ELECTROMECHANICAL VIBRATOR

Filed June 30, 1933 2 Sheets-Sheet 1

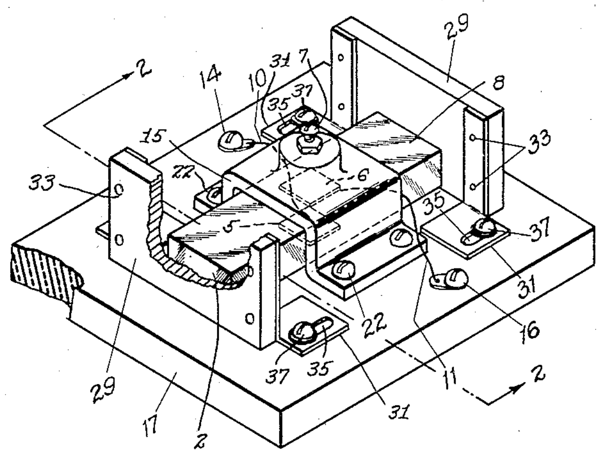


Fig 1

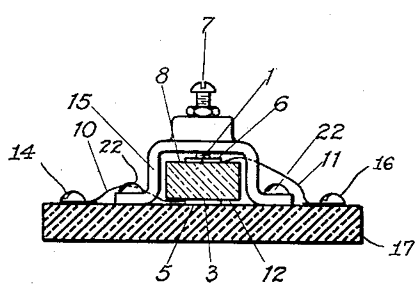


Fig 2

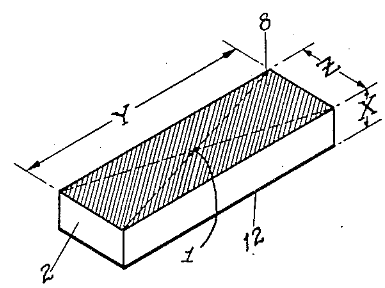


Fig 3

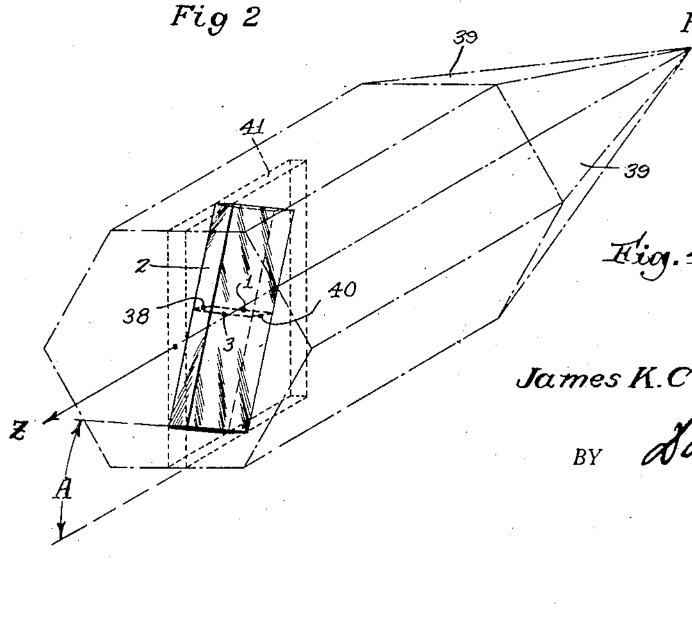


Fig. 4.

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ELECTROMECHANICAL VIBRATOR

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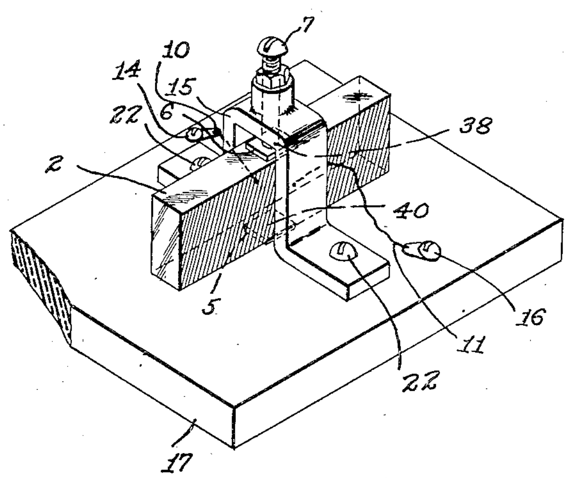
Fig. 5.

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2,029,358

## ELECTROMECHANICAL VIBRATOR

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Application June 30, 1933, Serial No. 678,416

14 Claims. (Cl. 171—327)

The present invention relates to electromechanical vibrators, and more particularly to piezo-electric crystals, and to supports and holders therefor.

Piezo-electric crystals, while vibrating, have a tendency to move bodily between their electrodes, due to friction between the surface of the vibrating crystal and its supporting surface, and to the reaction from the supersonic waves radiated from the crystal. Such motion is undesirable because of the resulting erratic changes in frequency. Methods of constraining the crystal to prevent these erratic changes of frequency must be carefully applied to be successful and must differ according to the mode of oscillation. For example, in a crystal plate of thickness small compared with the other dimensions and vibrating in the thickness mode, constraint of the entire periphery of the crystal is not satisfactory because the dimensions of the periphery change periodically with the vibrating expansions and contraction of the crystal. Such clamping of the periphery to prevent bodily movement consequently interferes with the free vibration of the plate. In the case of a quartz bar whose length is large compared with the other dimensions and vibrating in the length dimension, considerable interference with vibration in the direction of the length results from resting the crystal on a supporting surface, due to friction between the surfaces.

According to the invention disclosed in application Serial No. 571,930, filed October 29, 1931, a piezo-electric crystal is held nodally by adjustable holding members, preferably at points along its electric axis, and entirely out of contact with other points or surfaces. Though the crystal is thus held positively and prevented from moving bodily, it is permitted to vibrate freely.

This is a very efficient structure, but difficulties sometimes arise by reason of the fact that the crystal electrodes are independent of the crystal. Any change in the position of the electrodes relative to the crystal causes a change in frequency. For some purposes, advantage may be taken of this fact to obtain some adjustment of the frequency, without resorting to actual grinding of the quartz. For use in high-precision frequency standards, however, the presence of the air gap is detrimental, as it is desirable to avoid possible variations in frequency that might result from variations in the air gap. The air gap, furthermore, reduces the effectiveness of the crystal in controlling the frequency of the oscillator.

It is accordingly an object of the present invention to provide a new and improved electromechanical vibrator and mounting that shall be free from such defects.

With this end in view, a feature of the invention resides in integrally providing the nodally-supported vibrator with electrodes that, because they cannot shift with respect to it, can not, consequently, introduce any frequency variations of the type described.

Other and further objects will be explained hereinafter and will be particularly pointed out in the appended claims.

The invention will now be explained in connection with the accompanying drawings, in which Fig. 1 is a perspective illustrating a preferred embodiment of the invention, parts being broken away, for clearness; Fig. 2 is a section taken upon the line **2—2** of Fig. 1, looking in the direction of the arrows, the baffle plate being omitted, for clearness; Fig. 3 is a perspective of a piezo-electric-crystal vibrator embodying the present invention; Fig. 4 is a perspective illustrating a crystal vibrator and one method of cutting it from a quartz crystal, shown in dot-and-dash lines; and Fig. 5 is a view similar to Fig. 1, illustrating one method of clamping the crystal vibrator shown in Fig. 4 at points disposed along a line at right angles to the electric axis.

A rectangular, quartz-crystal plate **2** is shown provided with conducting electrodes **8** and **12**, integrally formed on opposite sides of the crystal in any desired manner, as by chemically depositing a silver coating. The electrodes **8** and **12** are suitably connected in an electric circuit (not shown) by means of connecting leads or wires **10** and **11**, that are permanently joined to the electrodes **8** and **12**; and that may be connected with binding posts or the like **14** and **16**.

The crystal plate is held against bodily movement out of the position in which it is fixed. It is, however held so as to vibrate freely, according to the desired mode of vibration, without restriction, and without interfering with its vibrations, and without introducing variations in frequency. This is effected, according to the preferred embodiment of the invention, by clamping the crystal at small, medial areas corresponding to nodes of movement, at oppositely disposed, central points **1** and **3** on opposite sides of the crystal, pads **5** and **6** of felt, cork or the like, being interposed against the lower and upper faces of the crystal over the central, stationary points **1** and **3**. The points **1** and **3** may be disposed along the electric axis of the crystal, where there is small vibratory movement when the crystal is vibrated transversely to the direction of this axis. The invention is particularly adapted for use with crystal bars or rods vibrating in the transverse mode at the gravest or lowest frequency.

The pad 5 rests in a yoke 15 that is secured to an insulating base 17 in any desired manner, as by means of screws 22. A screw 7 is positioned in the neck of the yoke 15 to engage the pad 6. The crystal plate 2 is thus held clamped in the yoke 15 upon the base 17, at the oppositely disposed points 1 and 3. As the electrodes can not move with respect to the crystal, it is impossible to introduce resulting frequency errors.

By threading the screw 7 in the yoke 15, the degree of nodal pressure may be adjusted so as to hold the crystal with any desired degree of tightness, and yet so as to introduce the least energy loss from the vibrating crystal to its supports. Damping of the vibrating crystal is thus reduced to the minimum.

As is also disclosed in the said application, baffle plates 29 are disposed on the base 17, parallel and near to the end faces of the crystal, and are adapted to be adjusted towards and from the crystal ends by angle plates 31 that are fixed to the baffle plates 29 at 33, and that are provided with elongated openings 35 adapted to receive screws 37 that are threaded into the base 17.

In the normal X-cut bar vibrating in the direction of its length (transversely to the X-axis) the central nodal region makes an angle across the larger faces of the crystal. That is, the nodal line on either of the larger faces makes an angle with the optic or Z axis, which is either positive or negative depending upon whether the bar is cut from "left" or "right-handed" quartz. If the bar is cut at the proper angle A, Fig. 4, the nodal line can be made to cross the larger faces of the crystal at right angles to the length of the bar.

Nodal support may therefore be provided otherwise than by disposing the points along the electric axis of the crystal, as at 1 and 3, and one such other way is illustrated in Fig. 4, where the plate vibrator is shown cut from the crystal 39 in a plane 41 parallel to the optic axis Z, and with its width dimension at the angle A to the optic axis Z of the crystal 39. The angle A is less than a right angle, and varies with circumstances. It may be about 29 degrees to the optic axis Z in normal, X-cut plates.

When the vibrator plate is properly cut in this manner, the intermediately disposed plane, shown at 1, 38, 3, 40, disposed at right angles across the larger faces of the crystal plate, is a nodal plane, about which the crystal oscillates with the plane substantially stationary, and the oppositely disposed points 1 and 3, or 38 and 40 of either pair of oppositely disposed faces of the crystal, therefore, are nodal points, at which the crystal bar may be held clamped.

If the crystal is clamped at 1 and 3, on the coated faces, or at 38 and 40, between the coated faces, and at right angles to the coated faces, it will be balanced at the points of support and free to vibrate.

A crystal bar cut in this manner has a very low piezo-electric coefficient, so that it is usually difficult to set it into oscillation in the usual, air-gap type of crystal holder. When the crystal is mounted and coated in accordance with the present invention, however, the operation is quite successful.

As the crystal is not free to move bodily, but is nevertheless free to vibrate without hindrance, all the objections heretofore inherent in electrode-coated, piezo-electric crystals have automatically become eliminated, and a very efficient and serviceable structure is provided, that is freer from error than any crystal mounting heretofore proposed, particularly when provided with the baffle plates 29 and when maintained at constant temperature, as explained more fully in the said application.

The nearer to the points of no motion that a crystal is held clamped, the lower is the temperature coefficient of the system as a whole, as experimentally observed. A crystal that is provided with coated electrodes in the above-described manner, it is found, has a smaller temperature coefficient than crystals provided with electrodes in any other way. The crystal of the present invention, furthermore, has a lower decrement, because it involves a very simple vibratory movement, coupled with a large ratio of the mass to the elasticity. This is of considerable importance, because large crystals are better frequency standards, having lower decrements, other things being the same. The improvement increases as the square of the length of the crystal plate.

It will, of course, be understood that the invention is not restricted to the exact embodiment thereof that is illustrated and described herein, as modifications may be made by persons skilled in the art, and all such are considered to fall within the spirit and scope of the invention, as defined in the appended claims.

What is claimed is:

1. An electromechanical vibrator comprising a piezo-electro-crystal body having electrodes integral therewith on opposite faces thereof, means for clamping the body at two oppositely disposed points of relatively small area along the electric axis of the body to prevent bodily movement of the body out of a predetermined position, and pads between the body and the clamping means.

2. Apparatus of the character described comprising an electromechanical vibrator comprising a freely vibratory body having electrodes integral therewith, means for holding the body against bodily movement out of a predetermined position, and means for suppressing supersonic radiation from the vibrator including a pair of baffles for the vibrator.

3. Apparatus of the character described comprising a piezo-electric crystal having electrodes integral therewith on opposite sides thereof, two oppositely disposed holding members between which the body is held against bodily movement out of a predetermined position, means for suppressing supersonic radiation from the vibrator including baffles adjacent to the ends of the crystal, and means for adjusting the baffles .

4. An electromechanical vibrator comprising a freely vibratory body having electrodes integral therewith, the body having a centrally disposed nodal region at right angles to the length of the body, and means engaging the body at oppositely disposed points of the nodal region for holding the body against bodily movement out of a predetermined position, said points being on surfaces of the vibratory body not covered by the electrodes.

5. An electromechanical vibrator comprising a piezo-electric crystal body having electrodes integral therewith, the body having a centrally disposed nodal region, and means for adjustably clamping the body at opposite sides of the nodal

region on surfaces other than the electrode surfaces to hold the body nodally against bodily movement out of a predetermined position.

6. Apparatus of the character described comprising an electromechanical vibrator comprising a freely vibratory body having electrodes integral therewith, the body having a centrally disposed nodal region, means engaging the body at oppositely disposed points of the nodal region for holding the body against bodily movement out of a predetermined position, and means for suppressing supersonic radiation from the vibrator including a pair of baffles for the vibrator.

7. Apparatus of the character described comprising a piezo-electric crystal having electrodes integral therewith on opposite sides thereof, the body having a centrally disposed nodal region, two oppositely disposed holding members engaging the body at oppositely disposed points of the nodal region and between which the body is held against bodily movement out of a predetermined position, means for suppressing supersonic radiation from the vibrator including baffles adjacent to the ends of the crystal, and means for adjusting the baffles.

8. An electromechanical vibrator comprising a piezo-electric crystal body having electrodes integral therewith on opposite faces thereof substantially at right angles to the electric axis of the body, the body having a centrally disposed nodal region, and means for clamping the body at opposite sides of the nodal region along a line at right angles to the electric axis to hold the body nodally independent of the electrodes against bodily movement of the body out of a predetermined position, said sides being on surfaces of the body not covered by the electrodes.

9. An electromechanical vibrator comprising a piezo-electric-crystal body having electrodes integral therewith on opposite faces thereof substantially at right angles to the electric axis of the body, the body being in the form of a bar the length of which is large compared with its other dimensions and having a centrally disposed nodal region with respect to which it is freely vibratory according to a fundamental mode of vibration in the direction of its length, two oppositely disposed supports provided with clamping members having portions of relatively small area the dimensions of which are small compared with the length and width of the bar, and means for adjusting one of the clamping members to cause the clamping members to clamp between the two portions of relatively small area small nodal portions of the body at opposite sides of the nodal region to hold the body nodally clamped and solely supported independent of the electrodes between the said two portions of relatively small area, the normal to said sides lying at right angles to the electric axis of the body.

10. An electromechanical vibrator comprising a piezo-electric crystal body having electrodes integral therewith on opposite faces thereof substantially at right angles to the electric axis of the body, the body having a centrally disposed nodal region, engaging means for clamping the body at two oppositely disposed points of relatively small area of the nodal region to hold the body against bodily movement out of a predetermined position, and pads between the body and the clamping means.

11. An electromechanical vibrator comprising a freely vibratory body having electrodes integral therewith on opposite faces thereof, two oppositely disposed supports provided with clamping members having portions of relatively small area, and means for adjusting one of the clamping members to clamp the body between the two portions of relatively small area to hold the body nodally clamped and solely supported between the said two portions of relatively small area, said clamping members bearing on surfaces of the crystal other than those covered by the electrodes.

12. An electromechanical vibrator comprising a freely vibratory body having electrodes integral therewith on opposite faces thereof, the body having a centrally disposed nodal region, two oppositely disposed supports provided with clamping members having portions of relatively small area, and means for adjusting one of the clamping members to clamp the body between the two portions of relatively small area at oppositely disposed points of the nodal region to hold the body nodally clamped and solely supported between the said two portions of relatively small area, said points being on surfaces of the vibratory body not covered by the electrodes.

13. An electromechanical vibrator comprising a piezo-electric crystal body having electrodes integral therewith on opposite faces thereof substantially at right angles to the electric axis of the body, the body having a centrally disposed nodal region, and means for clamping the body at opposite sides of the nodal region to hold the body nodally against bodily movement of the body out of a predetermined position, the normal to the said sides lying at right angles to the electric axis of the body.

14. An electromechanical vibrator comprising a piezo-electric crystal body having electrodes integral therewith, the body having a centrally disposed nodal region, and means for clamping the body in the nodal region on surfaces not covered by the electrodes to hold the body against bodily movement out of a predetermined position.

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