

## PATENT SPECIFICATION

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(54) METHOD OF ADJUSTING A GT-CUT  
 QUARTZ CRYSTAL OSCILLATOR

(71) We, KABUSHIKI KAISHA SEIKOSHA, a Japanese Company of 2-5, Kyobashi, 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:—

adjustment of a GT-cut quartz crystal oscillator;

Figure 5 illustrates a GT-cut quartz crystal oscillator according to the present invention;

Figure 6 is a plan view of a quartz crystal blank of the GT-cut quartz crystal oscillator of Figure 5;

Figure 7 is a plan view of the quartz crystal blank of Figure 6 with an electrode film formed thereon; and

Figures 8 and 9 are views of the quartz crystal blank of Figure 7 after adjustment.

The frequency temperature characteristics of a GT-cut quartz crystal oscillator are a function of the coupling between shorter side vibrations and longer side vibrations. The coupling can be changed by polishing a shorter side or a longer side as desired temperature characteristics are obtained at an optimum side ratio which is the ratio between the length of the shorter side and the length of the longer side. In particular, a GT-cut quartz crystal oscillator employs the shorter side vibration as the principal vibration. One advantage of a GT-cut quartz crystal oscillator is that the natural frequency does not change to any appreciable extent when the length of the longer side is adjusted, so that the adjustment of the natural frequency and the adjustment of the temperature coefficient can be independently performed. The relationship between the side ratio and the temperature characteristics will be explained in relation to Figure 2 which is a graph showing the temperature characteristic of a GT-cut quartz crystal oscillator. In Figure 2 the ordinate represents temperature coefficient and the abscissa the side ratio  $w/l$ . Usually the temperature coefficient is zero when the side ratio is 0.85. Figure 2 indicates that, within a certain range of dimensions, all GT-cut quartz crystal oscillators having a side ratio of  $a$  exhibit a temperature coefficient  $b$ . Figure 3 represents 3 GT-cut quartz crystal oscillators 1, 2, 3 whose

This invention relates to method of adjusting GT-cut quartz crystal oscillators.

According to one aspect of the present invention, there is provided a method of adjusting a GT-cut quartz crystal oscillator comprised from the steps of producing a predetermined ratio between a longer side and a shorter side of the oscillator, so that the oscillator has a substantially zero frequency temperature coefficient, and adjusting the size and/or shape of an electrode film formed on the oscillator so that the oscillator has a predetermined natural frequency.

The size and/or shape of the electrode film may be adjusted by means of a laser. In one embodiment the size of the electrode film is adjusted by removing a peripheral portion or portions thereof. In another embodiment the shape of the electrode film is adjusted by forming one or more holes therein.

According to a further aspect of the present invention, there is provided a GT-cut quartz crystal oscillator when made by the method recited above.

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

Figure 1 is a plan view of a GT-cut quartz crystal oscillator;

Figure 2 shows graphically the relationship between the side ratio and temperature coefficient of a GT-cut quartz crystal oscillator;

Figure 3 shows graphically the plurality of GT-cut quartz crystal oscillators having the same temperature coefficient;

Figure 4 illustrates the range of

adjustment of the natural frequency and the adjustment of the temperature coefficient can be independently performed. The relationship between the side ratio and the temperature characteristics will be explained in relation to Figure 2 which is a graph showing the temperature characteristic of a GT-cut quartz crystal oscillator. In Figure 2 the ordinate represents temperature coefficient and the abscissa the side ratio  $w/l$ . Usually the temperature coefficient is zero when the side ratio is 0.85. Figure 2 indicates that, within a certain range of dimensions, all GT-cut quartz crystal oscillators having a side ratio of  $a$  exhibit a temperature coefficient  $b$ . Figure 3 represents 3 GT-cut quartz crystal oscillators 1, 2, 3 whose

temperature coefficients are zero and whose side ratios are  $a_0$ . The GT-cut quartz crystal oscillators 1 to 3 have identical side ratios and the same temperature coefficient but are of different sizes. Moreover, the natural frequencies of the GT-cut quartz crystal oscillators 1 to 3 differ, the natural frequencies being determined by the lengths  $w$ ,  $w_1$ ,  $w_2$  of the shorter side. The natural frequency of the GT-cut quartz crystal oscillator 2 is greater than that of the GT-cut quartz crystal oscillator 1 which is greater than that of the GT-cut quartz crystal oscillator 3.

A conventional method of adjusting the frequency and the temperature coefficient of a GT-cut quartz crystal oscillator will now be described with reference to Figure 4. Assume that it is desired to make a GT-cut quartz crystal oscillator 1 indicated by the solid line, that is to say, a GT-cut quartz crystal oscillator whose temperature coefficient is zero (a side ratio of

$$a_0 = w_1/l_1)$$

and which has a natural frequency of  $f_1$ .

A GT-cut quartz crystal oscillator 4, indicated by a broken line in Figure 4, is similar to a GT-cut quartz crystal oscillator 5 also indicated by a broken line. The natural frequency  $f_5$  of the GT-cut quartz crystal oscillator 5 is greater than the natural frequency  $f_4$  of the GT-cut quartz crystal oscillator 4 ( $f_5 > f_4$ ). A GT-cut quartz crystal oscillator 6 indicated by a broken line, is one whose width  $w_2$  is equal to that of the GT-cut quartz crystal oscillator 4 and whose length  $l'_2$  is somewhat greater than that of the GT-cut quartz crystal oscillator 4 ( $l'_2 > l_2$ ). The temperature coefficient of the GT-cut quartz crystal oscillator 6 is a negative with respect to that of the GT-cut quartz crystal oscillator 4 and the natural frequencies of the GT-cut quartz crystal oscillators 4, 6 are substantially equal ( $f_4 \approx f_6$ ).

The GT-cut quartz crystal oscillator has a natural frequency which is less than that of the GT-cut quartz crystal oscillator 1 and has a temperature coefficient which is more negative than that of the GT-cut quartz crystal oscillator 1 (i.e.  $f_1 > f_6$ ). Whilst measuring the temperature characteristics of the GT-cut quartz crystal oscillator 6, a longer side  $l'_2$  thereof is polished to be equal to the longer side  $l_2$  of the GT-cut quartz crystal oscillator 4. Thus the temperature coefficient is substantially zero, and the GT-cut quartz crystal oscillator 6 becomes identical to the GT-cut quartz oscillator 4 and  $f_1 > f_4$ . The GT-cut quartz crystal oscillator 4 is made smaller so that it has the dimensions of the GT-cut quartz crystal oscillator 1, whose natural

frequency is  $f_1$  and whose temperature coefficient is zero.

Thus conventionally to adjust a GT-cut quartz crystal oscillator so that it has a predetermined natural frequency and so that it has a temperature coefficient of zero, the width  $w_2$  is polished so that it becomes  $w_1$ . However, since a given side ratio is necessary so that the temperature coefficient is zero, the length  $l_2$  must be polished so that it is equal to the length  $l_1$ . Fine adjustment of a GT-cut quartz crystal oscillator is, therefore, laborious and it is very difficult to make the adjustment so as to achieve both the desired temperature coefficient and the desired natural frequency.

Figure 5 shows a GT-cut quartz crystal oscillator according to the present invention. This GT-cut quartz crystal oscillator comprises a blank 7 of a quartz crystal vibrator on which is deposited an electrode film 8, a supporting spring 9, a support substrate 10, a base 11, which may be cold welded, and pins 12. Figure 6 shows the shape of the quartz crystal blank 7, the length  $l$  being 9.350 mm, the width  $w$  being 8.03 mm and the thickness being 0.65 mm. Figure 7 illustrates the shape of an electrode film 8a formed on the quartz crystal blank 7. The electrode film 8a covers the entire area of the quartz crystal blank. In Figure 8, the periphery of the electrode 8a has been removed on opposite planar faces so that portions 8b which are substantially 1.00 mm in width of the quartz crystal blanks 7 are exposed.

The electrode film 8a is made of gold and is of thickness of about 1,000 Å. Since the GT-cut quartz crystal oscillator employs shorter side vibrations, the natural frequency is changed by altering the shape of the electrode 8a, i.e. by exposing the portions 8b using for example, a laser or air abrasive. In the present example, the frequency variation  $\Delta f/f = 500$  p.p.m.

Whilst the natural frequency of the GT-cut quartz crystal oscillator can be changed in this manner, the temperature characteristics and crystal impedance are not noticeably changed. Any influences upon the temperature characteristics and crystal impedance can be made negligible by removing for example using a laser, the electrode films 8a in the form of holes 8c as shown in Figure 9.

A method according to the present invention of adjusting a GT-cut quartz crystal oscillator will now be described. The GT-cut quartz crystal oscillator is assembled as in Figure 5, and the temperature characteristics are measured. The longer side is polished until the temperature coefficient is zero or substantially zero. The electrode 8a is

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partially removed from the periphery of the quartz crystal blank in the shorter side direction by using, for example, a laser so that it is shaped as shown in Figure 8 or Figure 9. Accordingly, the GT-cut quartz crystal oscillator will have a predetermined natural frequency. It will be appreciated that the adjustment of the natural frequency does not change the side ratio so that the temperature characteristics of the GT-cut quartz crystal oscillator are unchanged, therefore, the temperature coefficient remains substantially zero. This method of adjusting a GT-cut quartz crystal oscillator is extraordinarily easy to perform.

To adjust the natural frequency of the GT-cut quartz crystal oscillator, instead of removing part of the electrode 8a a mass can be added to electrode film 8a by gettering.

The method according to the present invention of adjusting a GT-cut quartz crystal oscillator has none of the disadvantages of the conventional method described above and is relatively easy and simple to perform. The manufacturing output of GT-cut quartz crystal oscillators is thereby increased and cost is reduced.

#### WHAT WE CLAIM IS:—

1. A method of adjusting a GT-cut quartz crystal oscillator comprised from the steps

of producing a predetermined ratio between a longer side and a shorter side of the oscillator, so that the oscillator has a substantially zero frequency temperature coefficient, and adjusting the size and/or shape of an electrode film formed on the oscillator so that the oscillator has a predetermined natural frequency.

2. A method as claimed in Claim 1 in which the size and/or shape of the electrode film is adjusted by means of a laser.

3. A method as claimed in Claim 1 or 2 in which the size of the electrode film is adjusted by removing a peripheral portion or portions thereof.

4. A method as claimed in Claim 1 or 2 in which the shape of the electrode film is adjusted by forming one or more holes therein.

5. A method as substantially herein described with reference to the accompanying drawings.

6. A GT-cut quartz crystal oscillator when made by the method as claimed in any preceding Claim.

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