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[54] **MOUNTING DEVICE FOR OSCILLATORY CRYSTAL WHICH CONVERTS TORSIONAL VIBRATIONS TO FLEXURAL VIBRATIONS**

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[30] **Foreign Application Priority Data**

Feb. 26, 1971 France 71.06695

[52] **U.S. Cl.** **310/9.1;** 310/8.2

[51] **Int. Cl.** **H01l 41/04**

[58] **Field of Search** 310/8.2, 9.1, 9.4, 9.7, 310/9.8

[56] **References Cited**

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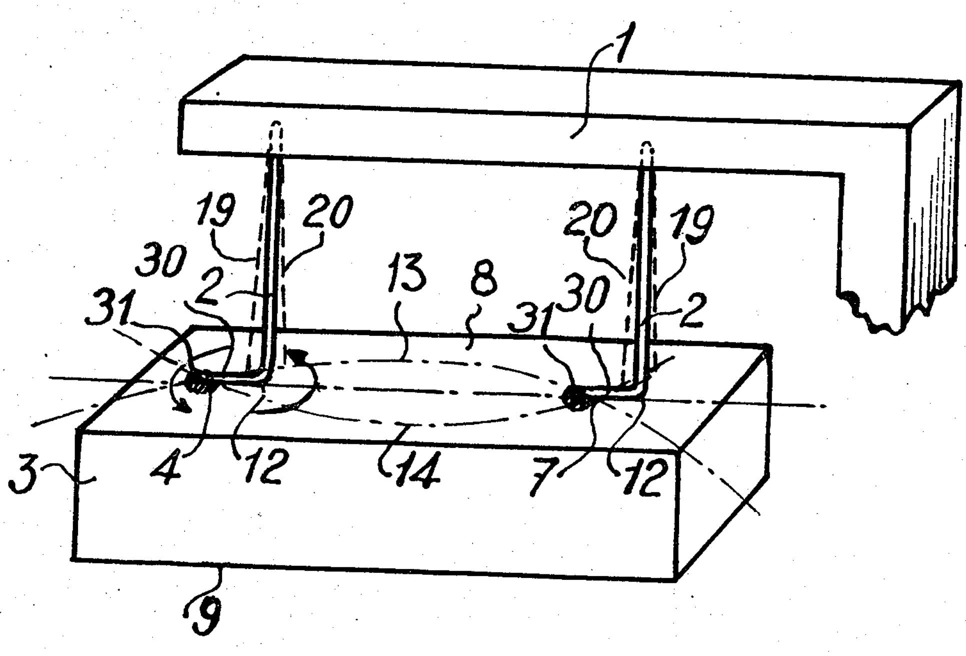
[57] **ABSTRACT**

Wire suspension device for piezoelectric oscillatory crystals in which the wires are fixed on the faces thereof by a part of their lateral surface acting as a conversion lever, replacing the usual wire's "$\lambda/4$" torsional mechanical oscillations by flexional oscillations, thus enabling use of short wires and improving aging stability.

6 Claims, 5 Drawing Figures



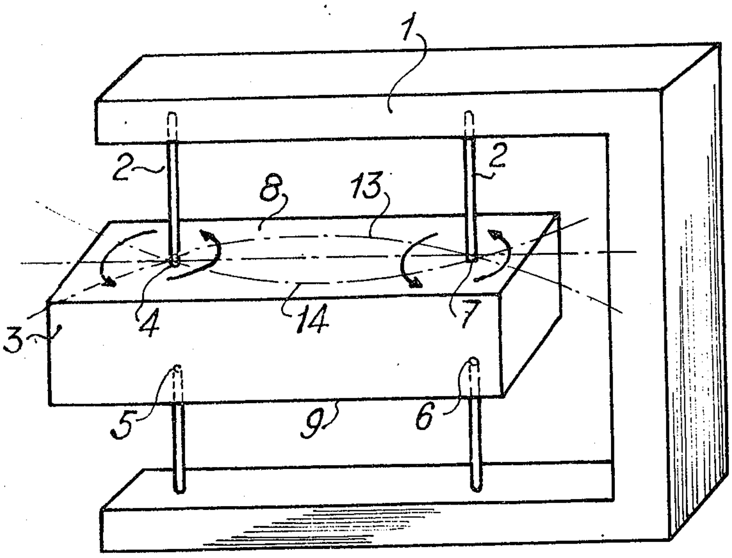


Fig_1

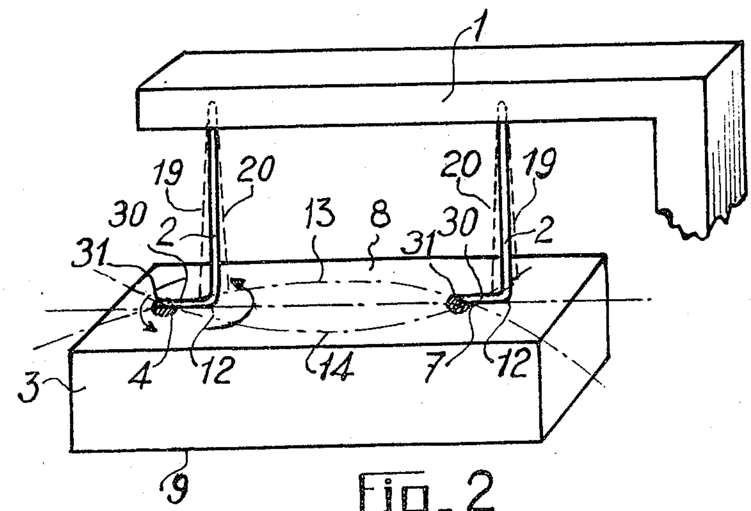


Fig_2

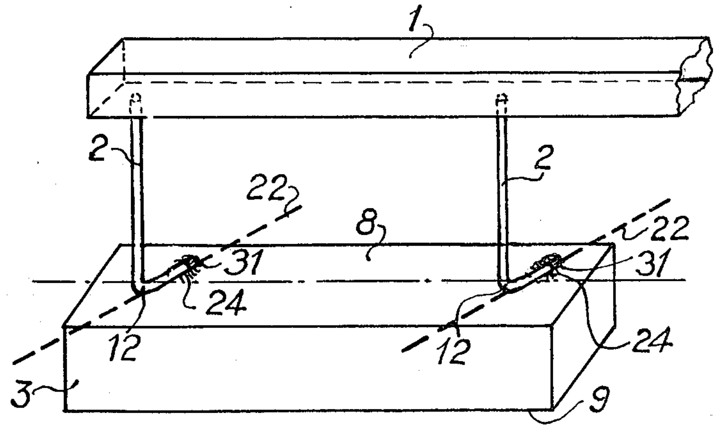


Fig_3

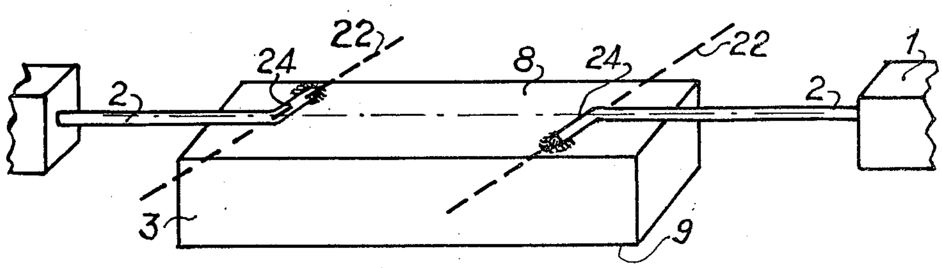


Fig_4

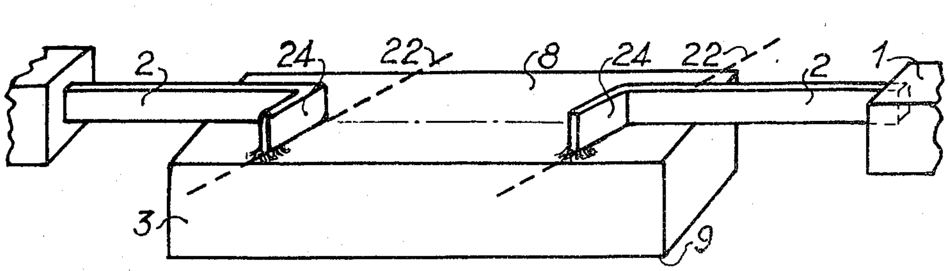


Fig_5

MOUNTING DEVICE FOR OSCILLATORY CRYSTAL WHICH CONVERTS TORSIONAL VIBRATIONS TO FLEXURAL VIBRATIONS

This application is a continuation-in-part of my co-pending application Ser. No. 223.604 filed Feb. 4, **1972.**

The present invention relates to oscillatory crystals for time-base purposes, these conventionally being electrically sustained by the piezoelectric effect through suitably disposed electrodes, and the material of which they are made being usually constituted by a quartz crystal cut in particular directions which are associated with its crystal lattice.

In the case of the low frequencies, ranging for example from a few kilohertz up to a few tens of megahertz, the crystal elements used take the form of elongated bars whose section is near-square, and which are equipped with electrodes whose shape and disposition are such that the resultant vibrations involve a bending or flexion motion of the whole bar.

However, the need to attach the vibrating crystal in mountings, normally by soldering operations, creates a substantial difficulty, namely that of the transmission of mechanical energy from the crystal to its mountings or supporting arrangements. This in turn means that modifications to the operating characteristics of the crystal on its own, are introduced; moreover, said modifications develop over a period of time, as a consequence of the aging of the soldered joints referred to.

These phenomena can be reduced by selecting upon the crystals, as points of attachment for the suspension elements, points which are usually referred to as "nodal points" where the amplitude of the vibration is minimum.

However, due to the development of industrial requirements, crystals of decreasing size have to be used, in relation to which, the dimensions of the suspension element have ceased to be negligible. This has given rise to the increasing problem for providing accurate and perfectly reproducible crystal fixings, with the consequence that ultimately the regularity of manufacture and time-based stability, have become mediocre.

The present invention relates to a suspension device which does not exhibit this drawback and more particularly to a fixing device for a crystalline bar of parallelepiped form which is capable of mechanical oscillations in a flexion mode and in a plane parallel to that of the fixing faces of said parallelepiped, said bar comprising a fixed support, and suspension wires respectively attached by one of the ends thereof to said support and at their other end to the crystal, at points of minimum vibration on the fixing faces thereof, said other end of each of said wires being fixed to said faces by a part of the lateral surface of the wire.

The invention will be better understood from a consideration of the ensuing description and the attached figures in which:

FIG. **1** illustrates a suspension device of prior art design;

FIG. **2** illustrates a suspension device in accordance with the invention;

FIGS. **3, 4** and **5** illustrates various embodiments of the invention.

FIG. **1** illustrates a suspension device in accordance with the prior art, applied to a crystal bar operating in the flexion mode. The device comprises a fixed support **1** to which there are attached suspension wires **2** whose ends terminate, at the surface of the crystal bar **3**,at nodal points, or points of minimum vibration as defined hereinbefore, namely **4, 5, 6** and **7.**

These points are located upon the longitudinal axes of the faces **8** and **9** at special distances from the ends, which distances, taking the flexion mode of vibration employed here, are equal to 0.224 times the overall length of the bar.

In operation, under the influence of electric fields applied to the piezoelectric bar electrodes, which have not been shown, the flexion mode oscillation takes place, and causes an alternating deformation of the neutral axis between the two extreme positions **13** and **14** illustrated in FIG. **1,** which are exaggerated in amplitude, for the sake of clarity.

This alternating movement induces an alternating torsional stress in the suspension wire,by virtue of the rotation of its extremity in the direction of the arrows-,at the frequency of vibration of the crystal, these torsional oscillations being propagated up, along the wire,to that part of the fixed support to which the suspension is attached. The suspension wire thus behaves as a transmission line carrying alternating mechanical energy, and the decisive role which this phenomenon plays on the correct operation of the crystal has been referred to hereinbefore.

It is well known, in the field of this kind of transmission line arrangement, to reduce the transmitted energy by causing the transmission line to vibrate in the so-called "quarter-wave" mode, this leading to a special value for the length of the suspension wires which is given by the relationship:

$$d = \frac{\lambda}{4} = \frac{V}{f}$$

where

d is the free length of the suspension wire;

f the frequency of oscillation of the crystal;

V is the velocity propagation of the oscillation along the wire; and

λ is the wavelength of propagation of the oscillation.

For reasons of size, it is desirable that the length d of the suspension wire should be short and this means that, for a given frequency f determined by each particular application, a velocity of propagation V has to be sought which is likewise low. However, the torsional mode of vibration described hereinbefore for a suspension of the prior art, as illustrated in FIG. **1,** corresponds to the contrary to a high velocity propagation through the wire, and does not enable efficient control of the reflection conditions at its ends to be achieved.

FIG. **2** illustrates a first embodiment of the device, in accordance with the invention where, for the sake of clarity, and this applying to the following figures as well, only the top part of the device has been shown.

The suspension wire is attached to the crystal by the provision of a fold **12** of its end, defining a segment **30** parallel to the fixing face, the one extremity **31** of this segment being fixed at points of minimum vibration of the fixing face.

In operation, this segment **30,** thus constituted by a part of the wire itself, acts as an oscillating lever, converting the conventional torsional oscillation of the wire into a flexion oscillation, the wire considered about its mean position **2,** occupying extreme positions **19** and **20**; this flexion mode corresponds to a very much lower velocity propagation, this being a factor the need for and advantages of which have been discussed hereinbefore.

It is to be noted that, for achieving the conversion operation of the lever, only one of its extremities **31** must be fixed on the crystal, usually by solder, excluding particularly the folded portion, or elbow portion **12** at the other lever extremity thereby securing a free movement for the oscillating lever segment.

Thus, a characteristic of the invention is that the lateral part of the wire acting as a conversion lever must be free of any fixating or anchoring material such as a solder, except at its very extremity **31** which is fixed to the crystal. As an order of magnitude in practical cases, the free portion of the lever must have a length greater than the two diameters of the wire suspension.

FIG. **3** illustrates a variant embodiment of the invention which lies on a geometric characteristic of the oscillating of the crystal, namely, the existence of nodal lines of minimum vibration at the surface thereof, on which lines are furthermore located the nodal points defined hereinbefore. In this variant embodiment, these nodal lines **22** are used as lines of soldered contact for the extremity of the wire acting as a converter lever. The operation is the same as that of the device shown in FIG. **2,** but the amplitudes of oscillation are reduced, and consequently the crystal has improved mechanical isolation.

FIG. **4** illustrates another simplified variant embodiment of the invention, in which the free part of the suspension is contained in a plane parallel to that of the face of the crystal to which it is attached by the lever **24.** The operation is the same as that of the devices of FIGS. **2** and **3** although there is an improvement in the conversion of one mode of oscillation to the other, because of the simplification of the mechanical structure, albeit at the expense of a greater longitudinal dimension.

FIG. **5** illustrates a variant embodiment of the device shown in FIG. **4,** in which the free part of the suspension has been given a rectangular section, the shorter side being attached to the crystal and the longer side being perpendicular to the fixing face of the crystal.

This kind of section, although enabling the suspension to oscillate in the plane parallel to the fixing face of the crystal, prevents it from doing so in the perpendicular plane and thus strictly defines the effective plane of vibration.

By way of example, the invention has been applied to crystal oscillators operating at low frequencies in the order of a few kilohertz, and has shown a major improvement in the quality factor of the crystal, e.g., on the order of a ratio of 2, and, compared with the case of crystals suspended by the conventional method, a substantial reduction in the time-based frequency drift normally brought about due to slow modifications in the mode of suspension.

Of course, the invention is not limited to the embodiment described and shown which was given solely by way of example.

What is claimed is:

1. In a fixing device for an oscillatory crystal bar of parallelepiped form capable of mechanical oscillations in a flexion mode in a plane parallel to that of the fixing faces of said parallelepiped, mounting means for converting torsional vibrations to flexional vibrations, said device comprising a fixed support, and a plurality of suspension wires each being attached at one end thereof to said support, and at the other end thereof being formed into a lever aligned parallel to sid flexion plane, the extremity of said lever portion of each of said wires being fixed on its lateral surface to the fixing faces at points of minimum vibration wherein the portion of each of said suspension wires between said one end and said other end having a length equal to a quarter of the wavelength of propagation of flexional oscillations in said suspension wires, the frequency of said flexion oscillations being equal to the frequency of said mechanical oscillations of said crystal bar.

2. A fixing device as claimed in claim **1,** wherein said lever portion of each of said wires makes an angle with the remaining portion of said wire attached to said fixed support.

3. A fixing device as claimed in claim **2,** wherein said angle is a 90° angle.

4. A fixing device as claimed in claim **3,** wherein said remaining portions of said wires attached to said support each makes a 90° angle with said fixing faces.

5. A fixing device as claimed in claim **2,** wherein the portion of each wire attached to said support is parallel to said fixing faces.

6. A fixing device as claimed in claim **5,** wherein said lever portion has a rectangular transverse section and wherein the short side of said rectangular section is attached to said fixing faces.

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