Feb. 26, 1946. B. TENENBAUM 2,395,434

PIEZOELECTRIC CRYSTALS

Filed March 28, 1944

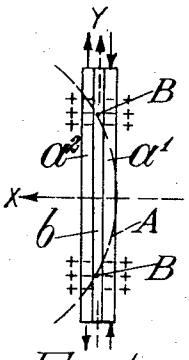

Fig. 1.

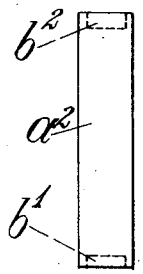

Fig. 4.

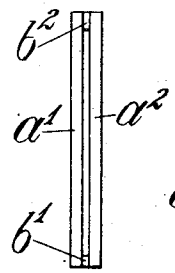

Fig. 5.

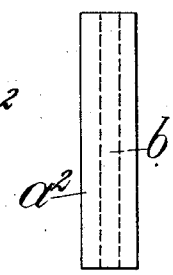

Fig. 2.

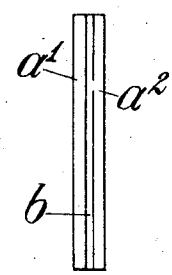

Fig. 3.

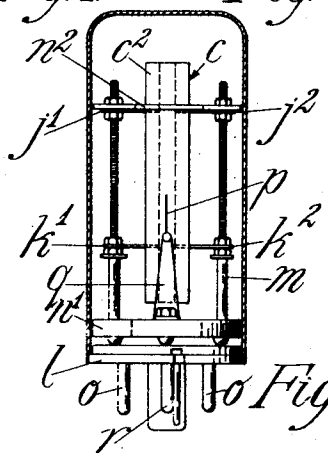

Fig. 8.

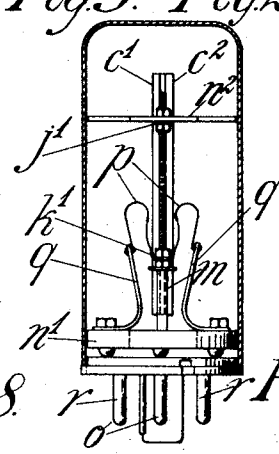

Fig. 9.

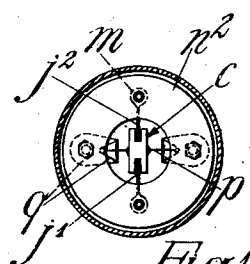

Fig. 10.

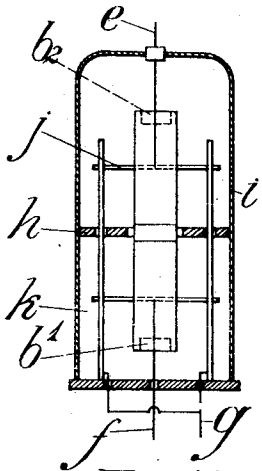

Fig. 11.

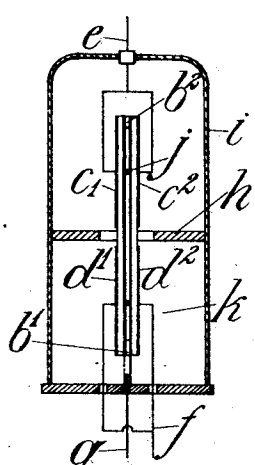

Fig. 12.

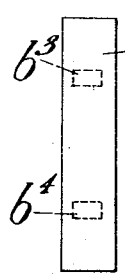

Fig. 6.

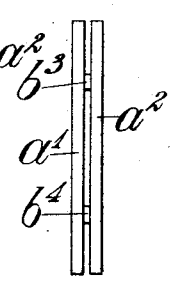

Fig. 7.

Inventor
B. Tenenbaum
By Glascock Downing & Seebold
Attys

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PIEZOELECTRIC CRYSTALS

Berko Tenenbaum, London, England

Application March 28, 1944, Serial No. 528,440
In Great Britain August 31, 1943

6 Claims. (Cl. 171—327)

This invention relates to an improved construction and mounting of piezo-electric crystals specially designed for low frequency.

Piezo-electric crystals are known consisting of an integral rectangular bar in which a recess has been cut on either side in the longitudinal direction leaving a central web extending longitudinally from one end to the other by which two thin rectangular sheets remain united in one integral piece, the outer and inner surfaces of the bar thus obtained being suitably metallised to form the electrodes, and the inner surfaces being electrically connected together to serve as one electrode, and similarly the outer surfaces to form the other electrode.

The original bar may be cut at right angles to the electrical axis X (X cut) the longest sides being parallel to the mechanical axis (Y); but it is to be understood that the cutting may be effected at any desired angle to any of the axes. If an alternating voltage is applied to a crystal bar formed as above referred to, the bar will vibrate by flexion and if the frequency of this mechanical vibration corresponds to the electric frequency of the alternating voltage substantial resonance effects will be produced. Piezo-electric crystals which thus vibrate by flexion are generally referred to as "flexural vibration crystals" and in the case of crystal bars as above referred to the frequency depends on the length and thickness of the crystal.

The present invention relates solely to flexural vibration crystals, the frequency of which depends on the length and thickness of the crystal, the invention being mainly directed to its general construction and mounting.

The invention consists in a flexural vibration piezo-electric crystal the frequency of which depends on the length and thickness of an integral crystal bar comprising: a rectangular crystal bar so slotted in its longitudinal direction as to leave in one integral piece two thin rectangular sheets separated by the slotting; metal coatings on the internal and the external surfaces of the slotted crystal bar respectively forming two electrodes; wires inserted into the slotting and connected to the internal metal coatings; a metal suspension frame acting as a support for the crystal bar through the intermediary of the said wires, which are also connected to the suspension frame; a contact terminal electrically connected to the suspension frame and thereby through the said wires to the electrode formed by the internal metal coatings; and fine wire connections to the electrode formed by the external metal coatings.

The invention further consists in so slotting the bar that its two thin rectangular sheets remain united at two points within the two end quarters of the bar as hereinafter described.

The invention also consists in the details of construction and mounting hereinafter referred to with reference to the accompanying drawing and claimed in the appended claims.

Referring to the accompanying drawing illustrating the invention diagrammatically and by way of example,

Figure 1 is an explanatory diagram of a flexural vibration piezo-electric crystal;

Figures 2 and 3 show a front and side elevation respectively of the known form of crystal bar above referred to;

Figures 4, 5, 6 and 7 show corresponding views of two forms of construction of hollowed crystal bar constituting a feature of the present invention;

Figures 8, 9, and 10 illustrate one form of construction and mounting according to the invention, Figures 8 and 9 showing two elevations at right angles to each other of a two-electrode piezo-electric crystal bar generally used in an oscillatory system, and Figure 10 being a plan view thereof;

Figures 11 and 12 show two views at right angles to each other similar to Figures 8 and 9 but showing the parts somewhat more diagrammatically of a three-electrode piezo-electric crystal bar embodying the present invention and generally used as a filter system.

Referring to Figure 1, a_1 and a_2 are the two sides of an X-cut crystal bar and b is the part by which they are left united as an integral piece. In such a crystal bar the X-axis is in the direction of the thickness and the Y-axis in the direction of its length.

The inner coatings of the bar being connected together, and similarly the outer coatings, if an A. C. electromotive force is applied to the coatings, it will be seen that at any particular moment the coatings will receive potentials having the + and — signs indicated in the diagram, and when the direction of the E. M. F. changes, the + and —signs indicated will be reversed. Now, since the direction of the electric field across the side a_1 of the bar follows the direction of the X-axis, whilst across the side a_2 it lies in opposite direction thereto, it follows that the side a_1 is subjected to tensional stresses in the direction of the Y-axis and in the side a_2 it is subjected

to compressional stresses in the direction of the Y-axis. As a result thereof the bar is deflected as indicated by the curve A passing through the two nodal points B which lie at a distance of about 0.224 of the length of the bar counted from its two ends. When the direction of the E. M. F. changes, the bar will be deflected in the opposite direction, whereby flexural vibrations are obtained.

In the construction shown in Figures 2 and 3, the two sides a_1, a_2, are left united by a longitudinal web b, a longitudinal recess being cut on either side of the web.

Referring to Figures 4 and 5 the integral crystal bar comprises two sides a_1 and a_2 united at the ends b_1, b_2, all cut in this way from one piece.

In the construction illustrated in Figures 6 and 7, the crystal bar comprises two sides a_1 and a_2 united at the nodal points b_3, b_4, all cut in this way from one piece.

In all these constructions the inner and outer surfaces are metallised to form the electrodes.

Referring to Figures 8 to 10 the bar c is supported on the base l through the wires j_1, j_2, k_1, k_2, which are connected to the inside electrode formed by the internal metallisations and are attached to the metal rods m of a suspension frame supported on the base l and formed by the said rods and two annular discs n_1, n_2, of insulating material to which the rods are secured. At their lower ends the rods are electrically connected to electrically interconnected contact pins o. The undivided external metallisations c_1, c_2, of the crystal bar forming the outside electrode are respectively connected by fine wires p to spring supports q electrically connected to electrically interconnected contact pins r.

Referring to Figures 11 and 12 the piezo-electric crystal bar, which is constructed in the manner shown in Figures 4 and 5, is divided into two electric parts by the metallisation on the two outer surfaces being cut into two parts c_1, d_1 and c_2, d_2 respectively in the longitudinal direction of the bar, whilst the internal metallisation remains undivided. Three electrodes are thereby obtained, viz: (1) an input electrode formed by the two halves c_1, c_2 of the two external metallisations which are electrically connected to an input terminal e; (2) an output electrode formed by the two other halves d_1, d_2 of the external metallisations and which are electrically connected to an output terminal f; and (3) an inside electrode formed by the internal metallisations which are electrically connected to a terminal g which may be earthed by being connected to the body of the apparatus. The input and the output electrodes are separated from each other by a metal screening plate h, which is mounted around and at right angles to the bar, at the point where the outer metallisation surfaces are subdivided, the said screen being secured to the inside of the shielding cap i.

The metallisation is preferably effected by means of an electrolytic bath of silver nitrate. The leads from the metallised surfaces to the various terminals of the crystal consist of wires fixed on to the said surfaces; the wires j, k fixed to the internal metallisations and to rods m^4 of a suspension frame supported on the base l^4 also act as supports for the crystal bar, in a manner similar to the construction described with reference to the construction shown in Figures 8 to 10, being secured in both constructions to the crystal bar at its nodal points, which are at a distance of about 0.224 of the length of the bar counted from its two ends.

By connecting, for instance, the secondary of a L. F. transformer to the input electrode of the crystal and the body of the apparatus in a filter system and thereby applying alternating current voltages of a frequency corresponding to the natural mechanical frequency of the crystal bar, the latter will resonate vigorously and its mechanical vibrations will produce electric charges between the output electrode and the body of the apparatus. The frequency of the alternating voltages thus produced will correspond exactly to the frequency of the voltages supplied to the input of the crystal and may be applied direct to the grid of a L. F. valve amplifier.

The selectivity is very sharp and I have found that it is possible by means of a single filter to suppress interfering signals the frequency of which differs only by 0.25% from that of the crystal filter, the amplitude reduction of the interfering signal being 20 decibels.

The range of low frequencies for which the crystal according to the present invention is especially suitable is between 1,000 and 30,000 cycles.

The union between the two sheets of the hollow or recessed crystal along its central longitudinal axis may lie at any suitable point or points along the said axis, e. g. as above described with reference to Figures 2 to 5, or at its nodal points.

The various details for carrying the invention into effect may be modified without in any way departing from the scope of the invention.

I claim:

1. A flexural vibration piezo-electric crystal the frequency of which depends on the length and thickness of an integral crystal bar comprising: a rectangular crystal bar so slotted in its longitudinal direction as to leave in one integral piece two thin rectangular sheets separated by the slotting; metal coatings on the internal and the external surfaces of the slotted crystal bar respectively forming two electrodes; wires inserted into the slotting and connected to the internal metal coatings; a suspension frame acting as a support for the crystal bar through the intermediary of the said wires, which are also connected to the suspension frame; a contact terminal electrically connected to the suspension frame and thereby through the said wires to the electrode formed by the internal metal coatings; fine wire connections to the electrode formed by the external metal coatings; and a second contact terminal electrically connected with the latter fine wire connections.

2. A flexural vibration piezo-electric crystal the frequency of which depends on the length and thickness of an integral crystal bar comprising: a rectangular crystal bar so slotted in its longitudinal direction as to leave in one integral piece two thin rectangular sheets separated by the slotting; electrode forming metal coatings on the internal and external surfaces of the slotted crystal bar; wires inserted into the slotting and connected to the internal metal coatings; a suspension frame acting as a support for the crystal bar through the intermediary of the said wires, which are also connected to the suspension frame; a contact terminal electrically connected to the suspension frame and thereby through the said wires to the electrode forming internal metal coatings; and fine wire connections to the external metal coatings.

3. A flexural vibration piezo-electric crystal as claimed in claim 2 in which the wires connected to the suspension frame are inserted in the slotting and connected to the internal metal coatings at the nodal points of the crystal bar.

4. A flexural vibration piezo-electric crystal as claimed in claim 2 in which spring supports are used to connect the contact terminal connected to the suspension frame with the fine wire connections which are attached to the external metal coatings of the crystal bar.

5. A flexural piezo-electric crystal as claimed in claim 2, in which the suspension frame comprises metal rods to which the wires connected to the internal metal coatings are attached and two annular discs of insulating material to which the rods are secured and in which a base having two contact terminals secured thereto serves as a support for the suspension frame carrying the crystal bar.

6. A flexural vibration piezo-electric crystal as claimed in claim 2 in which the wire connections with the internal metal coatings as well as those with the external metal coatings are effected at the two nodal points of the crystal bar.

BERKO TENENBAUM.