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(54) IMPROVEMENTS IN OR RELATING TO ELECTRIC WATCHES

(71) We, KABUSHIKI KAISHA SUWA SEIKOSHA, a Corporation of Japan, 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 electric watches e.g. wrist watches of the kind in which there is employed, as a time standard oscillator of the watch, an oscillator comprising, as the frequency determining element thereof, a highly stable piezo-electric oscillating crystal. Watches of this kind are often called quartz crystal watches and will be herein-after referred to as such.

The invention seeks to provide a quartz crystal watch which shall lend itself to easy after-sales service and handling, this result being achieved by adopting an improved construction in which each main portion of the watch is a self contained unit — especially the time standard oscillator unit. As will be seen later the invention provides, in the preferred embodiments thereof a watch which is highly stable and substantially unaffected by chance external disturbances, shocks or the like or caused to change in frequency by ambient stray capacity changes.

A quartz crystal watch generally includes a time standard oscillator and mechanical driving means such as a motor and a gear train. In practice the fraction of the whole space available for occupation by the time standard oscillator is only about $\frac{1}{3}$ to $\frac{1}{5}$.

The time standard oscillator includes the following six elements:—

1. the crystal oscillator itself (constituted by a crystal and electrodes hermetically sealed in an evacuated housing, with shield cap and external lead terminal).
2. an oscillation circuit.
3. means for fine adjustment of frequency.

4. a temperature compensating element.
5. a frequency divider circuit, and
6. a driving circuit of the motor.

In order that these elements shall be accommodated in the available small space, each of them must be of compact dimensions and favorably arranged with respect to the others. The whole arrangement must, moreover, satisfy the following requirements:—

1. When assembled in the case, there shall be no appreciable frequency change due to stray capacity effects.

2. In order that frequency change due to external shocks shall be a minimum, the crystal should be provided with protection against shock.

3. The elements shall themselves be formed as sub-units, readily accessible for adjustment, repair or exchange in the time standard oscillator unit of which they form part.

Satisfaction of the foregoing very onerous requirements is obviously very difficult and imposes severe practical problems which the present invention seeks to solve.

According to this invention, a quartz crystal watch having a time standard oscillator which includes a crystal oscillator and is constructed as a unit comprises a mounting member of resin (the term "resin" is employed in this specification, to include synthetic resins, so called) for said time standard oscillator, said mounting member having spaces accommodating said crystal oscillator, an oscillation circuit thereof, a frequency divider circuit and a driving circuit for mechanical driving means of the watch. Preferably an integrated circuit, and an element of an electromechanical converter providing mechanical drive for the watch are arranged on a round movement plate, the signal source for said integrated circuit being constituted by a highly stable crystal oscillator. Preferably also a tuning fork

[Price 25p]

Price 75p

crystal oscillator of a frequency of at least 16 kHz is employed as a time standard, and associated oscillation and divider circuits including MOS transistors, an integrated circuit driving circuit and an electro-mechanical converter constituting a pulse motor and serving as the mechanical driving means of the watch, are arranged on the round movement plate. This offers the advantages of simplification of connections between the elements of the watch; and easy after-sales service and handling, inasmuch as the main elements of the watch are formed as a unit, more particularly the crystal oscillator, the associated oscillation and the divider circuits and the driving circuit for the mechanical driving means.

The main elements of a watch in accordance with this invention may be considered to be (a) a battery, constituting the power source of the watch, (b) a crystal oscillator constituting the time standard of said watch, (c) an electronic circuit associated with the time standard and (d) pulse motor and an index mechanism. The invention provides a most convenient compact and favourable arrangement wherein these elements are incorporated in a very limited space. An important advantage of the invention, is that the battery, the crystal oscillator, the associated electronic circuit and the driving circuit which require relatively most space, can be arranged near the periphery of the round movement plate, while other elements are arranged centrally, thus resulting in a remarkably thin and flat overall shape.

By encasing the whole time standard oscillator so that it is formed as a unit, electrical connections between the watch elements, notably between the oscillation circuit, the divider circuit, the driving circuit for the motor, the crystal oscillator and the pulse motor are simplified, the provision of the necessary electric power source, and the connection of input and output signal terminals are all much simplified.

A battery power source occupies a considerable proportion of the available space in a wrist watch and is generally round in shape so that waste space usually exists round it. If other parts are piled on top of the battery the thickness of the watch is increased. The present invention does not involve disposing other parts on top of the battery.

As already stated the time standard preferably comprises a tuning fork crystal oscillator of at least 16 kHz in frequency, a temperature compensating device for frequency, and fine adjustment means for frequency. There are two main known types of oscillator which are available for use as a time standard. These are the tuning fork and leaf spring types. The leaf spring type oscillator is advantageous from the point of

view of mass production. However, a leaf spring oscillator of a frequency of about 16 kHz requires, in practice, to have a length of about 23 mm if it is to be stable in frequency even although subjected to external shock and disturbance. If the length is less than 23 mm, the frequency stability under practical conditions is not good enough for this type of oscillator to be satisfactory for use as the time standard of a wrist watch. If, in order to achieve protection against external shock and disturbance, a shock-protecting special mounting, hermetically sealed, is used for the leaf spring oscillator the length of the case required works out to be about 28 mm, and this makes it unsuitable for compact round movement watches.

To give the same degree of frequency stability in the face of external shock or disturbance as a leaf spring oscillator about 23 mm long, a tuning fork oscillator need be only about 13 mm long. Even if protected by a special mounting method, sealed hermetically, it can be incorporated in a cylindrical metal case only about 16 mm in length. The selection of this type of oscillator therefore offers substantial advantage where a compact, round movement wrist watch is required.

The electronic circuitry provided in a preferred embodiment of the invention comprises an oscillation circuit including a MOS transistor, a driving circuit (providing amplification of the divider circuit output) for the pulse motor, a 15-stage flip-flop divider circuit and a reset circuit, and is of integrated circuit construction. All this is incorporated in a case for the oscillator proper so as to constitute a time standard arrangement which is formed as a time standard unit (including the oscillator itself). Heretofore, in usual watch design, the oscillation and divider circuits have been of hybrid integrated circuit structure. However, by using MOS circuits, they can be made much more compact and, in fact, can be incorporated in a space which is only about 2 mm square. By "potting" the electronic circuitry in epoxy resin or the like excellent protection against external influences such as moisture is obtainable. The use of MOS circuits for the oscillation and divider circuits enables the space occupied to be brought down to about $\frac{1}{2}$ to $\frac{1}{3}$ of that required by the at present conventional forms of electronic circuits as used in watches. The use of MOS circuitry therefore offers substantial advantage for achieving a compact round wrist watch.

The pulse motor and the index mechanism comprise, in the preferred form, a six pole pulse motor responsive to pulses which reverse in polarity at one second intervals and a gear-train for driving second, minute

and hour hands together with regulating means for correcting time. A pallet fork indexing mechanism, designed to provide a step every second, involves an index wheel of such complexity as to require an outside diameter of about 5 to 7 mm, and it therefore does not lend itself to use in a compact wrist watch. The use of a pulse motor on the other hand, has the advantage that the shape of the rotor is round and the rotor is simple that it can have an outside diameter of only about 3 mm. The choice of such a motor as the electro-mechanical converter is therefore also of great advantage for obtaining a compact round wrist watch.

Although from the viewpoint of efficient occupation of space the square type of movement is advantageous, the market demand is for a round movement wrist watch and it is therefore, very desirable to be able to manufacture thin round movements of small outside diameter. The present invention enables this requirement to be satisfied.

The invention is illustrated, and explained in connection with the accompanying drawings, in which:—

Figure 1 is a simplified equivalent circuit diagram of a quartz crystal watch,

Figure 2 is a plan view of a time standard oscillator in accordance with the invention and comprising a crystal oscillator and circuit,

Figure 3 is a cross sectional view of a moulded resin case for the time standard oscillator,

Figure 4 is a cross-sectional representation of the time standard oscillator, and

Figure 5 is a plan view of a watch having a round movement.

Referring to Figure 1 the electrical equivalent circuit diagram of a time standard oscillator therein shown comprises a crystal oscillator 1 with its electrodes, an associated oscillation circuit 2, a step variable condenser 3 for adjusting the frequency, a temperature compensating element 4, a resin case for the time standard oscillator, a frequency divider circuit 6 and a driving circuit 7 for the motor (not shown) of the watch.

Figure 2 is a plan view of a preferred form of time standard oscillator provided by the present invention. 8 is a moulded resin case for said time standard oscillator, for example, a case formed of an elastic thermosetting synthetic resin. 9a is a cylindrical case for the crystal oscillator and contains the crystal with its electrodes, said crystal being hung to a stem with three external leads 10, said crystal being in vacuo and the stem and the case for the crystal oscillator being hermetically sealed.

A cap 9b covers most of the external lead lengths of the crystal in order that no material amount of stray capacity shall exist

between the external leads end and other parts, only short lengths of lead wire extending out through a window in said cap. Thus, the crystal oscillator is substantially completely shielded. The temperature compensating element, normally made of BaTiO₃, is indicated at 11. It is connected to required other leads by means of a terminal plate arrangement 12.

The step variable condenser arrangement for fine adjustment of frequency is a glass substrate 13 on which a group of condensers are formed by metal evaporation in vacuo. The glass substrate 13 is disposed on the resin case 8 for the time standard oscillator, a contact spring 14 for the variable condenser being fixed on it by a screw 15. Any condenser in the group can be cut in or out and the capacity value of the step variable condenser arrangement can be increased or decreased for desired adjustment in steps by inserting or removing pins 16 in holes provided in the ends of fingers formed on the contact spring. The oscillation circuit, the frequency divider circuit and the driving circuit for the motor are carried on the back of the resin case 8 for the time standard oscillator. These circuits are of I.C. construction and employ M.O.S. as their active elements. Their exteriors are covered with hardened epoxy resin or the like to protect against outside influences such as moisture. Connections between electric circuit units are made by screwed pin connector terminals in connectors such as 18 of thin plate. A cover member 19 (see Figure 2) made of metal covers the whole resin case of the time standard oscillator. It serves as a shield plate for the step variable condenser arrangement. Furthermore it serves as a fixing plate for the contact spring 14, the pins 16, and the crystal oscillator housing structure 9a, 9b.

As shown in Figures 3 and 4 there is provided on a surface of the moulded resin case 8 for the time standard oscillator, a channel 20 in which the crystal oscillator unit is inserted, a channel 21 for receiving the step variable condenser for fine adjustment of frequency, and a channel 23 for the temperature compensating element 11. At the back of the resin case 8 is a channel 22 for the oscillation and the divider circuits 17a and the driving circuit 17b for the motor, silicon protection 17c and epoxy resin 17d being provided for protecting the circuits. The channel 21 for the step variable condenser for adjusting the frequency and the channel 22 for the electric circuits are situated over one another.

As will now be seen there is provided a very advantageous unit structure in which channels on the front and back of a moulded resin case for the time standard oscillator accommodate the seven elements of that

standard oscillator with interconnections made by leads and screw and pin connectors, said time standard oscillator forming a self-contained unit.

5 The unit structure divides the parts of the watch into a larger number of unit parts than is normally achieved in electric watches and yet enables them to be disposed in a very limited space such as that of a wrist
10 watch. Because of this subdivision into unit parts manufacture, adjustment, and replacement are easy. It is particularly advantageous that the time standard oscillator is a single unit. Shielding is virtually complete
15 so that the time standard oscillator is isolated from its environment despite the limited available space for it. It will therefore give a good, highly constant performance. The invention lends itself to incorporation in a high precision watch for the
20 crystal oscillator housing is in the resin case, and has reasonably good elasticity of mounting so that good shock resistance and protection against external disturbance are obtained. The parts assembled in the circuit
25 case are fixed by single metal holder which serves to provide excellent shielding.

The invention is particularly described with reference to an embodiment using a
30 particular form of crystal oscillator, but it can be applied to a time standard oscillator using any form of crystal oscillator.

Referring now to Figure 5 the watch therein shown is a round movement watch
35 and has a round battery and a crystal oscillator in a cylindrical case. There is a pulse motor the driving coil of which is cylindrical. In order that the electro-mechanical conversion shall be acceptably efficient, the drive coil has to be relatively large
40 and occupies a good deal of the space of the round movement. It is moreover of substantial thickness so that it is impracticable to pile other components on top of it. With
45 a crystal oscillator and electronic circuitry, electric power and electric signal terminals are necessary and simplicity of connection and arrangement of these terminals is important in the design. The arrangement of
50 Figure 5 satisfies these and other design requirements and provides a very favourable relationship of the watch elements in the round movement as well as being very convenient as respects wiring.

55 In Figure 5, 100 is a stem near the position of 3 o'clock, 200 a round movement plate, 300 is a battery cover disposed near 12 o'clock and containing a battery, 400 is the negative terminal of the battery, and 500
60 is the case for the time standard arrangement which comprises a crystal oscillator as the time standard and an electronic circuit formed as a unit. 600 is the crystal oscillator which is disposed in a channel in the
65 case 500, and 700 is a fine adjustment means

for frequency, including a step adjustable condenser. 800 is a temperature compensating device for frequency and includes a BaTiO₃ condenser. 900 is the electronic circuit. This is potted in epoxy-resin or the like, the potting being carried out in a channel of the case 500. The terminals referenced 110 with letter suffixes are electrical signal terminals of the electronic circuit 900, 110a being the terminals for signals for driving the pulse motor and 110b being an earth terminal. These are wired on the driving coil side (the left side as viewed in Figure 5). 110c are connecting terminals of the crystal oscillator, 110d is a connecting terminal for the battery and 110e is a reset terminal. These are wired on the battery side (the right side as viewed in Figure 5). 111 are the electrical signal and output terminals of the tuning fork crystal oscillator and are disposed on the same side as the connecting terminals 110c of the crystal oscillator. This arrangement simplifies wiring. 112 is a group of terminals for connecting the condenser 700 and the BaTiO₃ condenser 800. The reference 113 with letter suffixes refer to the electro-mechanical converter which converts the electrical output signal from the electrical circuit into rotary movement of the gear-train. The coil 113a
95 which contains 15000 turns of copper wire of 2.5/100 mm diameter wound on a core formed of magnetic material is the driving coil of the pulse motor and is cylindrical.

A pulsed current which reverses in polarity every second flows from the driving circuit through the coil 113a of the pulse motor. The motor has stator pole pieces 113b and 113c and a rotor 114 which rotates through a predetermined angle at each pulse. The rotor has six poles with N and S poles alternately. Its rotation is transmitted to a fourth wheel 115, and then to a third wheel and then to a centre wheel. 116 is a second hand jumper acting on the fourth wheel 115 for driving the second hand. 117 is a setting lever for the second hand. One end of this setting lever is engaged with one end of the stem 100 and the other end is engaged with the jumper 116. There is a reset mechanism (not shown) disposed near the stem and having a switch mechanism which is arranged, when actuated, to open some part of the divider circuit to put it in non-operative condition and thus cut off the output signal of the divider. The details of the reset mechanism of the watch, form per se no part of this invention. A watch having the features illustrated in Fig. 5 is also described and claimed in the Specification of our co-pending Application No. 51935/73 (Serial No. 1,361,230).

To recapitulate, in the quartz crystal wrist watch illustrated in Figure 5, the compon- 130

ents are arranged on the round movement plate in such manner that the stem is conveniently disposed near the position of 3 o'clock, the battery is disposed near 12 o'clock, the case for the oscillator time standard in which the crystal oscillator and the electronic circuit are combined into a unit, is disposed adjacent to the battery, the driving coil of the pulse motor is disposed between the case for the oscillator time standard and the stem, and the upper portion of the round movement plate has round it the stem, the battery, the case for the oscillator time standard and the driving coil. Moreover, the rotor and the stator of the electro-mechanical converter, the gear-train and the stem are also conveniently arranged with the setting mechanism and the reset mechanism arranged in the remaining portion of the space near the stem.

The arrangement provides simplified terminal connections for the electrical input and output signals, and results in a flat round watch. There are three main blocks in the watch movement, one being the battery for power source, another being the case containing the oscillator time standard and the third being the mechanism. Each block can be separately adjusted and each can be removed by undoing screws and readily replaced so that after-sales service such as repairing is easy.

WHAT WE CLAIM IS:—

1. A quartz crystal watch having a time standard oscillator which includes a crystal oscillator and is constructed as a unit said watch comprising a mounting member of resin (as herein defined) for said time standard oscillator, said mounting member having spaces accommodating said crystal oscillator, an oscillation circuit thereof, a frequency divider circuit and a driving circuit for mechanical driving means of the watch.

2. A watch as claimed in claim 1 wherein the time standard oscillator includes fine adjustment means for adjusting the frequency thereof and a temperature compensating element, the electrical oscillation circuit of the crystal oscillator, the frequency divider circuit and the driving circuit for the motor being mounted under said fine adjustment means, the time standard oscillator being formed as a unit by mounting the crystal oscillator, the fine adjustment means, the temperature compensating element and foregoing circuits in channels in the resin mounting member.

3. A watch as claimed in claim 1 wherein channels accommodating a crystal oscillator, fine frequency adjustment means and a temperature compensating element are on one side of the resin member and a channel accommodating electric circuits forming parts of the time standard oscillator are on the other side of said resin mounting mem-

ber, the channel accommodating said fine adjustment means being above the channel accommodating said electric circuits.

4. A watch as claimed in either of the preceding claims 2 and 3 wherein unit parts of the time standard oscillator include a crystal oscillator held in place by a cover member for the resin member.

5. A watch as claimed in claim 4 wherein said cover member is a metal member providing shielding for the fine frequency adjustment means.

6. A watch as claimed in any of the preceding claims and comprising a tuning fork type of crystal oscillator of a frequency of at least 16 kHz, as a time standard, an oscillation circuit including a MOS transistor for maintaining said crystal oscillator in oscillation, a divider circuit including a MOS transistor for dividing the frequency of said crystal oscillator, a pulse motor driving circuit including an integrated circuit for amplifying output from said divider circuit, a pulse motor including a rotor and a stator with a driving coil driven by output from said driving circuit, a gear-train driven by said motor and a battery power source.

7. A watch as claimed in claim 6 having a round movement plate carrying the crystal oscillator, the oscillation circuit, the divider circuit, the driving circuit, the pulse motor, the gear-train and the battery wherein the elements of the watch are arranged to form three blocks, one comprising the battery, the second housing the crystal oscillator, oscillation circuit, divider circuit, and driving circuit formed as a unit, and a mechanism block wherein are the pulse motor and the gear train driven thereby.

8. A watch as claimed in claim 7 wherein there is a stem disposed substantially at the position of 3 o'clock, the battery is disposed substantially at the position of 12 o'clock, the second block is disposed adjacent to the battery and a driving coil for the motor is disposed between said second block and said stem, the battery, the second block and the coil being mounted round the round movement plate near its periphery and the rotor of the motor, and a gear train driven thereby being mounted centrally of the watch.

9. A watch as claimed in claim 7 or 8 wherein said second block has groups of connecting terminals for electrical input and output signals from the time standard oscillator, a connecting terminal for the crystal oscillator and a supply terminal for connection to the battery being led out on the battery side of the second block and an output terminal for supplying drive to the motor being led out on the other side of said second block.

10. Quartz crystal watches substantially as herein described with reference to Figures

ents are arranged on the round movement plate in such manner that the stem is conveniently disposed near the position of 3 o'clock, the battery is disposed near 12 o'clock, the case for the oscillator time standard in which the crystal oscillator and the electronic circuit are combined into a unit, is disposed adjacent to the battery, the driving coil of the pulse motor is disposed between the case for the oscillator time standard and the stem, and the upper portion of the round movement plate has round it the stem, the battery, the case for the oscillator time standard and the driving coil. Moreover, the rotor and the stator of the electro-mechanical converter, the gear-train and the stem are also conveniently arranged with the setting mechanism and the reset mechanism arranged in the remaining portion of the space near the stem.

The arrangement provides simplified terminal connections for the electrical input and output signals, and results in a flat round watch. There are three main blocks in the watch movement, one being the battery for power source, another being the case containing the oscillator time standard and the third being the mechanism. Each block can be separately adjusted and each can be removed by undoing screws and readily replaced so that after-sales service such as repairing is easy.

WHAT WE CLAIM IS:—

1. A quartz crystal watch having a time standard oscillator which includes a crystal oscillator and is constructed as a unit said watch comprising a mounting member of resin (as herein defined) for said time standard oscillator, said mounting member having spaces accommodating said crystal oscillator, an oscillation circuit thereof, a frequency divider circuit and a driving circuit for mechanical driving means of the watch.

2. A watch as claimed in claim 1 wherein the time standard oscillator includes fine adjustment means for adjusting the frequency thereof and a temperature compensating element, the electrical oscillation circuit of the crystal oscillator, the frequency divider circuit and the driving circuit for the motor being mounted under said fine adjustment means, the time standard oscillator being formed as a unit by mounting the crystal oscillator, the fine adjustment means, the temperature compensating element and foregoing circuits in channels in the resin mounting member.

3. A watch as claimed in claim 1 wherein channels accommodating a crystal oscillator, fine frequency adjustment means and a temperature compensating element are on one side of the resin member and a channel accommodating electric circuits forming parts of the time standard oscillator are on the other side of said resin mounting mem-

ber, the channel accommodating said fine adjustment means being above the channel accommodating said electric circuits.

4. A watch as claimed in either of the preceding claims 2 and 3 wherein unit parts of the time standard oscillator include a crystal oscillator held in place by a cover member for the resin member.

5. A watch as claimed in claim 4 wherein said cover member is a metal member providing shielding for the fine frequency adjustment means.

6. A watch as claimed in any of the preceding claims and comprising a tuning fork type of crystal oscillator of a frequency of at least 16 kHz, as a time standard, an oscillation circuit including a MOS transistor for maintaining said crystal oscillator in oscillation, a divider circuit including a MOS transistor for dividing the frequency of said crystal oscillator, a pulse motor driving circuit including an integrated circuit for amplifying output from said divider circuit, a pulse motor including a rotor and a stator with a driving coil driven by output from said driving circuit, a gear-train driven by said motor and a battery power source.

7. A watch as claimed in claim 6 having a round movement plate carrying the crystal oscillator, the oscillation circuit, the divider circuit, the driving circuit, the pulse motor, the gear-train and the battery wherein the elements of the watch are arranged to form three blocks, one comprising the battery, the second housing the crystal oscillator, oscillation circuit, divider circuit, and driving circuit formed as a unit, and a mechanism block wherein are the pulse motor and the gear train driven thereby.

8. A watch as claimed in claim 7 wherein there is a stem disposed substantially at the position of 3 o'clock, the battery is disposed substantially at the position of 12 o'clock, the second block is disposed adjacent to the battery and a driving coil for the motor is disposed between said second block and said stem, the battery, the second block and the coil being mounted round the round movement plate near its periphery and the rotor of the motor, and a gear train driven thereby being mounted centrally of the watch.

9. A watch as claimed in claim 7 or 8 wherein said second block has groups of connecting terminals for electrical input and output signals from the time standard oscillator, a connecting terminal for the crystal oscillator and a supply terminal for connection to the battery being led out on the battery side of the second block and an output terminal for supplying drive to the motor being led out on the other side of said second block.

10. Quartz crystal watches substantially as herein described with reference to Figures



1 to 4 inclusive of the accompanying drawings.

11. Quartz crystal watches substantially as herein described with reference to Figure 5 of the accompanying drawings.

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