

Aug. 15, 1967

L. G. MARTYN ET AL

3,336,487

CRYSTAL STRUCTURE

Filed April 13, 1965

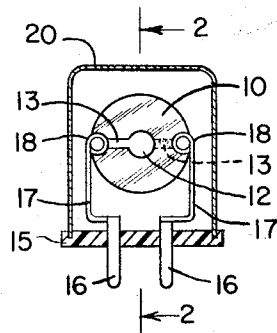


FIG. 1

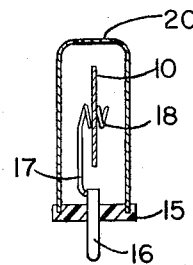


FIG. 2

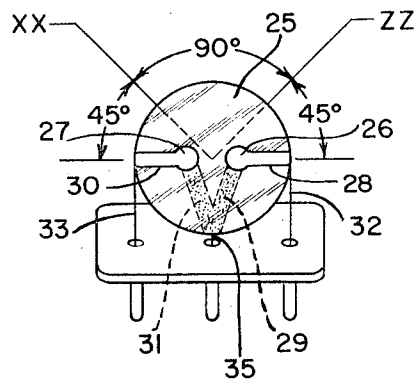


FIG. 3

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Filed Apr. 13, 1965, Ser. No. 447,626
9 Claims. (Cl. 310-9.5)

This invention relates generally to piezo-electric crystal devices, and more particularly to such a crystal device operating at a high order overtone for use in high frequency filter circuits.

Piezo-electric crystals have been used in filter circuits for many years. Such crystals have been used mainly in circuits operating at low frequencies below one megacycle. Problems have been encountered in providing crystal filters for operating at higher frequencies in the range from 7 megacycles to much higher frequencies, such as frequencies in the range from 135 to 175 megacycles, for example. For operation at these higher frequencies, AT-cut crystals may be used at odd order overtones such as the third, fifth and seventh overtones. In such operation, spurious responses have been produced by unwanted modes of operation of the crystals. These spurious responses may occur at frequencies relatively close to the frequency of operation, and thereby provide undesired response characteristics in the crystal filter circuits in which they are used.

It is, therefore, an object of the present invention to provide an improved crystal device for use in crystal filter circuits operating in the frequency range above 7 megacycles.

Another object of the invention is to provide a piezo-electric crystal device for operating at a high order overtone, such as the fifth or seventh, and in which spurious responses at frequencies adjacent the operating frequencies are of low amplitude.

Another object of the invention is to provide a crystal for overtone operation having a low series resistance at the frequency used and very high resistance at frequencies in the vicinity of the overtone frequency, at which unwanted modes of operation may appear.

A further object of the invention is to provide an overtone crystal for use in filter circuits wherein nonlinear diode effects are minimized.

A feature of this invention is the provision of an overtone crystal device including a flat circular AT-cut crystal blank with circular electrodes on the opposite flat faces thereof, and wherein the diameter of the crystal blank is no more than 8 times the diameter of the electrode. A plurality of electrodes may be placed on each flat face of the blank and in such case the diameter of the blank should be no more than 8 times the sum of the diameters of the electrodes on one side of the blank.

Another feature of the invention is the provision of a crystal device including a flat AT-cut crystal blank with electrodes on opposite faces, and a conducting shielding cover with conductors extending therefrom which are connected to the electrodes, and wherein the static capacity between the conductors is in the range from 0.9 to 1.1 micromicrofarads. The capacity between the conductors includes the capacity resulting from the size of the electrodes and the thickness of the blank, and in addition the capacity resulting from the action of the conducting shielding cover.

A further feature of the invention is the provision of a crystal device for operation at its seventh overtone in the frequency range from 135 to 175 megacycles, wherein the diameter of the blank lies in the range from .1 to .2 inch and the electrode diameter does not exceed .025 inch. The electrodes are formed on the crystal by a single

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plating so that there is no junction between dissimilar materials to provide a nonlinear diode effect.

The invention is illustrated in the drawing wherein:

FIG. 1 illustrates a crystal device in accordance with the invention having a single pair of electrodes;

FIG. 2 is a side view of the crystal device of FIG. 1; and

FIG. 3 illustrates a crystal device having a plurality of pairs of electrodes.

In practicing the invention there is provided a piezo-electric crystal device for operating at an overtone and to be used in a high frequency crystal filter circuit. The crystal blank is AT-cut so that the thickness determines the frequency of operation. The flat crystal blank is preferably circular in configuration with circular electrodes thereon. One or more pairs of electrodes may be applied, with each pair having electrodes positioned opposite each other on the flat sides of the blank. Electrodes are provided by plating a single material so there is no junction of dissimilar materials which will provide nonlinear diode effects. The crystal blank has a diameter in the range from 4 to 8 times the diameter of the electrode when a single electrode is provided on each side of the blank, and if a plurality of electrodes are provided the diameter of the blank should be in the range from 4 to 8 times the sum of the diameters of the electrodes on each side. The static capacity of the crystal device as evidenced at its terminals should be in the range from 0.9 to 1.1 micromicrofarads. This includes the capacity controlled by the diameter of the electrodes and the thickness of the crystal blank, and the additional capacity produced by the crystal enclosure. The thickness of the plating of the crystal is kept low, and in the construction of a crystal for operation in the range from 135 to 175 megacycles, for example, the thickness of the blank without plating should be at least 95 percent of the total thickness of the blank with the electrodes plated on the two sides thereof.

In the drawing, FIGS. 1 and 2 illustrate a crystal device in accordance with the invention. The crystal blank 10 is a thin plate of piezo-electric material having a circular periphery, and may be an AT-cut from a quartz crystal. An electrode 12 of a material such as aluminum is plated on each side of the crystal. The electrodes proper are of circular configuration and the electrodes on opposite sides are entirely coextensive. Extensions 13 on the platings form connections to the edge of the crystal blank 10. The crystal is supported on a base 15 through which conducting pins 16 extend for making electrical connections to the crystal electrodes, and also to provide a mechanical plug-in connection. Resilient wires 17 secured to the conducting pins 16 have clip portions 18 which extend on both sides of the crystal blank 10 to support the same. The clip portions engage the extensions 13 of the platings so that electrical connections are made to the two electrodes 12 on the opposite sides of the blank 10. A cover 20 is secured to the mounting base and forms an enclosure for the crystal. This is made of a conducting material to form a shield.

The crystal device is constructed to operate in an overtone made in a high frequency filter circuit. Unwanted modes of vibration producing spurious responses in the vicinity of the overtone are reduced by use of a crystal blank having a diameter no greater than 8 times the diameter of the electrodes 12, and preferably in the range from 4 to 8 times the electrode diameter. For operating at the seventh overtone in the frequency range from 135 to 175 megacycles, the diameter of the crystal blank may be in the range from .1 to .2 inch, with the electrode diameter not exceeding .025 inch. In such a crystal the series resistance at the seventh overtone is relatively low, being in the range between 200 and 600 ohms, and the resistance

for other modes of vibration in the vicinity of the seventh overtone is very high and may be greater than 100,000 ohms. This minimizes the spurious responses closely adjacent to the operating frequency.

It has been found that the static capacitance between the terminal 16 of the crystal device should be of the order of 0.9 to 1.1 micromicrofarads. This capacitance is made up of two main factors, the capacitance resulting from the electrodes with the crystal therebetween and the capacitance resulting from the coupling to the cover. The capacitance between the electrodes may be defined as D_e^2/T , where D_e is the diameter of the electrodes 12, and T is the thickness of the crystal blank 10. The static capacitance also includes the capacitance resulting from the coupling of the conducting cover to the electrodes and conductors extending therefrom. The two elements of capacity may be on the same order of magnitude.

Another factor which may be of importance in minimizing the spurious responses is to hold the thickness of the electrodes to a minimum value which provides reliable plated electrodes on the crystal blank. For crystals operating in the frequency range from 135 to 175 megacycles, the thickness of the plating should be such that the thickness T of the crystal blank alone is at least 95 percent of the total thickness TP of the blank and platings.

In FIG. 3 there is illustrated another embodiment of the invention, and in this construction the crystal may operate as two separate sections with the sections having the same, or somewhat different frequency responses. The crystal blank 25 has thereon a first set of electrodes 26 which are of circular configuration and coextensive on the two sides of the crystal blank, and a second set of electrodes 27 which are similarly coextensive on the two sides of the blank. The electrodes are plated on the blank, and the platings extend from the electrode 26 on one side to form a connector 28 thereto, and from the electrode 26 on the other side of the crystal blank to form connector 29. Similarly connectors 30 and 31 extend from the electrodes 27. The connector extensions 28 and 30 may be engaged by clips of supporting wires 32 and 33 as in the structure of FIG. 1. The connectors 29 and 31 join together and are connected to a third supporting wire 35 which may also be of the same construction as in FIG. 1. If desired, the connectors 29 and 31 can be separate and engaged by separate clips, but in many applications one electrode of each section may be held at a common potential.

In the structure of FIG. 3 the same basic considerations apply as set forth in connection with the structure of FIG. 1. By control of the thickness of the plating of the electrodes, the two crystal sections may have series resonant frequencies spaced from each other. The sections can then be used in a bandpass crystal filter circuit. The two sets of electrodes are mounted on the crystal blank at approximately 45° with respect to the XX or electrical axis of the quartz blank, and also 45° with respect to the ZZ or optical axis of the blank. This reduces the coupling between the sections. In order to reduce undesired spurious responses, the ratio of the diameters of the blank and the electrode must take into account the two electrodes on each side of the blank. The diameter of the blank should be 4 to 8 times twice the diameter of the individual electrodes, or 4 to 8 times the sum of the diameters of the two electrodes on each side. For operating in the frequency range between 135 and 175 megacycles, the diameter of the blank may be .400 inch and the diameter of each electrode may be .025 inch. The capacity between the contact pins connected to each pair of electrodes should be within the range of 0.9 to 1.1 micromicrofarads.

It may be desired in certain instances to provide more than two pairs of electrodes on a crystal blank. It would be possible to provide 4 pairs of electrodes, with the third and fourth pairs positioned along a line at right angles to the line through the first and second pairs as shown in FIG. 3. Then each pair would be at 45° to both the elec-

trical and optical axis of the crystal blank. In such case the diameter of the blank should be from 4 to 8 times the sum of the diameters of the four electrodes on each side of the blank, or 4 to 8 times 4 times the diameter of each electrode. The plating extensions forming connections to the electrodes should be arranged so that they are not directly opposite each other on the two sides of the blank, and can be entirely separate or joined in pairs as may be desired for particular circuit applications. The crystal device would therefore act as four separate crystal sections and could be used in a four crystal filter circuit.

The additional plating on the crystal blank providing a plurality of electrodes, and for the connectors therefor, acts to stiffen the crystal blank. This increases the power handling capability of the blank. It may be desired to apply platings which are not connected in a circuit to provide added stiffness to the crystal blank.

Crystals constructed as has been described have operated at high frequencies and have been substantially free of spurious response. Such crystal have operated satisfactorily in the frequency range between 135 and 175 megacycles. Filter circuits using a plurality of crystal sections on a single blank, as described, have provided the desired characteristics.

We claim:

1. A crystal device including in combination, a thin flat AT-cut crystal blank having a circular periphery, first and second electrodes of circular configuration secured to opposite flat sides of said blank, a mounting base, support means for said blank including first and second conductors connected respectively to said first and second electrodes, said conductors being supported by said mounting base and having portions extending there-through for connection to a circuit, and conducting cover means supported by said mounting base and cooperating therewith to enclose said crystal blank and said electrodes, said crystal blank having a diameter in the range from 4 to 8 times the diameter of each electrode, and the static capacity between said conductors including the capacity between said electrodes with the blank therebetween, and the capacity resulting from said cover, being in the range from 0.9 to 1.1 micromicrofarads.

2. A crystal device for operating in the frequency range from 135 to 175 megacycles including in combination, a thin flat AT-cut crystal blank having a circular periphery, first and second electrodes of circular configuration secured to opposite flat sides of said blank, said electrodes being formed by conductive platings on said blank which have portions extending from said electrodes, a mounting base, support means for said blank including first and second conductors supported by said mounting base and having portions extending there-through for connection to a circuit, resilient conducting wires connected to said first and second conductors and supporting said blank and engaging said portions extending from said first and second electrodes respectively and conducting cover means supported by said mounting base and cooperating therewith to enclose said crystal blank and said electrodes, said crystal blank having a diameter in the range from 4 to 8 times the diameter of each electrode, and the thickness of said blank alone being at least 95 percent of the total thickness of said blank and said platings thereon.

3. A crystal device including in combination, a thin flat AT-cut crystal blank having a circular periphery, first and second electrodes of circular configuration secured to opposite flat sides of said blank, said electrodes being formed by conductive platings on said blank which have portions extending from said electrodes, a mounting base, support means for said blank including first and second conductors supported by said mounting base and having portions extending there-through for connection to a circuit, resilient conducting wires connected to said first and second conductors and supporting said blank

and engaging respectively said portions extending from said first and second electrodes, and conducting cover means supported by said mounting base and cooperating therewith to enclose said crystal blank and said electrodes, said crystal blank having a diameter in the range from 4 to 8 times the diameter of each electrode, the static capacity between said conductors including the capacity between said electrodes with the blank therebetween and the capacity resulting from said cover being in the range from 0.9 to 1.1 micromicrofarads, and the thickness of said blank alone being at least 95 percent of the total thickness of said blank and said platings thereon.

4. A crystal device for operating in the frequency range from 135 to 175 megacycles including in combination, a flat AT-cut crystal blank having a circular periphery, first and second electrodes of circular configuration secured to opposite flat sides of said blank, a mounting base, support means for said blank including first and second conductors connected respectively to said first and second electrodes, said conductors being supported by said mounting base and having portions extending therethrough for connection to a circuit, and conducting cover means supported by said mounting base and cooperating therewith to enclose said crystal blank and said electrodes, said crystal blank having a diameter in the range from 0.1 to 0.2 inch and the diameter of each electrode being no greater than 0.25 inch.

5. A crystal device for operating in the frequency range from 135 to 175 megacycles including in combination, a flat AT-cut crystal blank having a circular periphery, first and second electrodes of circular configuration secured to opposite flat sides of said blank, a mounting base, support means for said blank including first and second conductors connected respectively to said first and second electrodes, said conductors being supported by said mounting base and having portions extending therethrough for connection to a circuit, and conducting cover means supported by said mounting base and cooperating therewith to enclose said crystal blank and said electrodes, said crystal blank having a diameter in the range from 0.1 to 0.2 inch and the diameter of each electrode being no greater than .025 inch, the static capacity between said conductors including the capacity between said electrodes with the blank therebetween and the capacity resulting from said cover being in the range from 0.9 to 1.1 micromicrofarads.

6. A crystal device including in combination, a flat AT-cut crystal blank having a circular periphery, a plurality of electrodes of circular configuration positioned in pairs on opposite sides of said blank, a mounting base, support means for said blank including a plurality of conductors connected to said electrodes and supported by said mounting base, said conductors having portions extending through said mounting base for connection to a circuit, and cover means supported by said mounting base and cooperating therewith to enclose said crystal blank, said crystal blank having a diameter in the range from 4 to 8 times the sum of the diameters of the electrodes on one side of said blank, and the capacity between said conductors connected to each pair of electrodes including the capacity between said electrodes with the blank therebetween and the capacity resulting from said cover being in the range from 0.9 to 1.1 micromicrofarads.

7. A crystal device including in combination, a flat AT-cut crystal blank having a circular periphery, a plurality of electrodes of circular configuration positioned in pairs on opposite sides of said blank, said electrodes being formed by conductive platings on said blank which have portions extending from said electrodes, a mounting base, support means for said blank including a plurality

of conductors engaging said plating extensions and mechanically connected to said blank and supported by said mounting base, said conductors having portions extending through said mounting base for connection to a circuit, and cover means supported by said mounting base and cooperating therewith to enclose said crystal blank, said crystal blank having a diameter in the range from 4 to 8 times the sum of the diameters of the electrodes on one side of said blank, and the static capacity between said conductors connected to each pair of electrodes including the capacity between said electrodes with the blank therebetween and the capacity resulting from said cover being in the range from 0.9 to 1.1 micromicrofarads.

8. A crystal device for operating in the frequency range from 135 to 175 megacycles including in combination, a flat AT-cut crystal blank having a circular periphery, first and second pairs of electrodes of circular configuration positioned each having an electrode on each flat side of said blank, said electrodes being formed by conductive platings on said blank which have portions extending from said electrodes, a mounting base, support means for said blank including a plurality of conductors engaging said plating extensions and mechanically connected to said blank and supported by said mounting base, said conductors having portions extending through said mounting base for connection to a circuit, and cover means supported by said mounting base and cooperating therewith to enclose said crystal blank, said crystal blank having a diameter in the range from .2 to .4 inch, and the diameter of each electrode being no greater than .025 inch, and the static capacity between said conductors connected to each pair of electrodes including the capacity between said electrodes with the blank therebetween and the capacity resulting from said cover being in the range from 0.9 to 1.1 micromicrofarads.

9. A crystal device for operating in the frequency range from 135 to 175 megacycles including in combination, a flat AT-cut crystal blank having a circular periphery, a plurality of electrodes of circular configuration positioned in pairs on opposite sides of said blank, said electrodes being formed by conductive platings on said blank which have portions extending from said electrodes, a mounting base, support means for said blank including a plurality of conductors engaging said plating extensions and mechanically connected to said blank and supported by said mounting base, said conductors having portions extending through said mounting base for connection to a circuit, and cover means supported by said mounting base and cooperating therewith to enclose said crystal blank, said crystal blank having a diameter in the range from 4 to 8 times the sum of the diameters of the electrodes on one side of said blank, the static capacity between said conductors connected to each pair of electrodes including the capacity between said electrodes with the blank therebetween and the capacity resulting from said cover being in the range from 0.9 to 1.1 micromicrofarads, and the thickness of said blank alone being at least 95 percent of the total thickness of said blanks and said platings thereon.

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