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(54) OSCILLATOR

(71) We, MURATA MANUFACTURING CO., LTD., a Japanese Body Corporate, of 26-10, Tenjin 2-chome, Nagaokakyo-shi Kyoto-fu, 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:—

The present invention relates to an oscillator and, more particularly, to an improved oscillator employing a ceramic resonator or a single crystal piezo-electric resonator other than quartz.

Quartz resonators which resonate at a predetermined frequency in a stable condition regardless of temperature change have conventionally been used in oscillators. In other words, oscillators employing a quartz resonator oscillate in a comparatively stable condition when compared with oscillators employing inductor and capacitor elements, even if the environmental temperature changes. For further stabilizing the temperature-oscillation frequency characteristics of the quartz resonator, it has been common practice to employ, as shown in Fig. 1 (showing a circuit diagram of the conventional type oscillator), capacitors Ca and Cb having appropriate electrostatic capacitance-temperature characteristics. For example, according to the oscillator shown in Fig. 1, in which a quartz resonator Q is employed, the capacitors Ca and Cb generally have a temperature coefficient of dielectric constant of about −5,000 to 200 ppm/°C. When the quartz resonator Q is employed in the oscilaltor as oscillating element, such capacitors Ca and Cb would correct the oscillation frequency deviation caused by the temperature change.

Instead of employing the quartz resonator, this can be replaced with a ceramic resonator or a single crystal piezo-electric resonator other than quartz which is less expensive, but is apt to deviate in resonance frequency, under the influence of temperature change. Accordingly, such ceramic resonator and single crystal piezo-electric resonator have been considered unsuitable for use in oscillators.

Recently, there has been produced an improved type of ceramic resonator or single crystal piezo-electric resonator for use in a filter or in a frequency discriminator as a reactance element which shows less deviation in resonance frequency with respect to temperature change. However, even such an improved type of resonator, for example, a resonator composed of piezo-electric ceramic material of the lead zirconate titanate system mixed with a material which reduced the temperature coefficient of the resonance frequency, would yet have a temperature coefficient of electrostatic capacitance as large as 2,000 to 6,000 ppm/°C. In the event that such a resonator having a smaller temperature coefficient of resonance frequency and thus appropriate to be employed in a filter and frequency discriminator as a reactance element is employed in the oscillator shown in Fig. 1, the capacitors Ca and Cb will will not correct the oscillation frequency deviaion caused by the temperature change. This is because the temperature coefficient of the electrostatic capacitance of such a resonator is still comparatively large. When the capacitors Ca and Cb have 0 ppm/°C of temperature coefficient of electrostatic capacitance, the oscillation frequency of the improved type of resonator deviates disadvantageously upon temperature change, as shown by a graph in Fig. 2, in which the axes of abscissa and ordinate respresent temperature and oscillation frequency, respectively.

In accordance with the invention, there is provided an oscillator comprising:

a resonator element constituted by a ceramic material or a single crystal piezo-electric material other than quartz; and

at least one capacitor coupled to the resonator, said capacitor being constituted by a dielectric material and a pair of electrodes bonded on the dielectric material in a spaced relation to each other, said dielectric material having temperature coefficient of dielectric constant substantially equal to that of the resonator element. According to one preferred embodiment, the dielectric material is the same as the material used for constituting the resonator.

According to a preferred embodiment of the present invention, the resonator has a small temperature coefficient of resonance frequancy, comparable to that of the quartz, and a large temperature coefficient of dielectric constant, for example, 2,000 to 6,000 ppm/°C or more. Similarly, the capacitor coupled to the resonator has a large amount of temperature coefficient of dielectric constant, for example, 2,000 to 6,000 ppm/°C or more.

With such arrangement as described above, the oscillation frequancy deviation caused by the temperature change is corrected.

As it is understood from the foregoing description, the resonator employed in the oscillator of the present invention preferably satisfies the above described requirements of both of the temperature coefficient of resonance frequency and the temperature coefficient of dielectric constant. On the other hand, the capacitor coupled to the resonator has to satisfy the requirement of the temperature coefficient of dielectric constant. Generally, when the resonator is employed in the filter or in the frequency discriminator, the temperature coefficient of the resonance frequency of such resonator is small. However, such a resonator may have a temperature coefficient of dielectric consant varying from a large amount to a small amount. One of the advantages of the present invention is that it is possible to employ all types of resonators having large or small temperature coefficient of the dielectric constant, provided that the capacitor coupled to the resonator has an approximatley equal temperature coefficient of dielectric constant. For example, in the case where the oscillator of the present invention employs a resonator having a comparatively large temperature coefficient of dielectric constant, a capacitor having large temperature coefficient of dielectric constant, that is one approximately equal to that of the resonator is employed. On the other hand, in the case where the oscillator of the present invention employes a resonator having a comparatively small temperature coefficient of dielectric constant a capacitor having a small temperature coefficient of dielectric constant that is approximately equal to that of the resonator is employed.

The invention is illustrated by the following description of a preferred embodiment thereof with reference to the accompanying drawings, in which:

Figs. 1 and 2 are drawings already referred to in the foregoing description, Fig. 1 being a circuit diagram of the prior art oscillator, Fig. 2 being a graph of a temperature-oscilaltion frequency characteristics of an oscillator employing ceramic or single crystal piezo-electric material for the resonator and capacitors having 0 ppm/°C of temperature coefficient of electrostatic capacitance;

Fig. 3 is a circuit diagram of an oscillator of one embodiment of the present invention;

Figure 4 is a graph of a temperature-oscillation frequency characteristics of the oscillator shown in Fig. 3;

Figs. 5, 6 and 7 are circuit diagrams similar to that of Fig. 3, but particularly showing further embodiments thereof;

Fig. 8 is a perspective view of an element having resonator and capacitor coupled therein; and

Fig. 9 is a front view of the element which is a modification of the element shown in Fig. 8.

Before the description of the present invention proceeds, it is to be noted that like parts are designated by like reference numerals throughout the accompanying drawings.

Referring to Fig. 3, an oscillator 2a of the present invention comprises a resonator 4 having opposite electrodes 4a and 4b. One electrode 4a of the resonator 4 is connected through a capacitor C_1 to the ground, while the other electrode 4b is connected through a capacitor C_2 to the ground. A resistor R_1 is connected in parallel to the resonator 4 and also an amplifier AMP_1 is connected in parallel to the resonator 4. An output of the amplifier AMP_1 is connected through another amplifier AMP_2 to an output terminal 6.

The resonator 4 is constituted by a ceramic or single crystal piezo-electric material other than quartz. According to the embodiment shown in Fig. 3, the resonator 4 is constituted by ceramic material obtained from the lead-zirconate-titrate system mixed with a material which reduces the temperature coefficient of the resonance frequency. Such resonator 4 has a temperature coefficient of dielectric constant from 2,000 to 6,000 ppm/°C.

Generally, when a material, i.e., the resonator 4 as described above having comparatively small temperature coefficient of resolance frequency and having comparatively large temperature coefficient of dielectric constant is employed in a oscillator, it is found that the oscillation frequency deviates to a high degree with respect to the temperature changes. For the purpose of eliminating such oscillation frequency deviation, there are employed capacitors C_1 and C_2. Each of the capacitors C_1 and C_2 are constituted by opposed electrodes with a dielectric material between them. However, it is found by the present inventors that the capacitors of the ordinary type employing dielectric material having comparatively small temperature coefficient of dielectric constant not appropriately correct to oscillation frequency deviation, but that the capacitors employing dielectric material having a temperature coefficient of dielectric constant approximately equal to that of the resonator 4 advantageously reduces the oscillation frequency deviation. For example, according to the embodiment shown in Fig. 3, the capacitors C_1 and C_2 employ the same material for the dielectric as the material used for constituting the resonator 4.

With such arrangement as described above, the oscillator 2a oscilaltes at a comparatively stable oscillation frequency with respect to temperature change, as shown by a graph of Fig. 4 in which the axes of abscissa and ordinate represent temperature and oscillation frequency, respectively.

Such stable operating condition of the oscillator is available even in the oscillators prepared in other designs as shown in Figs. 5, 6 and 7.

Referring to Fig. 5, there is shown an oscillator 2b according to another embodiment of the present invention. The oscillator 2b comprises a resonator 8 having opposite electrodes 8a and 8b. One electrode 8a is connected to the ground while the other electrode 8b is connected to a junction J_1 betwen series-connected resistors R_2 and R_3. Such series-connected resistors R_2 and R_3 are connected between a source of power voltage +Vcc and the ground. The oscillator 2b further comprises a transistor T_1 having a base connected to the junction J_1, an emitter connected to the ground through a resistor R_4 and, a collector connected to the power source +Vcc through a resistor R_5. Series-connected capacitors C_3 and C_4 are connected between the base of the transistor T_1 and the ground. A junction J_2 between the capacitors C_3 and C_4 is connected to the emitter of the transistor T_1. It is to be noted that the material, such as ceramic, used for constituting the resonator 8 is also used for constituting the dielectric material for the capacitors C_3 and C_4.

Referring to Fig. 6, there is shown an oscillator 2c according to a further embodiment of the present invention. The oscillator 2c comprises a resonator 10 having opposed electrodes 10a and 10b. One electrode 10a of the oscillator 10 is connected to the ground through a capacitor C_5 while the other electrode 10b is connected to the collector of a transistor T_2. The transistor T_2 has an emitter connected to the ground through a resistor R_6 and the base connected to the ground through a resistor R_7 and also to the source of power through a resitor R_8. The base of the transistor T_2 is also connected to said one electrode 10a of the resonator 10. The oscillator 2c further comprises a transformer 12 having a primary winding 12a and a secondary winding 12b. The primary winding 12a is connected between the electrode 10b of the resonator 10 and the ground through a resistor R_9 and is also connected across a capacitor C_6 which is grounded through another capacitor C_7. It is to be noted that the material, such as ceramic, used for constituting the resonator 10 is also used for constituting the dielectric material for the capacitor C_5.

Referring to Fig. 7, there is shown an oscillator 2d according to a yet further embodiment of the present invention. The only difference between the oscillator 2d shown in Fig. 7 and the oscillator 2c shown in Fig. 6 is in the respective positions of the capacitor C_5 and the resonator 10 which are substantially reversed.

In constituting each of the oscillators described above, the capacitor or capacitors having the same material as the resonator may be assembled separately from the resonator as described above, or may be assembled together with the resonator in a manner described hereinbelow to provide a unit element.

Referring to Fig. 8, there is shown a unit element 14a which is particularly designed for use in the oscillators 2a and 2b shown in Figs. 3 and 5. The unit element 14a comprises a ceramic plate 16 which is thouroughly polarized to construct a piezo-electric plate. A portion 20 encircled by the chain line on one surface thereof is bonded with a metallic plate 22a serving as an electrode. On the other surface of the ceramic plate 16, there is bonded a metallic plate 22b which is in face-to-face relation with the metallic plate 22a. Thus, a trapped energy resonator is constructed between the metallic plate 22a and 22b within the portion 20. Portions 24 and 26 encircled by the chain line on one surface of the ceramic plate 16 are bonded with metallic plates 28a and 30a and, on the other surface of the ceramic plate 16, there are bonded metallic plates 28b and 30b which are in face-to-face relation with the metallic plates 28a and 30a, respectively. In order to form capacitors between the metallic plates 28a and 28b within the portion 24 and also between the metallic plates 30a and 30b within the portion 26, the portions 24 and 26 may be arranged with mechanical damping in a known manner by deposition of hardening material such as solder or synthetic resin for preventing the portions 24 and 26 from being vibrated by the influence of the trapped energy resonator, or otherwise such portions 24 and 26 may be heated for removing the polarization. It is to be noted that the ceramic plate 16 which has been described as being thouroughly polarized can be partially polarized at the portion 20 for constituting the capacitors in the portions 24 and 26 without any mechanical damping or without any heating treatment. It is to be noted that the portions 24 and 26 may be arranged with mechanical damping in a known manner by soldering or by depositing synthetic resin for preventing the portions 24 and 26 from being vibrated by the influence of the trapped energy resonator.

The trapped energy resonator and the capacitors are connected with each other by a suitable thin layer of metal in such a manner that the metallic plate 22a is connected to the metallic plate 28a and further to a first terminal 32, and the metallic plate 22b is connected to the metallic plate 30b and further to a second terminal 34, and that the metallic plate 28b is connected to the metallic plate 30a and further to a third terminal 36.

Referring to Fig. 9, there is shown a unit element 14b which is a modification of the unit element 14a shown in Fig. 8 and is particularly designed for use in the oscillators 2c and 2d shown in Figs. 6 and 7. The unit element 14b shown in this modification has one capacitor formed by the metallic plates 30a and 30b and the trapped energy resonator formed by the metallic plates 22a and 22b. Such capacitor and trapped energy resonator are connected in such a manner that the metallic plate 22a is connected to the first terminal 32, the metallic plate 30a is connected to the second terminal 34 and the metallic plate 22b is connected to the metallic plate 30b and further to the third terminal 36.

It is to be noted that the unit element is not limited to those shown in Figs. 8 and 9, but other arrangement can be employed for preparing the capacitor with a material having approximately the same amount of temperature coefficient of electrostatic capacitance with that of the material used for preparing the resonator.

It is also to be noted that the piezo-electric ceramic material which has been described as obtained from lead-zirconate-titanate can be obtained from other piezo-electric ceramic material such as barium titanate ceramics. Furthermore, the resonator which has been described as constituted by piezo-electric ceramic material can be constituted by single crystal piezo-electric material, such as lithium-niobate (LiNbo3), other than quartz, which single crystal piezo-electric material has a temperature coefficient of dielectric constant 2,000 to 6,000 ppm/°C.

According to the oscillator of the present invention described above, since the capacitor is formed with the material having approximately the same amount of temperature coefficient of dielectric constant with that of the material used for preparing the resonator, the capacitor stabilizes the oscilaltion frequency of the oscillator irrespective of the temperature change.

It is to be noted that the metallic plates 28a and 28b of opposite polarities or metallic plates 30a and 30b of opposite polarities which have been described as being arranged in face-to-face relation can be arranged in different manner. For example, the metallic plates of opposite polarities bonded on the opposite flat surface of the ceramic plate may be deviated from each other or such metallic plates of opposite polarities may be bonded on the same surface closely adjacent to each other. In a further modification, the ceramic material may be prepared in a form of tube having opposite electrodes mounted on the opposite ends of the tube.

It is further to be noted that the resonator can be arranged other than the trapped energy type.

Although the present invention has fully been described by way of examples with reference to the accompanying drawings, it is to be noted that various changes and modifications are apparent to those skilled in the art. For example, the oscillator shown in any one of Figs. 3, 5, 6 and 7 may be designed in other circuit connections as long as they employ the mechanical resonator and at least one capacitor. Therefore, such changes and modifications are, unless they depart from the true scope of the present invention, to be undersood as included therein.

WHAT WE CLAIM IS:—

1. An oscillator comprising:

a resonator element constituted by a ceramic material or a single crystal piezo-electric material other than quartz; and

at least one capacitor coupled to the resonator, said capacitor being constituted by a dielectric material and a pair of electrodes bonded on the dielectric material in a spaced relation to each other, said dielectric material having a temperature coefficient of dielectric constant substantially equal to that of the resonator element.

2. An oscillator as claimed in claim 1, wherein said dielectric material is the same as that constituting the resonator element.

3. An oscillator as claimed in claim 1 or claim 2 wherein the resonator element is constituted by a ceramic material selected from the lead zirconate titanate system.

4. An oscillator as claimed in claim 1 or claim 2, wherein the resonator element is constituted by a single crystal piezo-electric material which is lithium niobate.

5. An oscillator as claimed in any one of claims 1 to 3 wherein said resonator element and the capacitor are arranged in a unit element including a ceramic plate having at least one portion thereof polarized, a first pair of metallic plates bonded on the opposite surfaces of the ceramic plate at said polarized portion for constituting the resonator thereat, a second pair of metallic plate bonded on the ceramic plate for constituting the capacitor thereat, and conductive lead bonded on the ceramic plate for electrically connecting the resonator and capacitor and for external electrical connection.

6. An oscillator as claimed in claim 5, wherein said second pair of metallic plates are provided with hardening member for mechanically damping the ceramic plate at a portion where said second pair of metallic plates are bonded.

7. An oscillator as claimed in any preceding claim wherein said resonator element has a small temperature coefficient of resonance frequency.

8. An oscillator as claimed in claim 7, wherein said resonator element has a large temperature coefficient of dielectric constant.

9. An oscillator substantially as hereinbefore described with reference to and as illustrated in any of Figures 3 to 9 and the accompanying drawings.

10. A method of manufacturing an oscillator comprising steps of:

preparing a ceramic plate having at least one portion thereof polarized;

bonding a first pair of electrodes on the ceramic plate at the polarized portion and on opposite surfaces in face-to-face relation to each other for constituting a resonator thereat;

bonding a second pair of electrodes on the ceramic plate at a portion other than said polarized portion but having a temperature constant of dielectric constant substantially equal to that of the polarized portion for constituting a capacitor thereat; and

bonding a conductive lead member on the ceramic plate for electrically connecting the resonator and capacitor and for external electrically connection.

11. A method of manufacturing an oscillator substantially as hereinbefore described with reference to and as illustrated in any of Figures 3 to 9 of the accompanying drawings.

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1576704 COMPLETE SPECIFICATION

3 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 1

Fig. 1

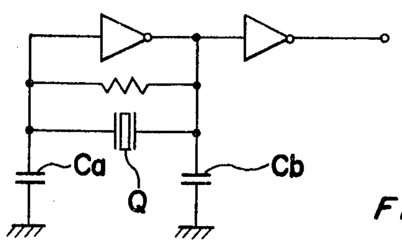


Fig. 2

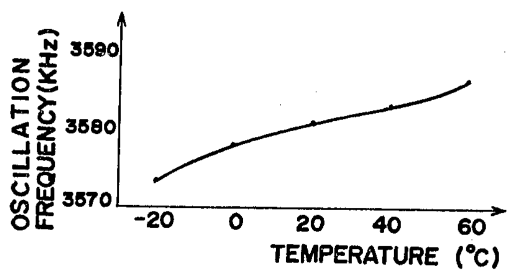


Fig. 3

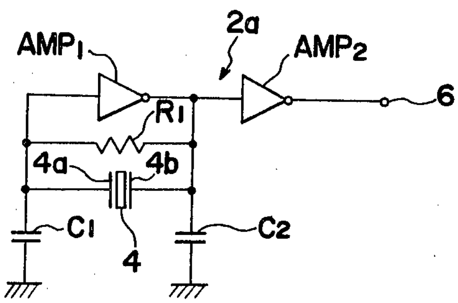


Fig. 4

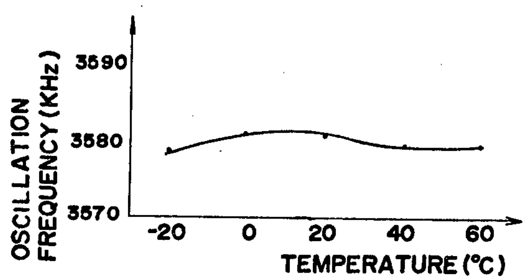


Fig. 5

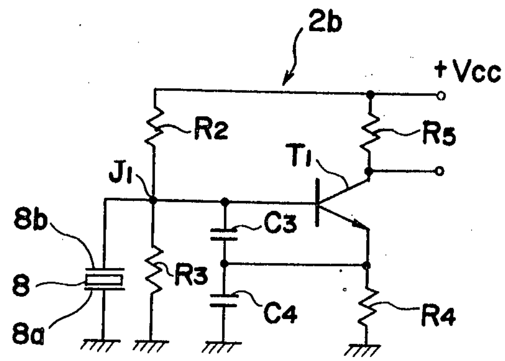


Fig. 6

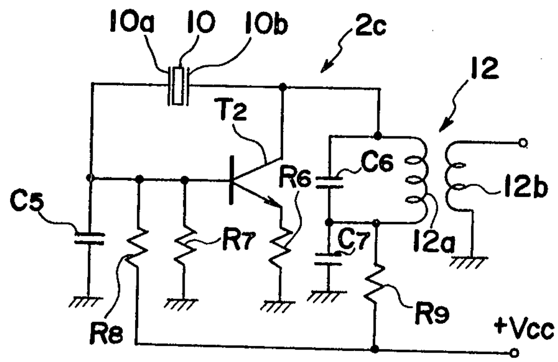
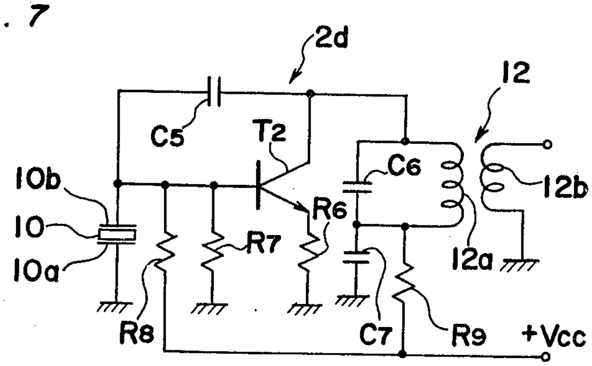


Fig. 7



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3 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 3

Fig. 8

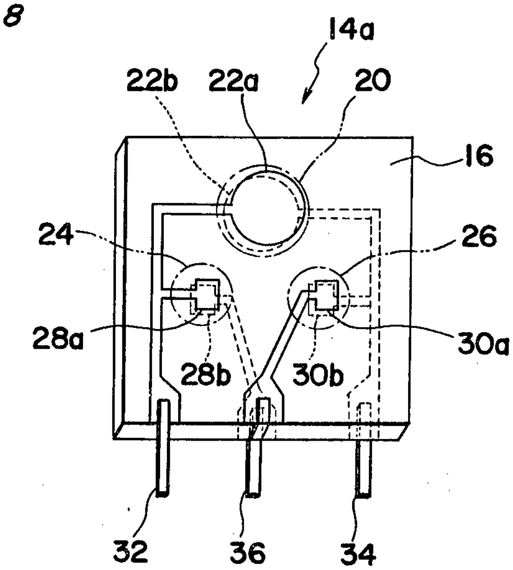

Fig. 9