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(54) IMPROVEMENTS IN OR RELATING TO PIEZO-ELECTRIC OSCILLATORS

(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 relates to piezo-electric oscillators (quartz crystal vibrator oscillators) and has for its object to provide improved piezo-electric oscillators having compensation for frequency variation with temperature and which shall be simple, of very low power consumption, and able to be made of very small size so as to especially advantageous for use as the time standard oscillator of a small electric timepiece such as an electric wristwatch.

As will be seen later, the invention provides an oscillator in which the frequency variation with temperature of a quartz vibrator used therein is compensated by what is herein called a "temperature sensitive condenser" i.e. a condenser (for example a TiO_2BaO or like ceramic condenser) which changes its capacitance with temperature. In the preferred embodiments oscillation is maintained by an oscillation maintaining circuit employing a single field-effect MOS transistor as the active element therein, there being only this one active element for maintaining oscillation of a four-terminal quartz vibrator, and the components of the said oscillation maintaining circuit being integrated in an integrated circuit construction.

According to this invention a piezo-electric oscillator comprises a piezo-electric crystal having four electrodes arranged in two pairs of opposite electrodes, the electrodes of one pair being connected together to a capacity circuit including a temperature sensitive condenser for compensating for the variation of frequency with temperature of the crystal, the other two of said four electrodes being connected to an oscillation maintaining circuit including a field effect transistor. The use of an integral circuit

construction in which as many as possible of the circuit components employed are integrated on a semi-conductor substrate obviously enables great reduction in size and weight to be achieved and the present invention enables this expedient — the adoption of integrated circuit construction — to be fully used to the maximum extent.

The invention is illustrated in and further explained in connection with the accompanying drawings in which Figure 1, which is provided for the purpose of explanatory comparison, shows diagrammatically a typical known quartz oscillator, and Figures 2 and 3 show diagrammatically two embodiments of this invention, that of Figure 3 being preferred.

Referring to Figure 1, X is a conventional four-terminal quartz vibrator driven by two bipolar transistors T_1 and T_2 . The circuit includes the usual resistors R_1, R_2, R_3, R_4, R_5 , coupling condenser C_1 and condenser C_2 which is in series with the quartz vibrator X and is in practice mounted externally of the rest of the circuit unit so as to be available for use as a frequency adjusting means.

In the known oscillator of Figure 1, the resistors and the active elements (the transistors) can be embodied readily in integrated circuit construction but the coupling condenser C_1 is, in practice, of relatively large capacitance. For example, to quote a practical case, it would have to be at least one nanofarad if oscillating frequency is about 8 kHz. Such a condenser is difficult to construct to be small enough to be part of an integrated circuit. Moreover, the input impedance of the bipolar npn transistor T_2 between the base and emitter of the common emitter amplifier circuit is too small, when the input signal is positive, to be really adequate to drive the quartz vibrator, and this is why the oscillation circuit of Figure 1 is provided with the emitter follower T_1 . This makes necessary the provision of the coupling condenser for coupling the emitter electrode of T_1 with the base electrode of

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T_2 , and this coupling condenser must be of large capacitance — e.g. from about 1000 pico-farad to about 5000 pico-farad for a low frequency quartz vibrator of a frequency of 8192 Hz or 16384 Hz vibrator, two frequencies which are popular for the time standard oscillator of a conventional electric watch using a quartz vibrator for the oscillator.

Figure 2 shows an improved oscillator in accordance with this invention. As will be seen it requires only a few resistors, a minimum number of transistors (only one in Figure 2) and no condensers of large capacitance. It also includes means for compensating for variation of the frequency of the quartz crystal with temperature.

Referring to Figure 2, T_3 is a field effect transistor constituted by a N-channel type MOS transistor and the oscillator has only three resistors R_6 , R_7 , R_8 . A temperature sensitive condenser C_{th} is for compensating for variation of frequency of the vibrator X with temperature and the condensers C_2 , C_3 which are for adjusting the quartz frequency closely to the required value are connected as shown with C_1 in series with condenser C_{th} and C_3 across the series connected elements C_2 and C_{th} . The part of the circuit to the left of the line II—II' in Figure 2 is the quartz vibrator unit (including its temperature compensating and adjusting means) while that to the right of said line is an oscillation circuit which lends itself admirably to integrated circuit construction. As will be apparent the circuit does not include any large capacitance condenser (like the coupling condenser C_1 of Figure 1) too big to lend itself to integrated circuit construction, the three condensers C_{th} , C_2 and C_3 constituting a relatively low capacitance capacity circuit the condensers in which are quite small relative to C_1 of Figure 1. Instead of using a MOS transistor, a MIS transistor provided with an insulating layer between its metallic gate and its substrate could be used.

Figure 3 shows another embodiment of the invention. Comparing this with Figure 2 it will be seen that the resistors of Figure 2 are replaced by MOS transistors, referenced T_1 , T_4 , T_7 . These can easily be integrated in an integrated circuit structure. The transistor T_4 is an active element for oscillation. The part of the circuit to the left of the line III—III' in Figure 3 is the quartz vibrator unit and the part to the right is a wholly integrated associated circuit.

The lead (oscillation detecting terminal) G from the quartz vibrator is connected to the gate electrode of the insulated gate field effect transistor T_3 in Figure 2 or T_4 in Figure 3. The input impedances of these transistors are very high in comparison with that of a bipolar transistor, and therefore an

oscillator as shown in Figure 2 does not require the emitter follower circuit which is provided in Figure 1, and is that much simpler.

A quartz oscillation circuit in accordance with this invention has a power consumption which can readily be brought down to about 1 micro watt, while the means for compensating for frequency variation with temperature does not involve (for all practical purposes) any additional power consumption. This is in sharp distinction from the known type of temperature stabilised quartz oscillator which is mounted in a thermostatically controlled heated housing and involves, therefore, a large consumption of power.

The advantages of an oscillator in accordance with this invention make it particularly desirable for use in a small timepiece, such as a wristwatch, in which satisfaction of the requirements of small size and low power consumption are of paramount importance.

WHAT WE CLAIM IS:—

1. A piezo-electric oscillator comprising a piezo-electric crystal having four electrodes arranged in two pairs of opposite electrodes, the electrodes of one pair being connected together and to a capacity circuit including a temperature sensitive condenser for compensating for the variation of frequency with temperature of the crystal, the other two of said four electrodes being connected to an oscillation maintaining circuit including a field effect transistor.

2. An oscillator as claimed in claim 1 wherein the field effect transistor is a MOS transistor.

3. An oscillator as claimed in claim 1 wherein the transistor is an MIS transistor with an insulating layer between its metallic gate and its substrate.

4. An oscillator as claimed in any of claims 1 to 3 wherein the oscillation maintaining circuit comprises only one active element, which is constituted by the field effect transistor, and a plurality of associated resistors.

5. An oscillator as claimed in claim 4 wherein the associated resistors are constituted by additional field effect transistors.

6. An oscillator as claimed in any of the preceding claims wherein at least the parts of the oscillation maintaining circuit are integrated in an integrated circuit structure.

7. An oscillator as claimed in any of the preceding claims wherein the capacity circuit includes three condensers, two of which are in series and the third of which is connected in parallel with said two, one of said two being the temperature sensitive condenser and the other two being condensers for adjusting the frequency.

8. Piezo-electric oscillators substantially 130

T_2 , and this coupling condenser must be of large capacitance — e.g. from about 1000 pico-farad to about 5000 pico-farad for a low frequency quartz vibrator of a frequency of 8192 Hz or 16384 Hz vibrator, two frequencies which are popular for the time standard oscillator of a conventional electric watch using a quartz vibrator for the oscillator.

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2. An oscillator as claimed in claim 1 wherein the field effect transistor is a MOS transistor.
3. An oscillator as claimed in claim 1 wherein the transistor is an MIS transistor with an insulating layer between its metallic gate and its substrate.
4. An oscillator as claimed in any of claims 1 to 3 wherein the oscillation maintaining circuit comprises only one active element, which is constituted by the field effect transistor, and a plurality of associated resistors.
5. An oscillator as claimed in claim 4 wherein the associated resistors are constituted by additional field effect transistors.
6. An oscillator as claimed in any of the preceding claims wherein at least the parts of the oscillation maintaining circuit are integrated in an integrated circuit structure.
7. An oscillator as claimed in any of the preceding claims wherein the capacity circuit includes three condensers, two of which are in series and the third of which is connected in parallel with said two, one of said two being the temperature sensitive condenser and the other two being condensers for adjusting the frequency.
8. Piezo-electric oscillators substantially



as herein described and illustrated in Figures 2 and 3 of the accompanying drawings.
9. An electronic timepiece having as its time standard an oscillator as claimed in
5 any of the preceding claims.

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