed April 29, 1946

2 Sheets-Sheet 1

FIG. 1

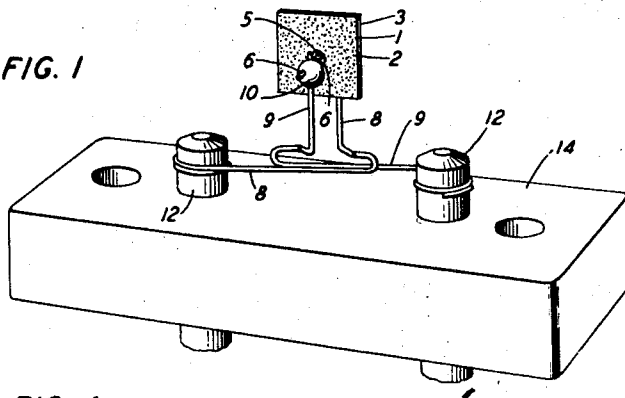


FIG. 4

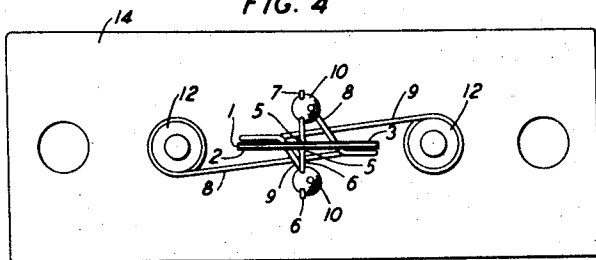


FIG. 2

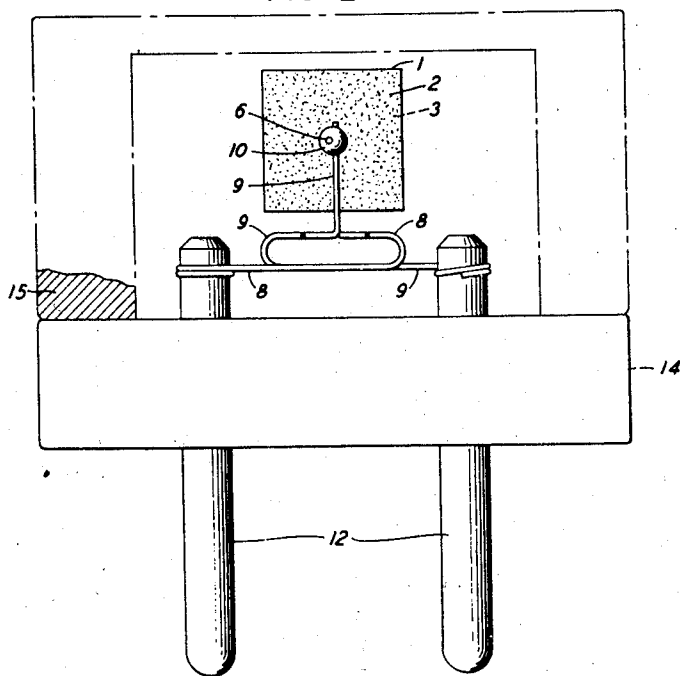
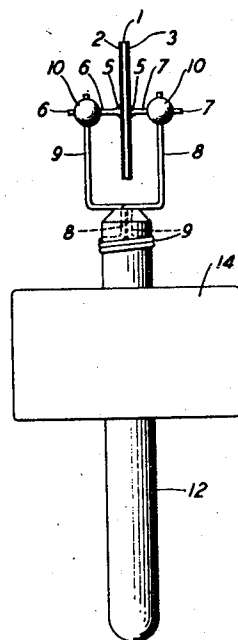


FIG. 3



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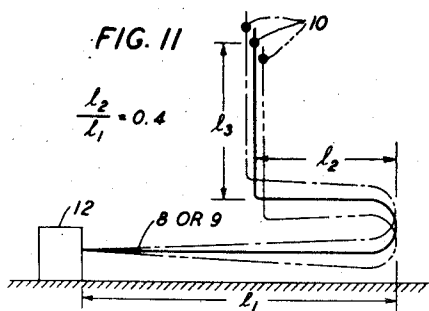
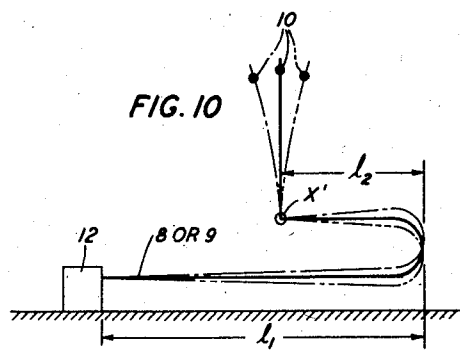
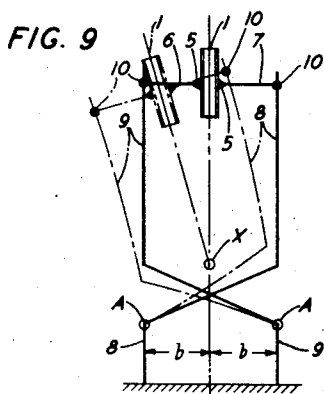
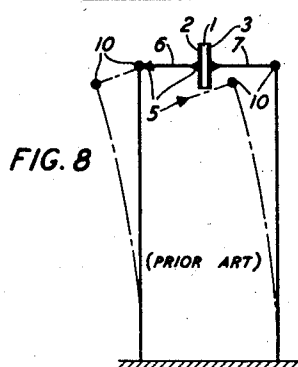
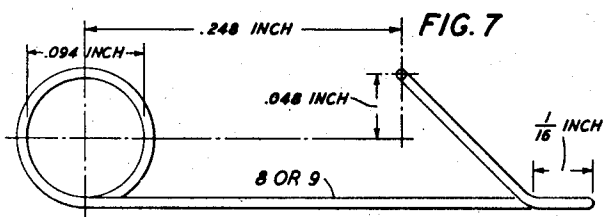
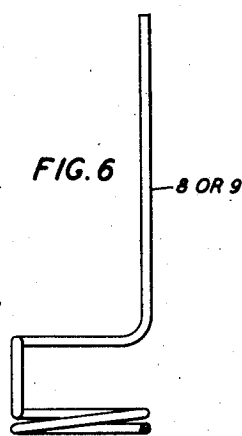
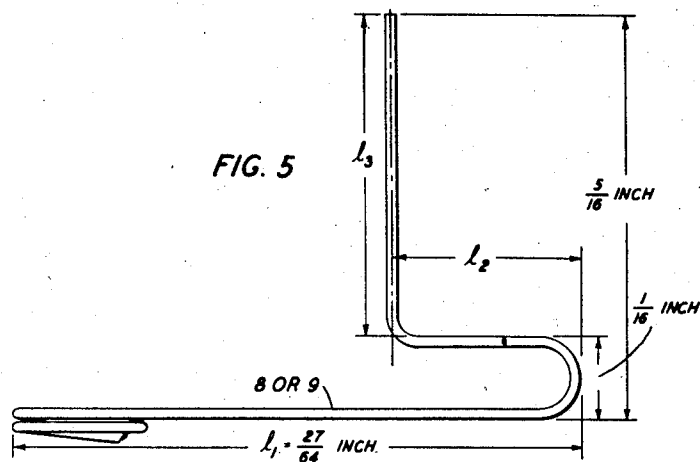
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PIEZOELECTRIC CRYSTAL MOUNTING

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2 Sheets-Sheet 2



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UNITED STATES PATENT OFFICE

2,441,139

PIEZOELECTRIC CRYSTAL MOUNTING

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Application April 29, 1946, Serial No. 665,688

11 Claims. (Cl. 171-327)

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This invention relates to piezoelectric crystal apparatus and particularly to spring wire support systems for piezoelectric crystal elements utilized as frequency-controlling circuit elements in oscillation generator systems, electric wave filter systems, and in electromechanical vibratory systems generally.

One of the objects of this invention is to prevent damage to the crystal assembly resulting from mechanical shock or vibration.

A particular object of this invention is to eliminate or reduce stresses in the lead wires and soldered joints of a wire mounting system for a piezoelectric crystal body.

Another object of this invention is to provide improved wire mounting springs for a piezoelectric crystal element.

Another object of this invention is to provide a spring wire mounting suitable for supporting a crystal element of comparatively small size such as, for example, a crystal plate having its major face length and width dimensions of the order of one-eighth inch.

To facilitate the use of piezoelectric crystal plates in electrical circuits, it is common practice to provide coatings of suitable conductive material on the electrode surfaces of the crystal plate and to support the crystal plate by means of electrically conductive spring wires which may be attached to the respective electrode coatings of the crystal plate by metallic fusion, solder, conductive cement, spring clamps or other suitable adhesive or fastening means.

In order that the piezoelectric crystal element may be able to vibrate freely, it is desirable that the spring wire system used to support the crystal element and to maintain contact with its plated electrode surfaces, have a low mechanical impedance and at the same time have sufficient rigidity that the complete crystal unit when subjected to mechanical shock or other externally applied jar or vibration may not change its characteristics as an oscillator.

The supporting wire system for the crystal element forms a shock cushioning system which functions to reduce the effect of shock on the crystal element and on the soldered or cemented joints and other joint fastening masses that may be associated with the crystal element. If the spring support wires are made too stiff, the effect of shock will not be absorbed therein, and if the spring support wires are made too thin, the displacement due to the applied shock may be such as to permit the crystal element to bump against its enclosing container or casing with possible

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resultant injury to the crystal element. Accordingly, the thickness or diameter of the supporting wires may be made of a more or less critical size to provide a shock-absorbing cushioning action therein sufficient to absorb the shock without bumping the crystal element against its enclosing casing.

In accordance with this invention, there is provided a spring wire mounting system for a piezoelectric crystal that will withstand considerable shock and vibration. This result is obtained by constructing the wire mounting in a manner to reduce the shock on the crystal and to reduce the stress in the supporting lead wires which may be soldered, cemented or otherwise fastened to the crystal. For this purpose, the main mounting springs may be made in a shape that can be readily manufactured when using wire of relatively small diameter or cross-section and that will provide the advantages mentioned. The shape of the two support wires used may be identical and the two support wires may be crossed over and provided with relatively short radius of curvature bends therein and suitably proportioned as to their dimensions to give the desired results of more freedom of motion in the three mutually perpendicular directions, with balanced shock absorption and without stressing the solder points of the crystal wire mounting. Such an arrangement is useful where a more rugged crystal unit is desired for applications where the unit must withstand shock and vibration, as in automobiles, aircraft and other mobile equipment.

The present invention is particularly adaptable to crystal assemblies in which very fine lead wires have been attached directly to the electrode coatings of the piezoelectric crystal plate, and spring supporting wires having a suitable configuration and degree of stiffness or compliance are provided whereby the transmission of mechanical shock to and the introduction of stress in the junctions of the lead wires with the crystal plate is reduced or effectively prevented, and damage to the crystal assembly resulting from such shock or vibration is prevented. The crystal plate may be supported directly by the very fine lead wires and the main mounting wires may be bent in a definite manner in order to effectively prevent the transmission of mechanical shock from introducing stress at the points of adhesive junction between the lead wires and the electrode coatings of the crystal plate. A strain is a displacement caused by an applied stress. If the lead wire is strained, as by being displaced by bending, a stress is produced in the adhesive joint, and such

a stress will tend to cause the adhesive joint to fail mechanically and electrically.

If desired, mechanical stops or bumpers may be provided closely adjacent to but not normally touching the crystal plate and, hence, not interfering in any way with the desired electrically induced vibrations of the crystal plate, but preventing excessive bodily displacement of the crystal plate beyond predetermined limits resulting from an excessively large mechanical shock applied to the assembly. Such bumpers may be of the general type illustrated, for example, in United States Patent 2,275,122 granted March 3, 1942, to A. W. Ziegler.

The fine lead wires, which may be connected directly to the integral coatings of the crystal element, are part of the piezoelectric crystal vibrating system. When the crystal supporting spring lead wire is fastened to and held as by solder or by cement against the crystal element, the oscillating crystal element tends to generate motion in the support wire disposed in contact therewith, and the closer the support wire can be placed to a node of the crystal element, the less will be the motion generated by the crystal element in the supporting lead wire. In order to provide a low mechanical impedance in the supporting lead wire, the lead wire may be provided with a nodal reflector as disclosed, for example, in my United States Patent 2,371,613 dated March 20, 1945. The nodal reflector provided on the support wire may involve a massed solder weight associated with the joint between the main support wire and the fine lead wire directly attached to an integral coating of the crystal element.

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 drawing, in which like reference characters represent like or similar parts and in which:

Fig. 1 is an enlarged perspective view and

Figs. 2, 3 and 4 are enlarged front, side and top views respectively of a piezoelectric crystal mounting embodying this invention, Fig. 3 being a side view of Fig. 2, and Fig. 4 being a top view of Fig. 2;

Figs. 5, 6 and 7 are greatly enlarged detailed views showing either of the two main supporting spring wires illustrated in Figs. 1 to 4, Fig. 6 being a side view of Fig. 5, and Fig. 7 being a top view of Fig. 5; and

Figs. 8 to 11 are diagrams illustrating schematically the principles of operation involved in the wire supporting system shown in Figs. 1 to 7, Fig. 8 illustrating a prior art arrangement.

Referring to the drawing, Fig. 1 is a perspective view and Figs. 2, 3 and 4 are enlarged front, side and top views respectively, of a piezoelectric crystal device comprising a face shear mode type of quartz crystal element 1 having a pair of conductive electrode coatings 2 and 3 formed integral with the two opposite major surfaces thereof. The conductive coatings 2 and 3 may be suitably thickened in the nodal regions of support where the ends of a pair of coaxial and horizontally extending fine spring lead wires 6 and 7 may be soldered to the respective coatings 2 and 3 by means of small solder dots or cones 5, which secure the two supporting lead wires 6 and 7 to the two metallic coatings 2 and 3 respectively, of the crystal plate 1.

The crystal element 1 may be of any type that

it may be desired to mount such as, for example, a quartz crystal element of the face shear mode type having its node or point of minimum motion at or near the center of the crystal element 1 as illustrated in Figs. 1 to 4. Examples of such face shear mode crystal elements 1 are disclosed for example in G. W. Willard United States Patent 2,268,365 dated December 30, 1941. The thickness or thin dimension of the crystal plate 1 may be adjusted to a suitable value relative to the larger major face length and width dimensions in order to place nearby undesired resonances or modes of motion in regions that do not conflict or interfere with the desired main resonance, which in the example illustrated in Figs. 1 to 4 is a face shear mode of motion controlled mainly by the major face dimensions of the crystal plate 1.

The crystal coatings 2 and 3 may consist of any suitable conductive coatings such as silver or gold applied to the crystal surfaces by any suitable process such as by evaporation in vacuum. At the nodal region 5 where the inner ends of the lead wires 6 and 7 are to be attached, a small spot of baked silver paste may be applied to the quartz and baked firmly thereon in a known manner. After the silver spot has been baked onto the quartz surface, the thin electrode films 2 and 3 of evaporated silver, for example, may be applied thereover and the inner ends of lead wires 6 and 7 may be soldered to the respective baked silver paste spots by means of small solder dots or cones 5. The effect of the solder dots 5 on the activity of the crystal element 1 may be minimized by making them as small as possible and by placing them as near as possible to a node of motion of the crystal element 1.

The conductive lead wires 6 and 7 may be, for example, a pair of fine spring wires composed of phosphor bronze or of other suitable conductive spring wire material which may be of the order of .003 inch diameter, for example. The innermost end of each of the lead wires 6 and 7 may be attached to the respective crystal coatings 2 and 3 by soldering, the wire ends being either embedded in cones of solder 5 or the wire ends being provided with a small flat integral head which may be soldered by a thin layer of solder to the respective metallic coatings 2 and 3 of the crystal plate. For purposes of mechanical strength and electrical conductivity, a good joint is needed between the coatings 2 and 3 of the crystal element 1 and the supporting lead wires 6 and 7, and also between each of the outer ends of the lead wires 6 and 7 and the respective spring mount wires 8 and 9.

The outermost ends of the two horizontal lead wires 6 and 7 may be provided with small cast solder balls 10 in which may be embedded the outer ends of the two horizontal lead wires 6 and 7 and also the top ends of two upright spring wires 8 and 9. As illustrated in Figs. 1 to 4, the support wires 8 and 9 may extend vertically downwardly from the two solder balls 10 at each side of the crystal element 1 and then in the region below the crystal element 1, extend across to the opposite side of the crystal element 1 where U-shaped bends are provided therein, the lower ends of which may be carried by two fixed plug-in type pin terminals 12 provided in the supporting base 14 of any suitable enclosing container or casing 15. As illustrated in Figs. 1 to 4, the coaxial fine lead wires 6 and 7 follow relatively short paths perpendicular to the vertical major faces of the crystal plate 1, and the support wires

8 and 9 may follow a vertical path parallel to the major faces of the crystal plate 1 and, below the crystal plate 1, are transposed or crossed over from one side to the opposite side of the crystal plate 1 and then are formed into a U-shaped portion and finally are secured at their ends by solder or any suitable means to the respective fixed terminal supports 12.

As illustrated in Figs. 1, 2, 3 and 4, the crystal element 1 may be a small square-shaped face-shear-mode quartz plate 1 operating at any suitable frequency such as, for example, a frequency of the order of from 200 up to 1100 or more kilocycles per second, and it may be mounted so that the sides of the crystal element 1 may be disposed in a vertical position as illustrated in Figs. 1 to 4. After soldering the springs 8 and 9 to the upper ends of the terminal pins 12 of the base assembly 14, the crystal element 1 with its coaxial lead wires 6 and 7 secured thereto, may be mounted on the top ends of the springs 8 and 9, and the springs 8 and 9 may be then adjusted by hand so that the sides of the crystal element 1 will be in the vertical position mentioned. After mounting the crystal element 1 in the assembly, the crystal element 1 and the holder may be cleaned to remove flux and other foreign matter, and then the crystal element 1 may be adjusted to the desired frequency. The spring wires 6, 7, 8 and 9 may be soldered with any suitable solder and flux, such as, for example, with a rosin-alcohol flux and a tin-lead eutectic solder composed of 63 per cent tin and 37 per cent lead.

The horizontal lead wires 6 and 7, which connect the crystal element 1 to the main spring wires 8 and 9, are part of the piezoelectric vibrating system, and the solder balls 10, which may be used to connect the outer ends of the horizontal lead wires 6 and 7 to the top ends of the vertical support wires 8 and 9, each act as a terminating impedance for preventing transmission of piezoelectrically induced motion in the lead wires 6 and 7 to the support wires 8 and 9. The lead wires 6 and 7 preferably have a high reactance-resistance ratio Q and are terminated at the correct point by the massed weights 10. The massed weights 10 may be nodally disposed on each of the lead wires 6 and 7 in order to reflect the wave motion therein and thereby improve the activity of the vibrating crystal system as a whole, as disclosed, for example, in United States Patent 2,371,613 granted March 20, 1945, to I. E. Fair.

The spring wires 6, 7, 8 and 9 are flexible and function to resiliently support the electroded crystal element 1, and to establish individual electrical connections with the opposite electrode coatings 2 and 3 of the crystal element 1. The wires 6 to 9 may comprise any suitable spring wire material such as tinned steel or phosphor bronze spring wire, for example. The horizontal lead wires 6 and 7 may consist of fine spring wires having a diameter of about .003 to .005 inch or of any diameter suitable for supporting the crystal element 1 and fine soldering by solder masses 5 to the respective metal coatings 2 and 3 of the crystal element 1. The upright support wires 8 and 9 may be spring wires having a diameter sufficient to support the crystal element 1 and to absorb externally applied jar or shock without allowing excessive bodily displacement of the crystal element 1 due to such shock. For this purpose, the thickness and elastic stiffness of the support wires 8 and 9 may be more or less critical. The spring wires 8 and 9 may also be provided with suitable bends and critical length portions

therein in order to prevent cracking of the solder masses 5 and 10 when such wires 8 and 9 are displaced by externally applied shock or jar as occurs in mobile installations or during transportation and handling.

The shape of the bends in the spring mounting wires 8 and 9 are of importance as they result in obtaining not only an increase in the compliance of the wires 8 and 9 but also a reduction of stress in the points of adhesive junction 5 between the lead wires 6 and 7 and the crystal element 1. While the mount wires 8 and 9 prevent to some extent the transmission of mechanical shock to the crystal element 1 in the event the assembly is suddenly displaced, they also prevent or limit stress at the points of junction 5 and 10 of the lead wires 6 and 7 with the electrode coatings 2 and 3 and with the support wires 8 and 9.

When the crystal element 1 is jarred or moved in a direction generally parallel to the horizontal lead wires 6 and 7, a stress may be produced in the soldered connections 5 therewith, if no means be provided to eliminate such stress and continued shock or motion in this direction may result in a crack in the solder connections 5 which introduces a mechanical loss into the piezoelectric vibrating system and thereby reduces the activity of the crystal element 1. In accordance with this invention, a wire mounting system 8 and 9 is provided which eliminates or reduces stress in the lead wires 6 and 7 and in the solder joints 5 of the supporting wire system associated with the crystal element 1. This is accomplished by absorbing the mechanical shock in the spring wires 8 and 9 without introducing strains in the supporting lead wires 6 and 7 soldered to the crystal coatings 2 and 3 when the crystal element 1 is jarred in any or all three directions. For this purpose, the spring wires 8 and 9 may be bent in such a way that a flexure introduced therein by shock or vibration is compensated for by a simultaneous torsion therein, and the diameter or size of the spring wires 8 and 9 may be made of such thickness as to give enough cushioning action by the wires 8 and 9 to absorb the shock without bumping the crystal element 1 against its container casing 15, the lengths and diameters of the wires 8 and 9 and positions of bends in the wires 8 and 9 being made somewhat critical.

As illustrated in Figs. 1 to 7, the wire mounting system for the crystal element 1 may comprise a pair of identical spring support wires 8 and 9 each of which may be provided with a U-shaped bent wire portion carried by one of the fixed base supports 12 disposed at the opposite sides of the crystal element 1, and each of which is also provided with a crossed-over or transposed portion carried by the U-shaped portion and bent to extend from one to the other or opposite side of the crystal element 1. In this arrangement, the cross-over and U-shaped portions referred to of the support wires 8 and 9 may constitute torsional hinges which compensate for a flexure displacement introduced in the vertical wire portions of the wires 8 and 9 near to the lead wires 6 and 7 of the crystal element 1, when the assembly is subjected to jar and shock in a direction parallel to the horizontal lead wires 6 and 7.

Figs. 5, 6 and 7 are enlarged front, side and top views respectively, of the support springs 8 and 9 illustrated in Figs. 1 to 4, and may be taken to illustrate either of the springs 8 or 9 since both are identical. The springs 8 and 9 may be constructed from any suitable spring wire material of suitable diameter such as .008 tinned music

wire, for example. The set of dimensions given in Figs. 5, 6 and 7 illustrate an example of a particular set of values which may be used for the dimensioning of the bends and lengths of each of the supporting spring wires 8 and 9.

Figs. 8 to 11 are views in schematic form illustrating the operation of crystal support wires. Fig. 8 illustrates the action of a prior art type of support spring arrangement, and Figs. 9 to 11 illustrate the action of the support spring wires 6 to 9 illustrated in Figs. 1 to 7. The crystal element 1 is omitted from the showing in certain of these sketches.

Referring to Fig. 8, the displacement of the pair of solder cones 5 as shown in Fig. 8 displaced from their normally opposite relative positions, represents a measure of the amount of stress which may be produced in the horizontal lead wires 6 and 7 if soldered to the coatings 2 and 3 of the crystal element 1. As illustrated by the broken lines in Fig. 8, when the support wires of the crystal element 1 are moved or displaced in the general direction of the lead wires 6 and 7, a stress will be produced in the soldered connections 5 disposed between the lead wires 6 and 7 and the crystal element 1 of the prior art arrangement illustrated in Fig. 8. A continued shock or motion back and forth in this general direction may eventually result in a crack in the solder joints 5 which introduces a mechanical loss in the piezoelectric vibrating system and eventually reduces the activity of the crystal element 1. In some cases, the loss so introduced may be sufficient to cause complete failure. Such disadvantages of the prior art type of mounting illustrated in Fig. 8 may be avoided by the spring arrangement of Figs. 1 to 7.

The type of support springs 8 and 9 illustrated in Figs. 1 to 7 may be utilized to overcome the disadvantages mentioned in connection with the prior art type of mounting illustrated in Fig. 8. The manner in which the support springs 8 and 9 illustrated in Figs. 1 to 7 eliminates the stress in the lead wires 6 and 7 may be explained by reference to Fig. 9. In Fig. 9, the points labeled A represent lengths of the wires 8 and 9, perpendicular to the plane of the drawing in Fig. 9, which are in torsion and which therefore may act as hinges when the mounting wires 8 and 9 are moved to a position as indicated by the broken lines in Fig. 9. The broken lines in Fig. 9 show the normally linear vertical portions of the two wires 8 and 9 deflected or bent in flexure. By proportioning the deflection due to the flexure mentioned and that due to the torsion mentioned, the soldered masses at 5 may be made to keep their same relative opposite positions without producing stress in such soldered joints 5, for both the bent and unbent positions of the wires 8 and 9 as indicated in Fig. 9. This compensating action is governed mainly by the length $l_1 + l_2$ of the wire portion in torsion and by the distance b between the two parallel vertical planes of the U-shaped bends in the support wires 8 and 9 and the mid-point thereof. Another manner of stating this action is to say that the crystal element 1 may be made to swing about an imaginary axis X common to the two support wires 8 and 9, as illustrated in Fig. 9. The axis of rotation for the swing in the longitudinal direction is also made common to both of the support wires 8 and 9 as illustrated in the view shown in Fig. 10. By making the length of the wire portion l_2 approximately equal to four-tenths of the length of wire portion l_1 , the axis of rotation will be at X' as shown in Fig. 10. It turns out that this

ratio of about 0.4 for the length of the wire portion l_2 with respect to the length of the wire portion l_1 also allows the crystal element 1 to move in a vertical direction along the direction of the wire portion l_3 without changing the general direction of the wire portion l_3 , as shown in Fig. 11. This action is of importance since if the wire length portion l_3 should change its direction from the vertical direction, such a change would be in an opposite sense for the two support wires 8 and 9, and accordingly stresses would be then introduced in the lead wires 6 and 7 and their connecting joints 5 and 10.

It will be noted that the mounting springs 8 and 9 illustrated in Figs. 1 to 7 and 9 to 11 have considerable flexibility in the vertical direction as well as in other directions, that the same or similar springs 8 and 9 may be used for both of the support wires 8 and 9, that all of the bends in the wires 8 and 9 are of relatively small radii and, accordingly, may be easily constructed with small size diameter wire and still maintain close tolerances, and that this type of wire mounting will withstand considerable vibration and shock without cracking the adhesive means 5 used to join the lead wires 6 and 7 to the electroded crystal element 1 to be supported thereby. Each of the spring wire supports 8 and 9 crosses a plane parallel to the major faces of the crystal plate 1 and crosses a plane perpendicular to the major faces of the crystal plate 1 at sufficient distances to substantially reduce the strains in the fastening means 5 when the apparatus is subjected to shock or vibration.

While this invention has been particularly described in connection with wire supports of the general type disclosed in United States Patent 2,371,613, granted March 20, 1945, to I. E. Fair, it will be understood that it may also be applied to other forms of wire supports such as, for example, those of the general type disclosed in United States Patent 2,275,122, granted March 3, 1942, to A. W. Ziegler, and in United States Patent 2,392,429, granted January 8, 1946, to R. A. Sykes.

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.

What is claimed is:

1. Piezoelectric crystal apparatus comprising a piezoelectric crystal body having conductive electrode coatings formed integral therewith, means for supporting said piezoelectric crystal body including a pair of conductive bent spring wire supports and conductive means individually fastening the ends of said spring wire supports to said electrode coatings of said crystal body, each of said spring wire supports crossing a plane parallel to the major faces of said piezoelectric crystal body and crossing a plane perpendicular to the major faces of said piezoelectric crystal body, said crossings being at locations corresponding to sufficient distances to constitute means for substantially reducing the strains in said conductive means when said apparatus is subjected to shock or vibration.

2. Piezoelectric crystal apparatus comprising a piezoelectric crystal body having conductive electrode coatings formed integral therewith, means for supporting said piezoelectric crystal body including a pair of conductive bent spring wire supports and conductive adhesive means individ-

ually fastening the ends of said spring wire supports to said electrode coatings of said crystal body, each of said spring wire supports having a U-shaped portion, a cross-over portion carried by said U-shaped portion and extending from one side to the opposite side of said crystal body, and another wire portion connecting said cross-over portion with said electroded crystal body, said U-shaped and cross-over portions of said pair of wire supports constituting torsional hinge means compensating for bending displacement occurring in said other portions of said wire supports for reducing stress in said adhesive means when said apparatus is subjected to shock or vibration.

3. Piezoelectric crystal apparatus comprising a piezoelectric crystal body having conductive electrode coatings formed integral therewith, and conductive bent spring wire supports electrically and mechanically connected by adhesive means with said electrode coatings, said wire supports having a compliance sufficient to resiliently support said crystal body, said spring wire supports having cross-over portions extending from one side to the opposite side of said crystal body and U-shaped portions individually carrying said cross-over portions, said spring wire supports constituting means for reducing stresses in said adhesive means when said apparatus is subjected to shock or vibration.

4. Piezoelectric crystal apparatus comprising a piezoelectric crystal body, conductive electrode coatings formed integral with said crystal body, and means for supporting said electroded crystal body including a pair of conductive bent spring wire supports each individually carried by a stationary support disposed on one side of said crystal body and supporting said electroded crystal body on the opposite side thereof, each of said wire supports comprising a U-shaped portion carried by one of said stationary supports, a cross-over portion carried by said U-shaped portion and extending from one side to the opposite side of said crystal body in the region between said crystal body and said stationary supports, and another portion disposed between each of said cross-over portions and said electroded crystal body.

5. Piezoelectric crystal apparatus comprising a piezoelectric crystal body, conductive electrode coatings formed integral with said crystal body, a pair of conductive wire supports for said crystal body, conductive adhesive means individually fastening said wire supports to said electrode coatings of said crystal body, and stationary supports carrying said wire supports, said wire supports each comprising a similar bent wire spring having a U-shaped portion carried by one of said stationary supports, having a cross-over portion carried by said U-shaped portion and extending from one side to the opposite side of said crystal body in the region between said crystal body and said supports, and having a third portion carried by said cross-over portion and carrying said electroded crystal body.

6. Piezoelectric crystal apparatus comprising a piezoelectric crystal body, conductive electrode coatings formed integral with said crystal body, a pair of conductive wire supports for said crystal body, conductive adhesive means individually fastening said wire supports to said electrode coatings of said crystal body, and stationary supports individually carrying said wire supports, said wire supports each comprising a bent wire spring having a U-shaped portion, cross-over por-

tion and a third portion, said U-shaped portion having a long arm carried by one of said stationary supports and a short arm terminating in a bend carrying said cross-over portion, said cross-over portion extending from one side to the opposite side of said crystal body in a region between said crystal body and said stationary supports and terminating in a bend carrying said third portion, said third portion carrying said electroded crystal body, the ratio of the effective over-all length of said cross-over portion and said short arm as measured between said U-shaped bend and said third portion being with respect to the effective over-all length of said long arm of said U-shaped portion a value of substantially 0.4.

7. Piezoelectric crystal apparatus comprising a piezoelectric crystal body, conductive electrode coatings formed integral with opposite faces of said crystal body, and a resilient conductive wire mounting system for said electroded crystal body comprising a pair of substantially coaxial conductive flexible lead wires extending outwardly from said opposite electroded faces of said crystal body, conductive adhesive means comprising metallic joints for individually fastening the ends of said lead wires to said opposite electroded faces of said crystal body, and means comprising a pair of substantially identical bent conductive wire springs individually secured to said lead wires and carried by stationary supports for resiliently supporting said crystal body without introducing appreciable stress in said adhesive joints between said lead wires and said crystal body, each of said wire springs comprising a U-shaped portion having an arm carried by one of said stationary supports, a cross-over portion carried by the other arm of said U-shaped portion and extending from one side to the opposite side of said crystal body, and another portion carried by said cross-over portion at right angles to said U-shaped portion and carrying one of said lead wires.

8. Piezoelectric crystal apparatus comprising a piezoelectric crystal body, conductive electrode coatings formed integral with opposite major faces of said crystal body, and a resilient conductive wire mounting system for said electroded crystal body comprising a pair of substantially coaxial conductive flexible lead wires extending outwardly from and substantially perpendicular to said opposite electroded faces of said crystal body, conductive adhesive means comprising metallic joints for individually fastening the ends of said lead wires to said opposite electroded faces of said crystal body, and means comprising a pair of substantially identical bent conductive wire springs individually secured to said lead wires and individually carried by stationary supports for resiliently supporting said crystal body without introducing appreciable stress in said adhesive joints between said lead wires and said crystal body, each of said wire springs comprising a U-shaped portion having long and short arms, said long arm being carried by one of said stationary supports and said short arm having a bend terminating in a cross-over portion extending from one side to the opposite side of said crystal body, said cross-over portion having a bend terminating in a portion disposed transverse to and secured to one of said lead wires, the ratio of the effective over-all length of said cross-over portion and said short arm of said U-shaped portion with respect to the effective length of

said long arm of said U-shaped portion being a value of substantially 0.4.

9. Piezoelectric crystal apparatus comprising a piezoelectric crystal body, conductive electrode coatings formed integral with opposite faces of said crystal body, and a resilient conductive wire mounting system for said electroded crystal body comprising a pair of substantially coaxial conductive flexible lead wires extending outwardly from said opposite electroded faces of said crystal body, adhesive means for individually fastening said lead wires to said opposite electroded faces of said crystal body, and means comprising a pair of substantially identical bent conductive wire springs individually secured to said lead wires and carried by stationary supports for resiliently supporting said crystal body without introducing appreciable stress in said adhesive means between said lead wires and said crystal body, each of said wire springs comprising a U-shaped portion having long and short arms, said long arm being carried by one of said stationary supports and said short arm having a bend terminating in a cross-over portion extending from one side to the opposite side of said crystal body in a region between said crystal body and said stationary supports, said cross-over portion having a bend terminating in a portion disposed transverse to and secured to one of said lead wires.

10. Piezoelectric crystal apparatus comprising a piezoelectric crystal body, conductive electrode coatings formed integral with at least a part of the opposite major faces of said crystal body, and a conductive resilient wire mounting system for said electroded crystal body comprising a pair of substantially coaxial conductive flexible spring lead wires extending from said opposite electroded faces of said crystal body, adhesive means comprising metallic joints for individually fastening the ends of said lead wires to said opposite electroded faces of said crystal body, a pair of substantially identical bent conductive wire springs individually carried at one end thereof by a pair of fixed terminal supports and conductive adhesive means for individually fastening the other ends of said wire springs to said lead wires, said pair of wire springs resiliently supporting said electroded crystal body and constituting means for absorbing shock therein without introducing appreciable strain in said lead wires and in said adhesive joints between said lead wires and said crystal body, each of said wire springs comprising a U-shaped bent portion disposed in a substantially vertical plane and having a relatively long lower linear horizontal arm and a shorter upper linear horizontal arm, the end of said longer lower arm being carried by one of said fixed terminal supports and the end of said shorter upper arm having a bend terminating in a horizontal linear cross-over portion extending from one side to the opposite side of said crystal body in a region below said crystal body, said cross-over portion having a bend terminating in an upwardly extending linear vertical portion, said vertical portion having its upper end secured by said adhesive means to one of said lead wires, the ratio of the effective over-all length of said cross-over portion and said shorter upper arm of said U-shaped portion with respect to the length of said lower longer arm of said U-shaped portion being a value of substantially 0.4.

11. Piezoelectric crystal apparatus comprising a container, a piezoelectric crystal body and a

conductive wire mounting system therefor disposed in said container, a pair of opposite conductive metallic coatings formed integral with the opposite major faces of said crystal body, said crystal body comprising a face shear mode type quartz plate having its substantially rectangular-shaped major faces disposed in a substantially vertical direction and having its node of motion disposed substantially adjacent the centers of said major faces, said mounting system comprising a pair of similar substantially coaxial and horizontally disposed conductive flexible spring lead wires extending outwardly from said centers of said major faces of said crystal body, conductive adhesive means comprising metallic solder joints for individually fastening the innermost ends of said horizontal lead wires to said opposite coatings substantially at said centers of said major faces of said crystal body, a pair of substantially identical conductive flexible wire springs having a diameter slightly larger than the diameter of said horizontal lead wires, conductive adhesive means comprising metallic solder masses for individually fastening the upper ends of said wire springs to the outermost ends of said horizontal lead wires, said solder masses constituting a massed weight placed on each of said lead wires substantially at a nodal point of said lead wires and away from a loop of motion therein, and a pair of fixed conductive terminals disposed below said crystal body on opposite sides thereof and individually carrying said wire springs at the ends thereof that are remote from said upper ends thereof, said wire springs having a cross-sectional area sufficient to resiliently support said crystal body without bumping it against said enclosing container when subjected to normal shock, and said wire springs constituting means for absorbing said externally applied shock without introducing either appreciable strain in said lead wires or stress in said adhesive joints between said lead wires and said coatings of said crystal body, each of said wire springs comprising a U-shaped bent portion disposed in a substantially vertical plane and having a relatively long lower linear horizontal arm and a shorter upper linear horizontal arm, the end of said longer lower arm being secured to one of said fixed terminals and the end of said shorter upper arm having a bend terminating in a horizontal linear cross-over portion extending from one side to the opposite side of said crystal body in a region between said crystal body and said fixed terminals, said cross-over portion having a bend terminating in an upwardly extending linear vertical portion, said vertical portion having its upper end disposed adjacent said outermost end of one of said horizontal lead wires and embedded in one of said solder masses, the ratio of the vertical plane projected effective over-all length of said cross-over portion and said shorter upper arm of said U-shaped portion with respect to that of said lower longer arm of said U-shaped portion being a value of substantially 0.4, the length of said upwardly extending linear portions corresponding to a value to eliminate bending of said horizontal lead wires when said crystal apparatus is subjected to shock or vibration, and said bends having radii of curvature sufficiently small to permit construction of said wire springs from wire of relatively small diameter of the order of 0.003 inch diameter.

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