

# PATENT SPECIFICATION (11)

1 465 863

(21) Application No. 968/75 (22) Filed 9 Jan. 1975 (19)

(31) Convention Application Nos. 49/005 773 (32) Filed 9 Jan. 1974  
49/107 989 19 Sept. 1974 in

(33) Japan (JA)

(44) Complete Specification published 2 March 1977

(51) INT. CL.<sup>2</sup> H03H 9/10 9/20

(52) Index at acceptance

H1E 1



## (54) IMPROVEMENTS RELATING TO PIEZO-ELECTRIC TUNING FORK VIBRATORS

(71) We, KABUSHIKI KAISHA SUWA SEIKOSHA, a Japanese Company of 3-4, 4-chome, Ginza, Chuo-ku, Tokyo, Japan, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention concerns improvements relating to piezo-electric tuning fork vibrators.

The object of the present invention is to provide a vibrator assembly in which the vibrator is carried by a support in such a way that the vibrator is unlikely to be damaged by reason of a difference of the coefficients of thermal expansion of the vibrator and the support.

According to the present invention there is provided a vibrator assembly comprising a case within which is disposed a piezo-electric tuning fork vibrator formed from a quartz crystal plate having a thickness not exceeding 0.5 mm, the vibrator being carried by and secured to the case by a plurality of electrically conductive pins which are electrically connected to electrodes on the vibrator and which extend through and are supported by a wall of the case.

Preferably, the vibrator has one or more planar surfaces at least one of which has electrodes of opposite polarities disposed thereon.

All the electrodes of the vibrator may be connected to the pins by means of electrically conductive solder.

A surface of the vibrator may be mounted on the pins. For example, the last-mentioned surface of the vibrator may be mounted on and supported by flat surfaces on the pins.

Alternatively, the vibrator may be mounted in grooves in the pins.

The pins may be L-shaped or T-shaped.

The vibrator may have been cut from a piece of quartz crystal plate with directional angles the same as those of the plate which is obtained by between 0° and 10° rotation of an X-cut plate about the X axis followed by 70° to 90° rotation about the Y<sup>1</sup> axis.

The vibrator is preferably provided with electrodes on each of two planes which are parallel to the mean plane about which the vibrator vibrates.

At least one planar surface of the vibrator may be provided with two electrodes a portion of each of which is almost completely surrounded by a part of the other electrode, each said electrode portion being carried by a respective fork of the vibrator.

The invention also comprises a timepiece provided with a vibrator assembly as set forth above.

The invention is illustrated, merely by way of example, in the accompanying drawings, in which:—

Figure 1 is a perspective view, looking from above, of a known vibrator assembly incorporating a first vibrator,

Figure 2 is a perspective view of the base of the said first vibrator,

Figure 3 is a diagrammatic view which illustrates the manner in which the said first vibrator is cut from a sheet of quartz crystal material,

Figure 4 is a diagrammatic view which illustrates the manner in which the said first vibrator is driven,

Figure 5 is a perspective view, taken from above, of a vibrator assembly incorporating a second vibrator,

Figure 6 is a perspective view of the base of the said second vibrator,

Figure 7 is a diagrammatic view illustrating the manner in which the said second vibrator is cut from a sheet of quartz-crystal material,

Figure 8 is a diagrammatic view which illustrates the manner in which the said second vibrator is driven,

Figure 9a is a perspective view of a case for housing a vibrator,

Figure 9b is a view similar to Figure 9a but showing a vibrator in position in the case,

Figures 10a and 10b are respectively a perspective view and a broken-away sectional view of a first embodiment of a vibrator assembly according to the present invention,

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Figures 11a and 11b are diagrammatic plan views showing parts of the said first embodiment at two different temperatures.

Figures 12a and 12b are respectively broken away sectional views of second and third embodiments of a vibrator assembly according to the present invention.

Figures 13 and 14 are exploded perspective views of parts of vibrator assemblies according to the present invention to illustrate the manner in which the latter may be made.

Figures 15a and 15b are respectively a plan view and a broken-away sectional view of a fourth embodiment of a vibrator assembly according to the present invention.

Figures 16a and 16b are respectively a plan view and a broken-away cross-sectional view of a fifth embodiment of a vibrator assembly according to the present invention.

Figures 17a and 17b are respectively a plan view and a broken-away cross-sectional view of a sixth embodiment of a vibrator assembly according to the present invention.

Figure 18 is a perspective view of a seventh embodiment of a vibrator assembly according to the present invention.

Figures 19a and 19b are respectively a plan view and a broken-away cross-sectional view of an eighth embodiment of a vibrator assembly according to the present invention, and

Figures 20a and 20b are respectively a plan view and a broken-away cross-sectional view of a ninth embodiment of a vibrator assembly according to the present invention.

In Figure 1 there is shown a known vibrator assembly 21 which comprises a piezo-electric tuning fork vibrator 22 which is photo-chemically etched from an NT-cut quartz crystal plate having a thickness of several tens of microns. The vibrator 22 is provided with two forks 23, 24.

The upper surface of the vibrator 22 is provided with two electrodes 25, 26 portions of each of which extend throughout the forks 23, 24. The electrodes 25, 26 have terminal portions 30, 31 which are respectively bonded to wires 32, 33 by means of which the terminal portions 30, 31 are electrically connected to terminals 34, 35, respectively.

The base of the vibrator 22 is provided with a single electrode 36 having portions extending throughout the forks 23, 24. The electrode 36 is provided with a terminal portion 40 which is secured to an electrically conductive support 41, e.g. by means of an electrically conductive alloy solder, whereby the support 41 acts as an electrode terminal.

The electrodes 25, 26, 36 are employed for applying an electric field to the vibrator 22.

A quartz crystal vibrator assembly as shown in Figures 1 and 2 may be thin and small in size and, as such, is suitable

as the time standard of a timepiece such as a quartz crystal wrist watch. Moreover, such a quartz crystal vibrator may be made highly accurate, and, as it may be made by photographic and chemical etching techniques, it is suitable for mass production and is thus of low cost.

Figure 3 illustrates the manner in which the vibrator 22 is cut from a plate 42 of quartz crystal material. The crystal plate 42 and its directional angles the same as those of the plate which is obtained from an X-cut plate after 2 rotations. The first rotation is about the X axis and is made through an angle  $\alpha$  ranging from  $0^\circ$  to  $10^\circ$ . The second rotation is about the  $Y'$  axis and is made through an angle  $\beta$ , ranging from  $55^\circ$  to  $70^\circ$ .

Accordingly, when the electrodes 25, 26, 36 are supplied with electric potential as indicated in Figure 4, the vibrator 22 begins to vibrate in the tuning fork mode. In order to simplify Figure 4,  $\alpha$  is given the value  $0^\circ$ . As shown in Figure 4, however, all that is available for driving the vibrator 22 are the X-components 43, 44 of electric fields 45, 46.

Accordingly, when the angle  $\beta$  is made large, the dynamic impedance is high since it is inversely proportional to  $\cos^2\beta$ . Moreover, in order to be stable in various ambient temperatures, the vibrator should have its zero frequency temperature coefficient at about room temperature.

Thus the larger the angle  $\beta$ , the higher is the temperature at which the zero frequency temperature coefficient will be obtained. Thus an angle  $\beta$  of  $75^\circ$ , corresponds to a temperature of  $20^\circ\text{C}$ , and in this case the dynamic impedance will be 1 megohm or more. Accordingly, in order to satisfy the condition that the temperature at which the zero temperature coefficient necessary for the quartz crystal vibrator is obtained is about  $25^\circ\text{C}$ , the angle  $\beta$  must be substantially larger than  $75^\circ$ , in which case the dynamic impedance will amount to several tens of megohms. Accordingly, it is impossible to use the vibrator 22 is a wrist watch.

In Figure 5 there is shown a perspective view of a vibrator assembly which comprises a thin piezo-electric tuning fork vibrator 50 which has been produced by photo-chemical etching and whose thickness does not exceed 0.5 millimetres and is preferably less than 200 microns. The upper surface of the vibrator 50 is provided with two electrodes 51, 52 of opposite polarities. The electrode 51 has one portion 53 which extends throughout one fork 54 of the vibrator 50, and another portion 55 which extends throughout the greater part of the length of another fork 56 of the vibrator 50. Similarly, the vibrator 52 has a portion 60 which extends throughout the length of

the fork 56, and a portion 61 which extends throughout the greater part of the length of the fork 54. As clearly shown in Figure 5, the portion 55 of the electrode 51 is almost completely surrounded by the portion 60 of the electrode 52, while the portion 57 of the electrode 52 is almost completely surrounded by the portion 53 of the electrode 51.

Similarly, as shown in Figure 6, the base of the vibrator 50 is provided with electrodes 61, 62 of opposite polarities, the electrode 61 having a portion 63 which extends almost throughout the length of the fork 56, and a portion 64 which extends throughout the length of the fork 54. The electrode 62 has a portion 65 which extends throughout the length of the fork 56, and a portion 66 which extends throughout the greater part of the length of the fork 54. As seen in Figure 6, the portion 63 of the electrode 61 is almost completely surrounded by the portion 65 of the electrode 62, while the portion 66 of the electrode 65 is almost completely surrounded by the portion 64 of the electrode 61.

The vibrator 50 is thus provided with electrodes 51, 52, 61, 62 on each of the two planes which are parallel to the mean plane about which the vibrator vibrates.

The electrodes 51, 52 respectively have terminal portions 70, 71 which are bonded to wires 72, 73 respectively which respectively extend to terminals 74, 75.

The electrodes 61, 62 on the base of the vibrator 50 are respectively provided with terminal portions 76, 77 which are electrically connected to and are adhered to electrically conductive metallic films 80, 81. The latter are spaced apart from each other and are provided on a common insulating support 82, e.g. by deposition or sintering. The wires 72, 73, which electrically interconnect the terminal portions 70, 71 and the terminals 74, 75, are also connected to the films 80, 81.

As illustrated in Figure 7, the vibrator 50 is cut from a sheet or plate 83 of quartz crystal material. The crystal plate 83 has its directional angles the same as those of the plate which is obtained from an X-cut plate after 2 rotations. The first rotation is about the X axis 4 is made through  $0^\circ$  to  $10^\circ$ . The second rotation is about the Y<sup>1</sup> axis and is made through an angle of  $70^\circ$  to  $90^\circ$  ( $90^\circ$  in present figure for simplification).

As indicated in Figure 8, when the vibrator 50 is driven, its internal electric fields are parallel to the X axis as indicated by arrows. By reason of the shape and relative disposition of the electrodes of the vibrator 50 as illustrated in Figure 8, the dynamic impedance of the vibrator 50 is about 50 kilohms, and is thus very much smaller

than that of the vibrator 22 of Figures 1 and 2. Moreover, the temperature at which the temperature coefficient will be zero, can be given any value between  $20^\circ\text{C}$  and  $40^\circ\text{C}$ , merely by appropriate alteration of the value of the angle  $\alpha$ . Thus the vibrator 50 shown in Figures 5 and 6 has a good performance and can be made quite small so that it is extremely suitable for use as a quartz crystal vibrator for a wrist watch.

However, as illustrated in Figure 5, it is necessary in the case of the vibrator 50 to have leads extending to the electrodes of the two polarities not only from the base of the vibrator but also from its upper surface. Accordingly, a conventional mounting in which the whole of the base of the vibrator is secured to the mounting cannot be used.

As will be appreciated, the manner in which the vibrator 22 is mounted on the support 41, and the manner in which the vibrator 50 is mounted on the support 82 makes miniaturisation difficult and involves expensive bonding procedures. Moreover, in order to keep the vibrator stable against changes of temperature, it is necessary to ensure, in the construction of Figures 1 and 5, that the thermal expansion coefficients of the support and the vibrator are close to each other since otherwise the vibrator will crack during relative expansion or contraction.

Quartz crystal piezo electric tuning fork vibrators have previously been mounted in metallic cases. However, a further reduction in the size of the vibrator assembly is possible if an integrated circuit which co-operates therewith is contained in the same case. If this is done, however, it is advantageous if the case is made of an insulator such as a ceramics material in view of the need to lead out the leads through the case. Such a case may, for example, be constructed as shown in Figure 9a where a case 84 of ceramics material is shown as being provided with a step 85 the upper surface of which has been provided with two discrete metallic films 86, 87. The films 86, 87 may for example be a powdered material which have been sintered onto the step 85. The films 86, 87 are respectively electrically connected to the exterior of the ceramics case 84 by means (not shown) which extend through a wall of the case 84.

In Figure 9b the case 84 is shown as being provided with a vibrator 50 as illustrated in Figures 5 and 6. However, if the case 84 is made of an alumina ceramic having a thermal expansion coefficient of about  $7 \times 10^{-6}/^\circ\text{C}$ , while the thermal expansion coefficient of the Z plate quartz crystal is about  $13 \times 10^{-6}/^\circ\text{C}$ , since the vibrator and the case have such different thermal expansion coefficients it follows that when the vibrator is cooled after it has been

soldered to the case the strains set up in the quartz crystal material may cause it to break. On the other hand, no ceramic material is known having both a sufficiently high thermal expansion coefficient and other characteristics such as to match it suitably to the material of the vibrator. Thus it is not practicable to mount the vibrator 50 by a mounting of the kind shown in Figures 9a and 9b.

In Figures 10a and 10b, therefore, there is shown a first embodiment of a vibrator assembly according to the present invention in which a vibrator 50 as shown in Figures 5 and 6 is mounted within a ceramic case 90 and is carried by and secured to the case 90 by way of two metallic or other electrically conductive pins 91. The pins 91 are electrically connected by way of electrically conductive solder 92 to the electrodes 61, 62 which are provided on the base of the vibrator 50, and the pins 91 are also connected (either by the solder 92 or by means not shown) to the electrodes 51, 52. The pins 91 thus act as electrode leads, while the base of the vibrator is mounted on the pins 91. As shown in Figures 10a and 10b, the pins 91 extend through and are supported by a wall 94 of the case 90.

The pins 91 are of cylindrical shape, but at least their end portions 93 are provided with flat surfaces on which the base of the vibrator 50 is mounted and supported.

Figures 11a and 11b are plan views of part of the construction of Figures 10a and 10b at an higher operating temperature and at a lower temperature respectively. Since the coefficient of thermal expansion of the ceramics forming the side wall 94 of the case 90 is lower than that of the quartz crystal vibrator 50, the quartz crystal vibrator 50 contracts more than the side wall 94 when the whole vibrator assembly cools. However, as shown exaggeratedly in Figure 11b, the strains set up by the difference in the coefficients of thermal expansion of the side wall 94 and the vibrator 50, merely cause bending of the pins 91 so that the risk that the vibrator 50 will crack is reduced.

In the construction of Figures 10a and 10b, the pins 91 pass through a side wall of the case 90. However, these pins may pass through any wall of the case 90, as is illustrated in Figures 12a and 12b where the pins pass through the base 95 of the case 90.

Thus in the construction of Figure 12a, L-shaped metallic pins 96 are employed which pass through and are supported in the base 95, while in Figure 12b, T-shaped metallic pins 96 are employed which pass through and are supported in the base 95. Thus the strains which are set up during cooling are, in the case of the constructions shown in Figures 12a and 12b relieved by

the torsion and bending of the pins 96, 97. Both the pins 96 and the pins 97 have flat top surfaces.

The pins 91, 96, 97 also act as shock absorbers tending to prevent any shock which is applied to the case 90 from being transmitted completely to the vibrator 50.

As shown in Figure 13, the case 90 may comprise an upper portion 100 and a lower portion 101 each of which is made separately of ceramic material. Flat pins 102, or pins having flat end portions, are introduced between the upper and lower portions 100, 101 and the parts 100, 101, 102 are then hermetically sealed to each other by using glass (not shown) therebetween. This therefore produces a case in which the pins 102 are effectively integral therewith and in which there is air-tightness between the pins and the case.

Alternatively, as shown in Figure 14, a one-piece ceramics case 103 may be provided which is initially formed with through-holes 104. Cylindrical pins 105, having flattened end portions 106, are thereafter mounted in the through-holes 104 and are hermetically sealed therein by pouring glass (not shown) into the very narrow gap between the pins 105 and the case 103.

Although the case described above has been described as being formed of a ceramic material it may in fact be made of other materials e.g. a metallic material. For example a metallic case may be employed whose thermal expansion coefficient is higher than that of the quartz crystal vibrator mounted within it, the pins being insulated from such a metallic case.

In Figures 15a and 15b there is shown a construction which is similar to that of Figures 10a and 10b and which for this reason will not be described in detail, like reference numerals indicating like parts.

In the construction of Figures 15a and 15b however, flat metallic pins 105 are employed the end portions of which are both mechanically and electrically connected to the vibrator 50 by means of electrically conductive solder 106 which engages both the upper surface, the base and an end surface of the vibrator 50. Thus the electrodes on both the base and the upper surface of the vibrator 50 are electrically connected by the solder 106 to the respective pins 105.

In Figures 16a and 16b there is shown a construction which is generally similar to that of Figure 12a and which for that reason will not be described in detail, like reference numerals indicating like parts. In the construction of Figures 16a and 16b, however, flat metallic pins 107 are employed which are electrically and mechanically connected to the vibrator 50 by means of electrically conductive solder 108 which, like the solder 106 of Figures 15a and 15b engages the

upper surface, the base, and the end surface of the vibrator 50 and is thus electrically connected to electrodes both on the base and on the upper surface of the vibrator 50.

Although the pins 105 and 107 have been described above as being flat, it is alternatively possible to arrange that they are round pins whose end portions are flattened.

In Figures 17a and 17b there is shown a construction which is generally similar to that of Figure 12b and which for this reason will not be described in detail, like reference numerals indicating like parts. In the case of the construction of Figures 17a and 17b, however, portions of the metallic pins 97 extend outwardly of the vibrator 50, while the pins 97 are connected both electrically and mechanically to the vibrator 50 by means of electrically conductive solder 110 a portion of which engages the upper surface of the vibrator 50 and some of which engages the base of the vibrator 50 so that the respective electrodes on the upper surface on the base of the vibrator 50 are electrically connected to the respective pin 97. The pins 97 are of cylindrical shape but are flattened at their tops to provide the T-section shown in Figure 17b.

In Figure 18 there is shown a vibrator assembly comprising a vibrator 50 of the kind illustrated in Figures 5 and 6. The vibrator 50, however, is mounted in grooves 111 in two spaced apart cylindrical metallic pins 112, to which they are secured by means of electrically conductive solder (not shown) or other electrically conductive materials. The pins 112 pass through and are hermetically sealed to a ceramic support 113 which is itself hermetically sealed (by means not shown) to a case 114 within which the vibrator 50 is mounted. As will be appreciated, the construction of Figure 18 is such that the respective electrodes on the base and on the front surface of the vibrator 50 are each connected to the respective pin 112.

In Figures 19a and 19b there is illustrated a further embodiment of the present invention, the vibrator 50 being mounted within a ceramic case 115 (Figure 19b). The vibrator 50 is mounted in horizontally extending grooves 116 in straight metallic pins 117 which extend through and are supported in the base 118 of the case 115.

In Figures 20a and 20b there is shown a construction generally similar to that of Figures 19a and 19b and which for this reason will not be described in detail, like reference numerals indicating like parts.

In the construction of Figures 20a and 20b, however, the straight pins 117 of the construction of Figures 19a and 19b are replaced by pins 120 which are bent to an L-section. In this construction it is possible to make the case into a thin rectangular box.

In the constructions shown in the drawings, the vibrator 50 is directly secured to the respective pins, but if desired the vibrator 50 could be secured to the pins through the intermediary of another part. The pins themselves, moreover, are not necessarily integral members, but may be made up of a plurality of parts which are secured together.

It is also possible to use three or more pins instead of the two pins shown in the constructions illustrated, while the piezo electric material, instead of being quartz, could be lithium trantalate or a piezo ceramic material.

Since the strain caused by the difference in the coefficients of thermal expansion between the case and the vibrator can be absorbed by deformation of the pins, while any shock applied to the case is prevented from being directly transmitted to the vibrator, the construction is highly suitable for use in a small wrist watch.

#### WHAT WE CLAIM IS:—

1. A vibrator assembly comprising a case within which is disposed a piezo-electric tuning fork vibrator formed from a quartz crystal plate having a thickness not exceeding 0.5 mm, the vibrator being carried by and secured to the case by a plurality of electrically conductive pins which are electrically connected to electrodes on the vibrator and which extend through and are supported by a wall of the case.

2. A vibrator assembly as claimed in claim 1 in which the vibrator has one or more planar surfaces at least one of which has electrodes of opposite polarities disposed thereon.

3. A vibrator assembly as claimed in claim 1 or 2 in which all the electrodes of the vibrator are connected to the pins by means of electrically conductive solder.

4. A vibrator assembly as claimed in any preceding claim in which a surface of the vibrator is mounted on the pins.

5. A vibrator assembly as claimed in claim 4 in which the last-mentioned surface of the vibrator is mounted on and supported by flat surfaces on the pins.

6. A vibrator assembly as claimed in any of claims 1 to 3 in which the vibrator is mounted in grooves in the pins.

7. A vibrator assembly as claimed in any preceding claim in which the pins are L-shaped or T-shaped.

8. A vibrator assembly as claimed in any preceding claim in which the vibrator has been cut from a piece of quartz crystal plate with directional angles the same as those of the plate which is obtained by between 0° and 10° rotation of an X-cut plate about the X-axis followed by 70° to 90° rotation about the Y<sup>1</sup> axis.

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upper surface, the base, and the end surface of the vibrator 50 and is thus electrically connected to electrodes both on the base and on the upper surface of the vibrator 50.

Although the pins 105 and 107 have been described above as being flat, it is alternatively possible to arrange that they are round pins whose end portions are flattened.

In Figures 17a and 17b there is shown a construction which is generally similar to that of Figure 12b and which for this reason will not be described in detail, like reference numerals indicating like parts. In the case of the construction of Figures 17a and 17b, however, portions of the metallic pins 97 extend outwardly of the vibrator 50, while the pins 97 are connected both electrically and mechanically to the vibrator 50 by means of electrically conductive solder 110 a portion of which engages the upper surface of the vibrator 50 and some of which engages the base of the vibrator 50 so that the respective electrodes on the upper surface on the base of the vibrator 50 are electrically connected to the respective pin 97. The pins 97 are of cylindrical shape but are flattened at their tops to provide the T-section shown in Figure 17b.

In Figure 18 there is shown a vibrator assembly comprising a vibrator 50 of the kind illustrated in Figures 5 and 6. The vibrator 50, however, is mounted in grooves 111 in two spaced apart cylindrical metallic pins 112, to which they are secured by means of electrically conductive solder (not shown) or other electrically conductive materials. The pins 112 pass through and are hermetically sealed to a ceramic support 113 which is itself hermetically sealed (by means not shown) to a case 114 within which the vibrator 50 is mounted. As will be appreciated, the construction of Figure 18 is such that the respective electrodes on the base and on the front surface of the vibrator 50 are each connected to the respective pin 112.

In Figures 19a and 19b there is illustrated a further embodiment of the present invention, the vibrator 50 being mounted within a ceramic case 115 (Figure 19b). The vibrator 50 is mounted in horizontally extending grooves 116 in straight metallic pins 117 which extend through and are supported in the base 118 of the case 115.

In Figures 20a and 20b there is shown a construction generally similar to that of Figures 19a and 19b and which for this reason will not be described in detail, like reference numerals indicating like parts.

In the construction of Figures 20a and 20b, however, the straight pins 117 of the construction of Figures 19a and 19b are replaced by pins 120 which are bent to an L-section. In this construction it is possible to make the case into a thin rectangular box.

In the constructions shown in the drawings, the vibrator 50 is directly secured to the respective pins, but if desired the vibrator 50 could be secured to the pins through the intermediary of another part. The pins themselves, moreover, are not necessarily integral members, but may be made up of a plurality of parts which are secured together.

It is also possible to use three or more pins instead of the two pins shown in the constructions illustrated, while the piezo electric material, instead of being quartz, could be lithium trantalate or a piezo ceramic material.

Since the strain caused by the difference in the coefficients of thermal expansion between the case and the vibrator can be absorbed by deformation of the pins, while any shock applied to the case is prevented from being directly transmitted to the vibrator, the construction is highly suitable for use in a small wrist watch.

#### WHAT WE CLAIM IS:—

1. A vibrator assembly comprising a case within which is disposed a piezo-electric tuning fork vibrator formed from a quartz crystal plate having a thickness not exceeding 0.5 mm, the vibrator being carried by and secured to the case by a plurality of electrically conductive pins which are electrically connected to electrodes on the vibrator and which extend through and are supported by a wall of the case.

2. A vibrator assembly as claimed in claim 1 in which the vibrator has one or more planar surfaces at least one of which has electrodes of opposite polarities disposed thereon.

3. A vibrator assembly as claimed in claim 1 or 2 in which all the electrodes of the vibrator are connected to the pins by means of electrically conductive solder.

4. A vibrator assembly as claimed in any preceding claim in which a surface of the vibrator is mounted on the pins.

5. A vibrator assembly as claimed in claim 4 in which the last-mentioned surface of the vibrator is mounted on and supported by flat surfaces on the pins.

6. A vibrator assembly as claimed in any of claims 1 to 3 in which the vibrator is mounted in grooves in the pins.

7. A vibrator assembly as claimed in any preceding claim in which the pins are L-shaped or T-shaped.

8. A vibrator assembly as claimed in any preceding claim in which the vibrator has been cut from a piece of quartz crystal plate with directional angles the same as those of the plate which is obtained by between 0° and 10° rotation of an X-cut plate about the X-axis followed by 70° to 90° rotation about the Y<sup>1</sup> axis.



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9. A vibrator assembly as claimed in any preceding claim in which the vibrator is provided with electrodes on each of two planes which are parallel to the mean plane about which the vibrator vibrates.

10. A vibrator assembly as claimed in any preceding claim in which at least one planar surface of the vibrator is provided with two electrodes a portion of each of which is almost completely surrounded by a part of the other electrode, each said electrode portion being carried by a respective fork of the vibrator.

11. A vibrator assembly substantially as hereinbefore described with reference to and as shown in Figures 10a to 20b of the accompanying drawings.

12. A timepiece provided with a vibrator assembly as claimed in any preceding claim.

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Printed for Her Majesty's Stationery Office by Burgess & Son (Abingdon), Ltd.—1977.  
Published at The Patent Office, 25 Southampton Buildings, London, WC2A 1AY  
from which copies may be obtained.

