"PIEZO-ELECTRIC OSCILLATOR"

The present invention relates to a third overtone piezo-electric oscillator arranged to be oscillated in the thickness-shear mode.

A piezo-electric oscillator is known which is arranged to be oscillated in the thickness-shear mode. The known oscillator is made suitable for providing a main oscillating drive by forming circular driving electrodes on opposite surfaces of a circular quartz oscillator member. However, this oscillator has many spurious oscillations in addition to the main oscillation, and when the combination of higher order spurious oscillations are generated during the oscillation of the main oscillation, an abnormal frequency phenomenon is generated, especially in the frequency-temperature characteristics. Therefore, in order in particular to avoid spurious oscillations in the contour mode, attention has been paid to the shape or size of the circular driving electrodes, as may be seen, for example, from the publication of Japanese Patent Application No. 13608/1985, and the publication of Japanese Patent Application No. 40492/1988.

However, in such an oscillator, the application to a thickness-shear mode system of a spurious oscillation following the main oscillation may cause an harmonic oscillation of a higher order to be generated in addition to the spurious oscillation described above.

Therefore, the present Applicants have proposed in Japanese Patent Application No. 38764/1984 the use of frequency adjusting electrodes shaped like a pair of

spectacles in order to solve this problem by utilizing the mass loading effect.

However, in such a construction, an error may arise in the position of the mass load and the effect of the mass loading may be small, since the amount of adjustment is small and there may be a variation in the position of the mask used for forming the mass loading.

The object of the present invention is therefore to prevent the occurrence of the abnormal frequency phenomenon in a third overtone piezo-electric oscillator.

According to the present invention, there is provided a third overtone piezo-electric oscillator arranged to be oscillated in the thickness-shear mode, comprising a substantially circular piezo-electric element having oppositely disposed main surfaces each of which is provided with a driving electrode having a width W in the X axis direction and a length L in the Z' axis direction such that

$$W < D/3, \text{ and}$$

$$0.5D \leqq L \leqq 2D/3,$$

where D is the diameter of the piezo-electric element.

Preferably, each driving electrode is elongated in the Z'axis direction.

The piezo-electric element is preferably an AT cut quartz oscillator member. For example, the AT cut quartz oscillator member may be cut along a surface inclined at about 35.4° in the Y'axial direction from the Z' axis.

Each driving electrode is preferably provided with a lead electrode at the periphery of the piezo-electric element.

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

Figure 1(a) is a plan view of a piezo-electric oscillator according to an embodiment of the present invention, Figure 1(a) showing the surface electric charge distribution in the spurious oscillation of the third overtone and ninth overtone;

Figures 1(b) and (c) are the surface electric charge distribution curves in the case of the spurious oscillation shown in Figure 1(a);

Figure 2(a) is a view similar to Figure 1(a) but showing the surface electric charge distribution in the case of another spurious oscillation of the ninth overtone;

Figures 2(b) and 2(c) are the surface electric charge distribution curves in the case of the spurious oscillation shown in Figure 2(a);

Figure 3 is a plan view showing a driving electrode;

Figure 4 is a resonance characteristic diagram of the third overtone and of the ninth overtone in a piezo-electric oscillator according to the present invention;

Figure 5 is a frequency-temperature characteristic diagram of a piezo-electric oscillator according to the present invention;

Figure 6 is a resonance characteristic diagram of the third overtone of the ninth overtone in a known piezo-electric oscillator having a circular driving electrode; and

Figure 7 is a frequency-temperature characteristic diagram of the known piezo-electric oscillator.

In the case of the abnormal frequency phenomenon referred to above, the cause of the phenomenon is quite different from that of the so-called "jump phenomenon" (i.e. the phenomenon in which the main oscillation of the fundamental thickness-shear mode is pulled into the

spurious oscillation which is comparatively near it). On the contrary, the abnormal frequency phenomenon is closely related to the high frequency oscillation which occurs near to a frequency of n times the resonance frequency of the fundamental oscillation, where n is an odd number of at least 3, (especially, the oscillation near the frequency of 3 times the resonance frequency of the above-described fundamental oscillation). This occurs suddenly in the case when a frequency of 1/n times the high frequency oscillation coincides with the resonance frequency of the above-described fundamental oscillation. For example, it occurs frequently in combination with the fundamental oscillation, due to the relationship between this fundamental oscillation and the spurious oscillation of the third overtone, or in the case of the use of the third overtone, due to the spurious oscillation of the ninth overtome, and an abnormal frequency phenomenon is generated.

Figure 6 shows the resonance characteristics of a circular quartz oscillator having a known circular driving electrode when used in the third overtone. Although three times the frequency of the third overtone (F3) of 23.64495 MHz is 70.93485 MHz, in the vicinity of the latter frequency there exists an oscillation of the frequency of 70.92996 MHz in the form of a spurious oscillation (F 9S1), and moreover an oscillation of the frequency of 70.94705 MHz in the form of another spurious oscillation (F 9S2). Therefore, when this piezo-electric oscillator is used in the third overtone (F3), there is generated in combination therewith a spurious oscillation (F 9S1) of the ninth overtone (F9), due to the relationship with the ambient temperature. This abnormal frequency phenomenon can be seen in the position which is encircled in the frequency-temperature

characteristic diagram shown in Figure 7.

In order to avoid such an abnormal frequency phenomenon as described above, an analysis was carried out on respective oscillation modes, so as to avoid combination with the higher order spurious oscillation by utilizing the mass loading effect of an electrode film.

An embodiment of a piezo-electric oscillator according to the present invention is shown in Figures 1 and 2 in which transversely elongated driving electrodes 2 are formed on the opposite main surfaces of a substantially circular quartz oscillator member 1 which constitutes a piezo-electric element. The quartz oscillator member 1 is an AT cut quartz oscillator member which was cut along a surface inclined at a certain angle in the Y axial direction from the Z axis which is the primary coordinate axis, the said angle being about 35.4°. In the quartz plate cut out from the quartz at this angle, the respective axial directions are shown in Figures 1 and 2 are X, Y' and Z'. A quartz oscillator 1 which is to be given a circular shape of the diameter D is formed from a quartz plate cut out by the angle described above.

As shown in Figure 3, the elongated driving electrodes 2, which are formed on the oppositely disposed main surfaces of the quartz oscillator, extend in the Z' axis direction, each driving electrode 2 having a width W in the X axis direction and a length L in the Z' axis direction such that

$$W < D/3, \text{ and}$$

$$0.5D \leq L \leq 2\,D/3,$$

where D is the diameter of the oscillator member 1. The driving electrodes 2 are arranged centrally of the said main surfaces. Also, from this driving electrode 2, a

lead electrode 2a is formed at the periphery of the oscillator member 1.

The quartz oscillator 1 is used in the third overtone (F3), and the higher order harmonic oscillation and the spurious oscillation thereof are generated with the third overtone (F3). The ellipse 3 shown with a chain line in Figure 1(a) shows the electric charge concentrating region of the third overtone (F3), and although it is not shown in Figure 1(a), the electric charge is concentrated in the central part of the said region.

The three ellipses 4a, 4b and 4c shown with chain lines in Figure 1(a) are the electric charge concentrating regions of the spurious oscillation (F 9S1) of the ninth overtone (F9) generated by this third overtone (F3), and it is known that the electric charge is concentrated in the central part 4a on the X axis and on the Z' axis as shown in Figure 1(c) and Figure 1(b) respectively. An electric charge of different polarity is concentrated in the regions 4b and 4c, the latter being on opposite sides, with respect to the Z' axis, of the region 4a. As regards the spurious oscillation (F 9S1), since the driving electrodes 2 are provided over almost all the surfaces of the charge concentrating regions 4a, 4b and 4c, a mass loading effect is produced by the driving electrodes 2.

Further, the three ellipses 5a, 5b, and 5c shown with chain lines in Figure 2(a) are the electric charge concentrating regions of another spurious oscillation (F 9S2) of the ninth overtone (F9). It is known that the electric charge is concentrated at the central part 5a on the X axis and on the Z' axis as shown in Figure 2(c) and 2(b) respectively. Charges with different polarities are concentrated in both the side parts 5b

and 5c which are arranged on opposite sides of the region 5a with respect to the X axis. For this spurious oscillation (F 9S2), since the driving electrodes 2 are disposed in the central region 5a of the charge concentrating regions 4a, 4b and 4c, a reduction of the mass loading effect by the driving electrodes can be arranged.

In Figure 4 there are shown the resonance characteristics of the circular quartz oscillator 1 having the driving electrodes 2 tranversely elongated in the Z' axial direction, the oscillator having been used in the third overtone. The frequency of the third overtone (F3) is 23.64720 MHz, and the frequency of three times thereof is 70.94160 MHz.

In the vicinity of this frequency of three times that of the third overtone, there are present the spurious oscillation (F 9S1) of the above-described ninth overtone (F9) at the frequency of 70.92510 MHz, and the spurious oscillation (F 9S2) at the frequency of 70.97407 MHz, but these are displaced to the negative side in comparison with that of the spurious oscillation (F 9S1), and to the positive side in comparison with that of the spurious oscillation (F 9S2) so that the combination with the third overtone (F3) can be avoided. Thus an abnormal frequency phenomenon as seen in Figure 7 is not generated, as will be clear from the frequency temperature characteristic diagram shown in Figure 5.

The driving electrode 2 may be transversely elongated in the Z' direction, or may have the shape of an ellipse, elongated rectangle, etc.

In the third overtone piezo-electric oscillator described above, the frequency of the spurious oscillation of the ninth overtone becomes separated from the frequency of three times the third overtone of the

main oscillation. Consequently, the occurrence of the abnormal frequency phenomenon described above can be removed or suppressed for a wide temperature range. Therefore, a stable performance of the thickness-shear mode oscillation can be achieved, and the output frequency thereof is of very high precision. Moreover, since the shape of the driving electrodes is simple, a piezo-electric oscillator of uniform quality can be provided at a cheap price.



CLAIMS

1. A third overtone piezo-electric oscillator arranged to be oscillated in the thickness shear mode comprising a substantially circular piezo-electric element having oppositely disposed main surfaces each of which is provided with a driving electrode having a width W in the X axis direction and a length L in the Z' axis direction such that

$$W < D/3, \text{ and}$$

$$0.5D \leq L \leq 2\,D/3,$$

where D is the diameter of the piezo-electric element.

2. An oscillator as claimed in claim 1 in which each driving electrode is elongated in the Z' axis direction.

3. An oscillator as claimed in claim 1 or 2 in which the piezo-electric element is an AT cut quartz oscillator member.

4. An oscillator as claimed in claim 3 in which the AT cut quartz oscillator member was cut along a surface inclined at about 35.4° in the Y' axial direction from the Z' axis.

5. An oscillator as claimed in any preceding claim in which each driving electrode is provided with a lead electrode at the periphery of the piezo-electric element.

6. A third overtone piezo-electric oscillator substantially as hereinbefore described with reference to and as shown in Figures 1-3 of the accompanying drawings.