

[54] CRYSTAL OSCILLATOR TYPE SMALL TIMEPIECE

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[51] Int. Cl. **G04c 3/00**

[58] Field of Search **58/23 AC**, 25 A, 23 R, 23 MV, 58/50 R; 310/8.9, 9.1, 25; 331/155

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[57] **ABSTRACT**

A small electronic timepiece is disclosed, especially a watch, comprising a piezo-electric crystal oscillator as a time base means thereof, a frequency divider for dividing the oscillation fed from the oscillator, and a balance wheel motor for conversion of the frequency divided electric signal fed from the divider into a corresponding mechanical oscillative movement for driving a time-keeping gear train of the timepiece. The improvement of the timepiece comprises the oscillator comprising a piezoelectric oscillation crystal bar which is suspended in the interior of a totally enclosed and evacuated cylindrical container by suspension means at a position along its length defining a nodal point near at least one of the ends of the bar. The suspension means comprises at least two wire mounts each of which is formed at its intermediate portion into a shock-absorbing coil and suspended between two of four rigid supporting pillars fixedly mounted in the container, on the one hand, and the crystal bar, on the other hand. The container is mounted through a resilient sleeve tightly covering substantially the whole length of the container, thereby providing a doubled shock-absorbing means.

8 Claims, 18 Drawing Figures

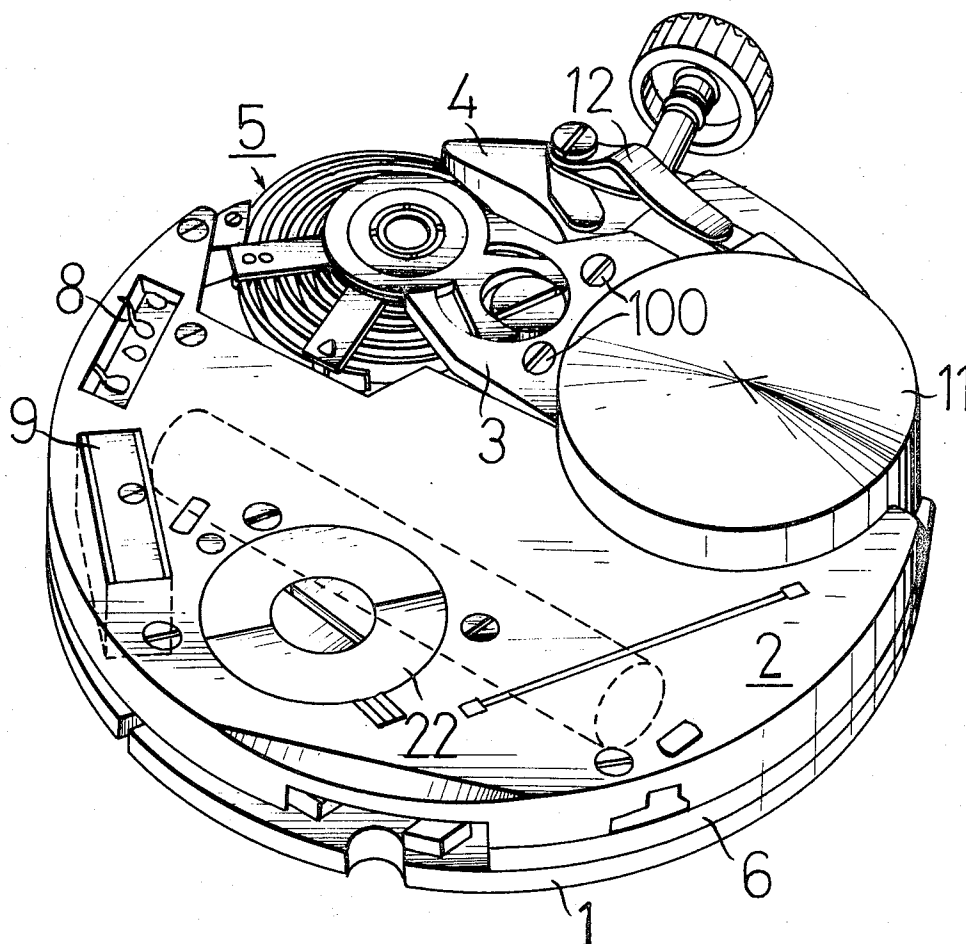


FIG. 1

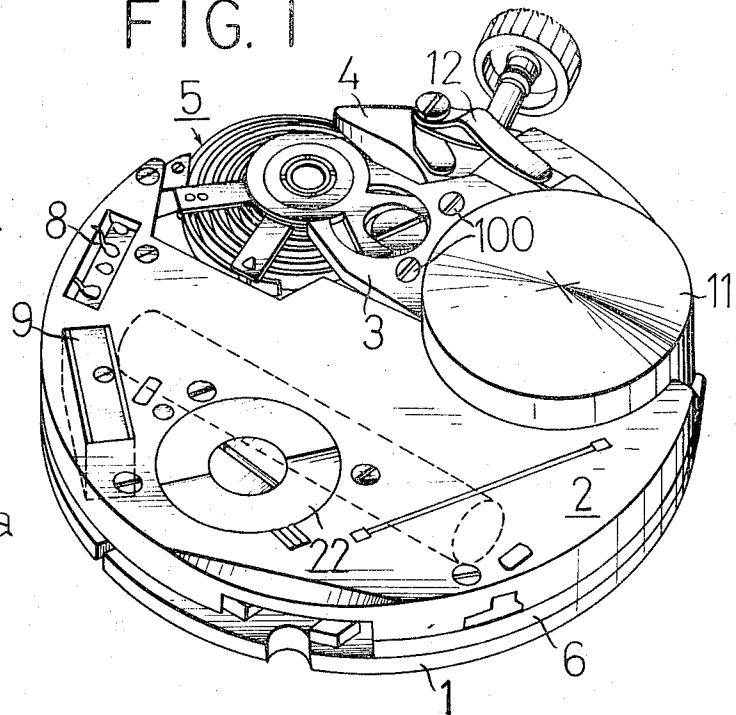


FIG. 4

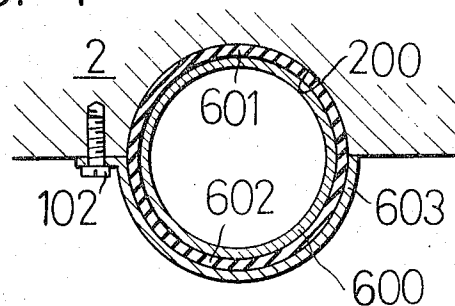


FIG. 3

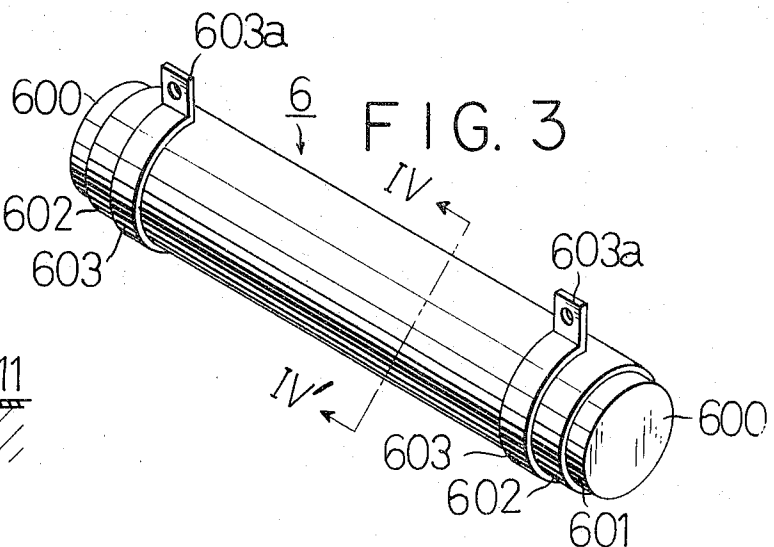


FIG. 5

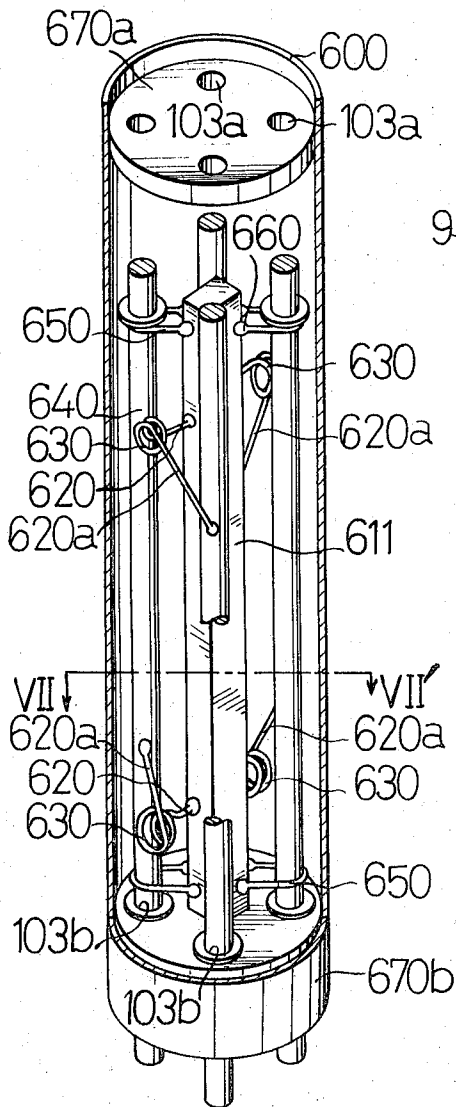


FIG. 6

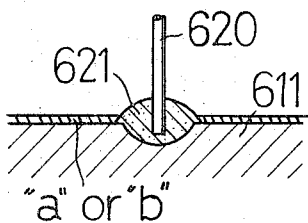
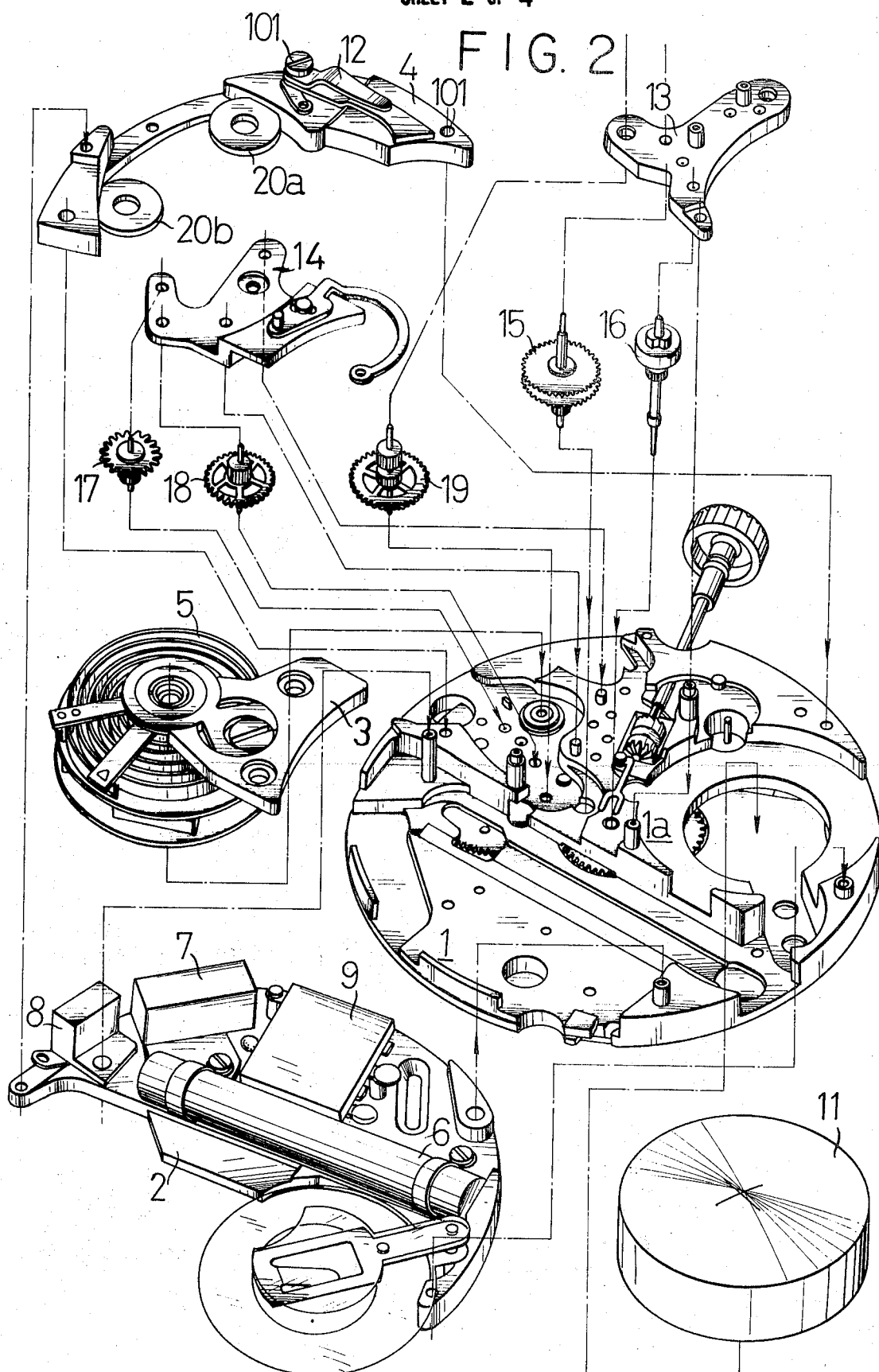


FIG. 2



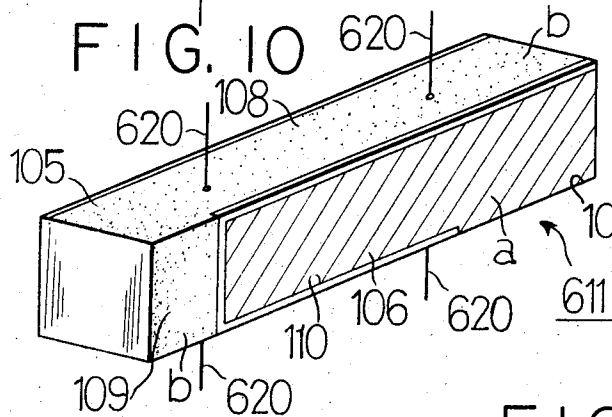
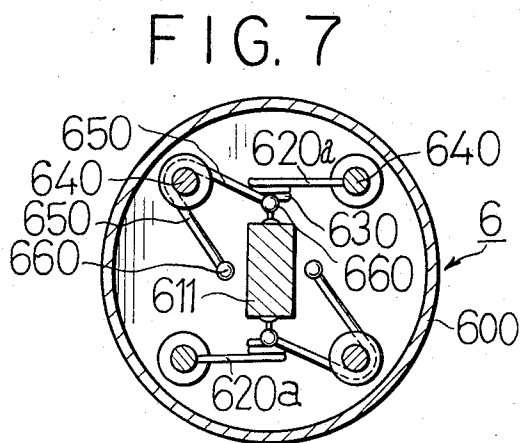
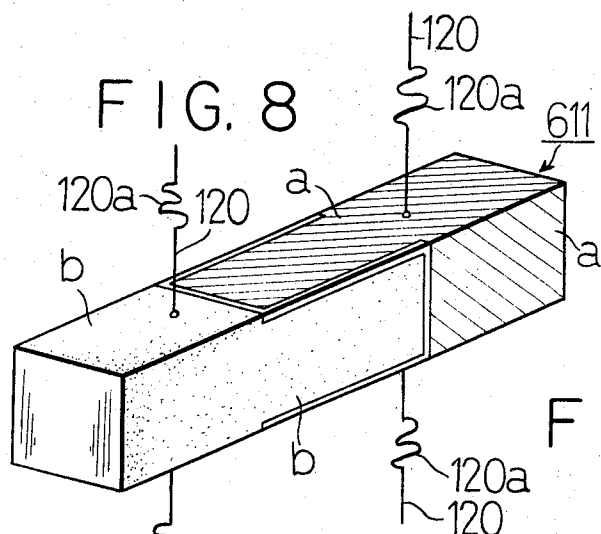


FIG. 9

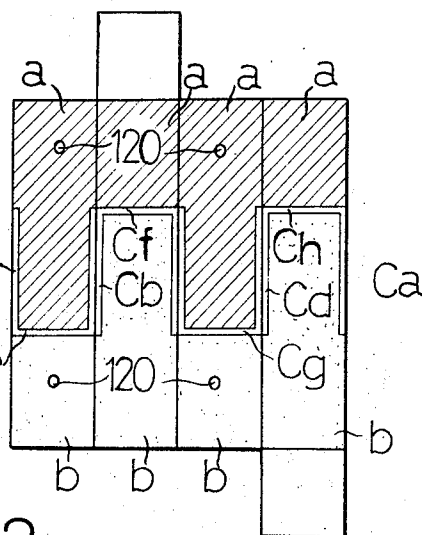
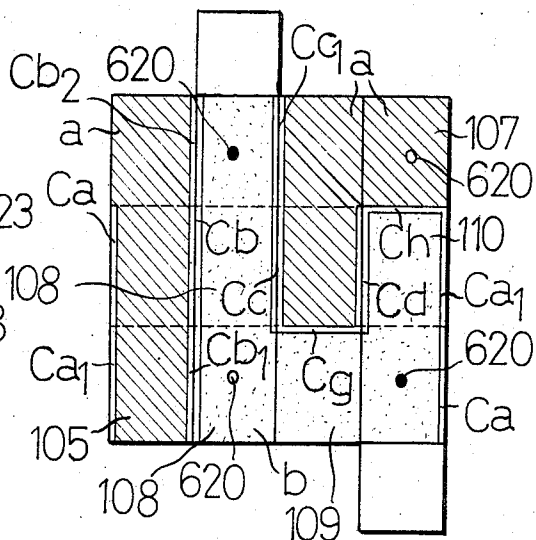
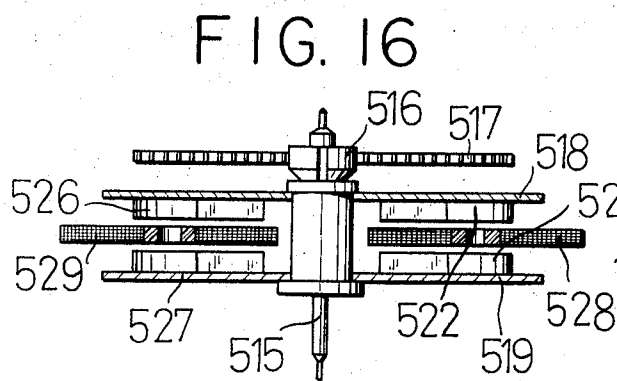
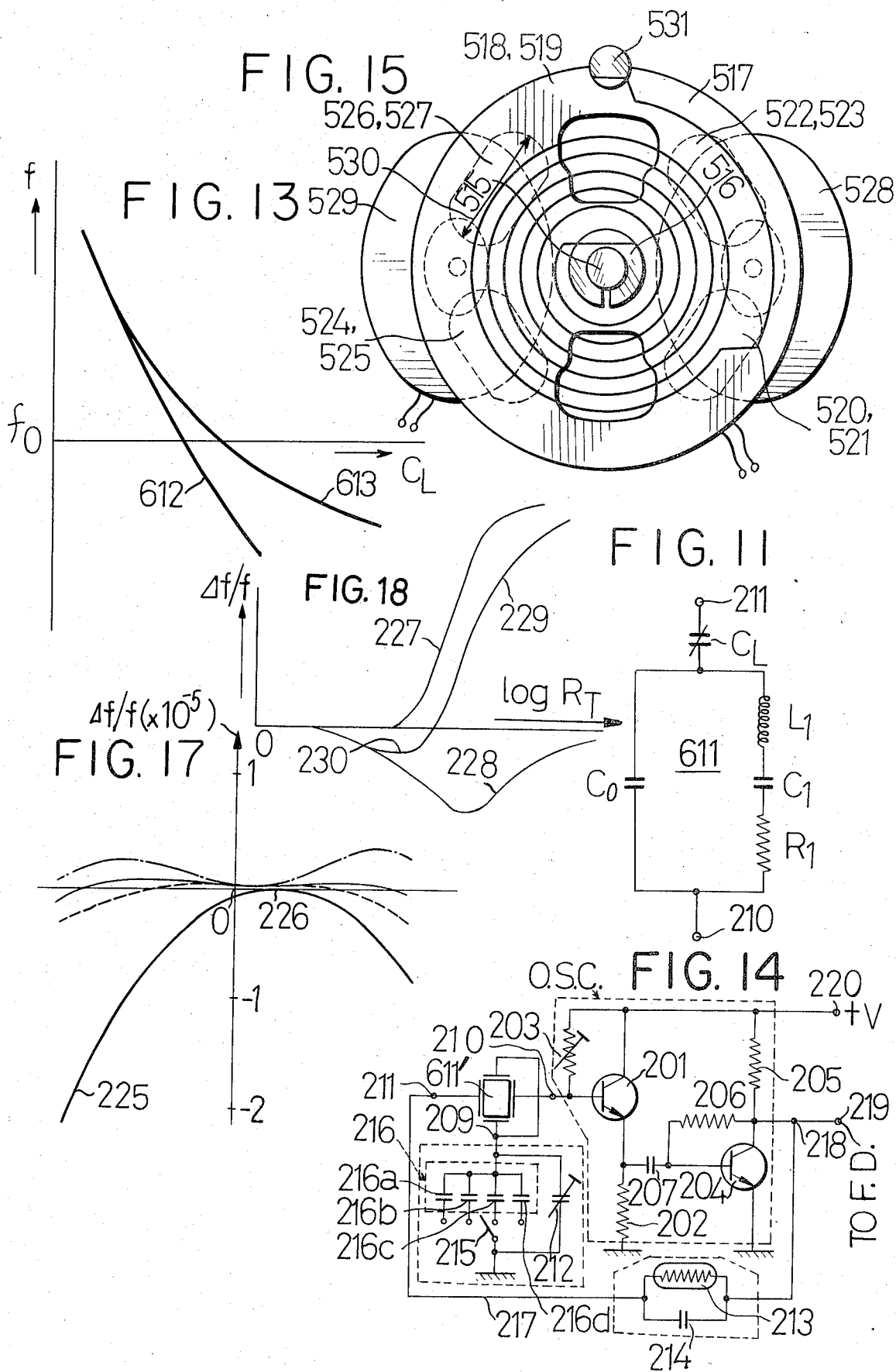


FIG. 12





CRYSTAL OSCILLATOR TYPE SMALL TIMEPIECE

BACKGROUND OF THE INVENTION

This invention relates to small electronic timepieces and improvements therein, especially electronic watches wherein an electrically driven crystal oscillator is used as the time base of the watch; the output signal is fed to a frequency divider comprising a plurality of flip-flops arranged in series one after another; the frequency-reduced output signal from the frequency divider, preferably of 16 hertz or so, is then supplied to a balance wheel motor so as to oscillate the latter in synchronism with the fed signal and for driving the conventional time-keeping and time-indicating gear trains of the watch movement. The crystal oscillator is provided with at least two thin metallic layer electrode elements deposited or stuck on the side surfaces of the crystal oscillator, so as to provide piezo-electric electrodes which are electrically connected with an electronic oscillator circuit for energization thereof to maintain oscillation movement at a certain higher and precise oscillation cycle.

SUMMARY OF THE INVENTION

The main object of the invention is to provide an aforementioned kind of small electronic timepiece, capable of suppressing adverse effects of outside shocks to the operational frequency of the crystal oscillator assembly.

A further object of the invention is to provide an optimum piezo-electric electrode arrangement adapted for use in the crystal oscillator type electronic timepiece and capable of operating improved performance characteristic.

BRIEF DESCRIPTION

These and further objects, features and advantages of the invention will become more apparent when read with the following detailed description and by referring to the accompanying drawings.

In the drawings:

FIG. 1 is a perspective view of a preferred embodiment of a watch movement embodying the novel features of the present invention.

FIG. 2 is an exploded perspective view of the watch movement shown in FIG. 1, wherein, however, the resilient cushioning sleeve attached to crystal oscillator and axially extending electrically connecting prongs provided thereon have been omitted for avoiding excess complexity of the drawing.

FIG. 3 is a somewhat schematic perspective view of a preferred embodiment of an improved crystal oscillator assembly employable in and to be fitted to the watch movement shown in the foregoing, and drawing on an enlarged scale, the shown position of the said assembly being somewhat rotated about its longitudinal axis for showing more clearly the attaching ends of spring clips used for fixingly attaching the assembly, wherein, however, said electrically connecting prongs have been omitted again for simplicity of the drawing.

FIG. 4 is somewhat enlarged cross-section of the crystal oscillator assembly as shown in FIG. 5 and is taken substantially along a section line V—V', said assembly being shown in its practically attached position.

FIG. 5 is a perspective view of the crystal oscillator assembly, wherein, however, the conducting support-

ing rods for an oscillatory crystal bar and the sealed and evacuated cylindrical container therefor have been partially broken away for better demonstration of the inner working parts.

FIG. 6 is an enlarged part of a longitudinal section view of the crystal bar, showing the attaching mode of the end of the longer arm of a shock-absorbing and current-conducting wire mounted to the crystal bar.

FIG. 7 is an enlarged cross-section view of the crystal oscillator assembly shown as in FIG. 5 and taken is substantially along a section line VII—VII' shown therein, wherein, however, the cushioning rubber sleeve covering the sealed container being omitted from the drawing only for convenience, this latter omission being equally applied to FIG. 5.

FIG. 8 is a perspective view of a conventional representative crystal oscillator bar.

FIG. 9 is a developed plan view of the piezo-electric electrodes deposited or stuck on the side surfaces of the oscillative crystal bar shown in FIG. 8.

FIG. 10 is a similar view to FIG. 8, showing an improved crystal oscillating bar which has, however, a square cross-section in place of the rectangular one employed in the foregoing shown in FIGS. 5 and 7.

FIG. 11 is a schematically represented electric equivalent circuit of the improved crystal piezo-electric oscillator shown in FIGS. 10 and 12.

FIG. 12 is a similar view to FIG. 10, showing an electrode arrangement of the crystal oscillatory bar shown in FIG. 10.

FIG. 13 is a schematic and comparative diagram showing the relationship between the operating frequency and the additional capacitance and the comparison of the improved crystal piezo-electric oscillator as shown in FIGS. 10—12 with the conventional comparative one as shown in FIGS. 8—9.

FIG. 14 is a wiring diagram showing an electronic oscillator circuit, including, however, the improved crystal piezo-electric oscillatory bar, and a preferred embodiment of a temperature compensating circuit.

FIG. 15 is an enlarged plan view of a balance wheel motor employable in the watch movement according to this invention.

FIG. 16 is somewhat reduced side elevational view of the balance wheel motor shown specifically in FIG. 15.

FIG. 17 is a comparative performance curves of the oscillator obtainable with or without attachment of the temperature compensating circuit.

FIG. 18 is an auxiliary illustrative diagram for better understanding of the performance characteristic curves shown in FIG. 17.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to FIG. 1 showing a watch movement having an improved crystal oscillator as its time base, numeral 1 represents a conventional pillar plate of said movement. An improved crystal oscillator which is shown in FIG. 1 only in its outline configuration by dotted lines and specifically shown in FIG. 5 in its entirety, is mounted through a supporting plate 2 on the pillar plate 1, as will be more fully described hereinafter.

A balance wheel bridge 3 mounting a balance wheel and regulator assembly 5 is attached fixedly to the pillar plate 1 by means of set screws 100.

A moulded synthetic resin block 4 contains several electronic circuit elements embedded therein, as will

be more fully described hereinafter, is detachably mounted on the pillar plate 1, although the attaching means have been omitted from the drawing for simplicity, said block 4 mounting in turn a drive coil means, again as will be more fully described hereinafter.

Numeral 2 represents a bridge member attached fixedly to the pillar plate 1 and mounts a crystal oscillator 6, an electronic oscillator circuit block 7, a stepping condenser 8, a frequency divider circuit block 9, a trimmer condenser 10 and the like electric and electronic working parts, said stepping condenser serving as a frequency adjuster as will be more fully described hereinafter.

A battery block 11 is mounted in a circular recess formed on the plate 1. A source switching lever 12 is attached onto the block by means of set screws 101, as more specifically shown in FIG. 2.

In FIG. 2, numeral 13 represents a further bridge member which is fixedly mounted on the plate, and said bridge member mounting in turn a second gear 15, a seconds hand arbor 16 and a reduction gear 19. Numeral 14 represents a still further bridge member fixedly mounted again on the plate 1 and mounts in turn a star wheel 17 and a reduction gear 18. Drive coils 20a and 20b are fixedly mounted on the stationary mould block 4.

The supporting plate 2 is formed with a recess 200 having a semi-circular cross section as clearly shown in FIG. 4, although in FIG. 1 such recess 200 has been omitted from the drawing only for simplicity.

The crystal oscillator assembly generally shown at 6 comprises a sealed cylindrical container 600 which is enclosed nearly over its whole length with a sheath 601 made of a resilient material, preferably silicone rubber. A pair of spring clips 603 are used for holding the assembly 6 in position. For this purpose, the clip 603 is formed at its root end with a plain or screw-receiving hole 603a through which a set screw 102 is threaded into the material of supporting plate 2. In place of the supporting plate, the pillar plate per se can be used as the mounting plate for the crystal oscillator assembly 6.

By use of the aforementioned resilient mount of the assembly 6, leaked oscillation energy from inside of the sealed container 600 and through the cylindrical wall thereof can be substantially absorbed by the resilient sheath 602 before being transmitted to the supporting plate 2, thereby the oscillation of the crystal oscillator to be described being substantially stabilized.

Next, referring to FIG. 5, the assembly 6 will be more fully explained. In this figure, numeral 611 represents a crystal oscillator bar of square or rectangular cross section, which is suspended through four suspension wires 620, each having a certain resiliency by the provision of intermediate coiled section 630. One end of each of these suspension wires 620 is attached by blazing or the like technique to the crystal bar 611, while the opposite end of the wire is fixedly attached by blazing or the like fixing technique to selected one of supporting rigid pillars 640 which serves as electrodes, as will be more fully described hereinafter. For better oscillatory suspension of the bar 611, it is suspended at its upper and lower nodal points by means of said pairs of suspension wires 620. The supporting pillars or electrodes 640 passes tightly through respective perforations 103a and 103b formed respectively through upper and lower mounting discs 670a and 670b, and fixed

thereto by suitable fixing means such as blazing, soldering or the like.

By the provision of the coiled suspension wires 620 in the above mentioned way, sudden shocks occasionally transmitted through the sealed container 600 or electrodes 640 can be effectively avoided from reaching the oscillator bar 611. At the upper and lower zones in proximity to the upper and lower ends of the bar 611, at least two of the supporting pillars 640 are provided with resilient supporting means, preferably wires 650, which are fitted at their inner ends with cushioning pads 660, made preferably of rubber, and designed and positioned to suppress occasionally excessive oscillation amplitudes of the crystal bar 611.

The aforementioned parts of the oscillator assembly are totally enclosed within the interior of the sealed container 600, with exception of the axially outwardly extruded ends of the electrodes which are to be connected to the electronic oscillator circuit and the current source, as will be more fully described hereinafter. It should be noted that the aforementioned protruding electrode ends have been shown only in FIG. 5 and thus, in other figures these have been omitted for avoiding confusion with other parts. The rubber pads 660 are arranged so as to keep slight idle gaps between them and the crystal bar for performing the above purpose. The members 650 and 660 can be designated in combination as stopper means.

In FIG. 6, the soldered connection of supporting wire 620 with crystal bar 611 is shown in an enlarged section. For this purpose, the bar 611 is formed with a recess 621 for the realization of a more rigid soldered connection thereat. For convenience of the drawing space, however, the enlarged section of FIG. 6 has been shown in its true or horizontally mounted position of the crystal oscillator substantially as demonstrated in FIGS. 1 and 2.

The embodiment can be more fully understood by reference of FIG. 7 which represents a cross sectional view taken along a section line VII-VII' in FIG. 5. If necessary, the excess oscillation suppression means 650;660 can be dispensed with.

In FIGS. 8 and 9, a conventional wire-suspendable piezo-electric crystal oscillator bar is specifically shown in its perspective and in its electrodes-developed view, respectively. FIGS. 10 and 12 are similar views to FIGS. 8 and 9, showing a novel piezo-electric crystal oscillator bar. FIG. 11 shows an electric equivalent circuit of the piezo-electric oscillator, employable in the present invention.

The interelectrode capacitance C_0 of the piezo-crystal oscillator shown in FIG. 12 can be determined by the following formula:

$$C_0 = (C_a + C_b + C_c + C_d) + (C_{a1} + C_{b1} + C_{b2} + C_{c1}) = C_{o1} + C_{o2}$$

where,

$C_{a1} + C_{b1} + C_{b2} + C_{c1}$; however, for small crystal oscillator as used in small timepiece such as watch, the values of C_g and C_h are so small that they may be neglected.

According to our comparative experiments between the said prior art crystal oscillator, FIGS. 8 and 9, and the improved one, FIGS. 10 and 12, the component C_{o2} is larger by about 40 percent in the latter which is naturally highly advantageous.

The relationship between the additional capacitance CL , see FIG. 11, and the oscillation frequency of the

crystal oscillator is shown in FIG. 13. A relatively acute curve 612 shows the frequency characteristic of the conventonal crystal oscillator shown in FIGS. 8 and 9, while a more gentle curve 613 represents that of the improved oscillator shown in FIGS. 10 and 12. As will be seen from the foregoing that the interelectrode capacitance can be substantially increased over that of the comparative conventional one, when employing the improved piezo-electric crystal bar according to this invention.

Referring back to FIGS. 8 and 9, thin metallic films, preferably of gold, silver or the like, are evaporatively deposited in vacuo on the four side surfaces of crystal bar 611. Film electrodes "a" and "b" constitute opposite polarity electrodes, yet may be made of the same material. The overall interelectrode capacitance "Co" is a sum of local interelectrode capacitances C_a - C_h , of which those denoted by C_e , C_f , C_g and C_h appearing at lateral and thus shorter interelectrode gaps can be practically neglected; thus, in the case of a small size crystal bar, such as, of dimensions: $15 \times 0.5 \times 0.5$ mm, those denoted by C_a - C_d appearing at longitudinal interelectrode gaps are the only one taken into account in practice. In this respect, it should be noted that the FIGS. 8, 9, 10 and 12 have been prepared as an intentionally shortened length of the crystal bar, and thus the lengths shown of the electrodes are only for the convenience of the drawing. In addition, these figures have been prepared in a preferred embodiment of the crystal bar which has a square cross-section.

Thus, in the conventional piezo-electric crystal bar, shown in FIGS. 8 and 9, the practical and overall interelectrode capacitance may be expressed by the following formula:

$$Co1 = Ca + Cb + Cc + Cd.$$

In the case of the improved piezo-electric oscillatable bar shown in FIGS. 10 and 12, similar or same constituent parts are shown by respective same reference numerals and characters with those used in the foregoing conventional crystal bar shown in FIGS. 8 and 9.

In FIGS. 10 and 12, two neighboring side surfaces 105 and 108 of the crystal bar 611 are stuck wholly with opposite polarity electrode films "a" and "b", respectively. The remaining two side surfaces 109 and 110 are stuck each with opposite polarity electrode films, equally designate with "a", and "b", respectively. It will be seen from the drawing that the respective longitudinal interelectrode gaps providing the capacitances C_a , C_b and C_c are highly longer than those in the foregoing conventional bar, thus providing a corresponding increased overall interelectrode capacitance "Co" which was explained hereinbefore, and in comparison with "Co1".

In the conventional electrodes arrangement shown in FIGS. 8 and 9, both kinds of electrode films "a" and "b" are positioned in a certain regular alternatingly zig-zagged, rectangular saw teeth configuration, and two pairs of wire mounts 120, each wire having a wavy intermediate shock-absorbing portion 120a at the most. In this case, it is almost impossible to reduce the number of such wire mounts from two pairs, or four as a whole. In addition, since these wire mounts serve at the same time as current conducting means from the supporting metallic and thus conductive bars as at 640 in FIG. 5 to the opposite polarity electrodes "a" and "b", a reduction of the wire mounts number from four is still further difficult.

In the improved electrodes arrangement shown in FIGS. 10 and 12, and described hereinbefore, each of the wire mounts 620 has a L-shape having a longer arm 620a, said coiled portion 630 being positioned at the intersection of these both arms. The longer arm 620a is attached to the allocated one of the conductive supporting pillars 640, while the shorter arm 620b is attached to the crystal bar 611. In addition, as seen from FIG. 5, the coiled portions 630 of a pair of the conductive supporting wire mounts 620, when seen vertically in FIG. 5, direct generally outwardly and upwardly or downwardly. By adopting such design and arrangement of the wire mounts 620, it has ascertained according to our practically experiments that substantially all the possible outside shocks coming from every directions can be effectively prevented from the arrival to the crystal bar, even if the number of pairs of the wire mounts should have been reduced from two to one, as shown schematically by small white or block circles in FIG. 12, as the case may be.

In addition, it should be further noted that the soldering job for fixing these conductive wire mounts to the crystal bar and the supporting pillars can be highly accelerated relative to the conventional crystal oscillator assembly which means a substantial progress in the art.

In FIG. 11, an equivalent circuit of the improved piezo-electric crystal oscillator shown in FIGS. 10 and 12 is shown. In this equivalent circuit, C_L represents an additional adjusting condenser of known construction and again of deposited film type one, consisting of a combination of a plurality of film condenser elements connected series or parallel one after another or a combination thereof, and is mounted preferably on one of both end surfaces of said crystal bar. C_o represents the interelectrode capacitance, as was referred to hereinbefore; L_1 represents a series resonance inductance; C_1 represents a series resonance capacitance; and R_1 represents a series resonance resistance, as will easily occur to any person skilled in the art.

Now considering the oscillation frequency of the crystal oscillator of the equivalent circuit shown in FIG. 11, the increased interelectrode capacitance C_o and the attainment of the more gentle curve 612, FIG. 13, the following merits can be attained.

1. The fine adjustment of the oscillation frequency can be made highly easy.

2. Variation in the oscillation frequency caused by unavoidable aging of the electrode material can be made substantially smaller, thus the desired high frequency stability being assured.

3. When considering the combination of the crystal oscillator with the electronic oscillator to be described hereinbelow by reference to FIG. 14, otherwise larger dependency of the oscillation frequency of the former upon the characteristics of the latter can be reduced so far.

4. Temperature compensation can be performed rather easier.

In FIG. 14, a preferred embodiment of the electronic oscillator circuit which cooperates with the piezo-electric crystal oscillator which is somewhat modified from that so far shown and described. In the foregoing piezo-electric crystal oscillator, it was in substance of two-terminal two-electrode type. However, in the present circuit arrangement shown in FIG. 14, the crystal oscillator is of the four- (or three-) terminal, four elec-

trode type. By adding certain means, the foregoing one can be easily practiced into the latter.

In this circuit, 216 represents a first condenser adapted for rough adjustment of the oscillation frequency. Numeral 212 represents a second condenser adapted for fine adjustment of the oscillator frequency. By use of these two adjusting condensers, unavoidable frequency deviation from the designed oscillation value caused by manufacturing inaccuracies can be remedied in an easy manner. The condenser 216 comprises a parallel arrangement of a plurality of film condenser elements 216a-216d, shown only representatively, and selector switch means 215 which is preferably a plurality of easily breakable conductive strip elements. The condenser elements 216a-216d have stepwise increasing capacity values in succession.

A second condenser or a trimmer condenser 212 is earthed directly and in parallel with said first condenser 212. These condenser elements, the trimmer condenser and said switch means are connected with each other and with the electrodes of said modified crystal oscillator 611' and constitute in combination a frequency adjusting circuit.

Numeral 201 represents a first stage transistor; 202 an emitter resistance thereof; 203 a base-bias resistor; 204 a second stage transistor; 205 a collector resistor thereof; 206 an emitter follower resistor; 207 a coupling condenser. These circuit elements are connected with each other as shown. In this way, an electronic oscillator circuit as a kind of amplifier is provided.

One of electrodes, shown at 210, of the crystal oscillator 611' is connected to the base electrode of the first stage transistor 201 of electronic oscillator circuit.

Junction 218 positioned in proximity to output terminal 219 is connected through feedback line 217 to opposite terminal 211 of the crystal oscillator 611'. As seen, a temperature compensator comprising a parallel arrangement of thermistor 213 and a condenser 214 is inserted in this feedback line 217. Output terminal 219 is connected to a frequency divider circuit, as only hinted and not specifically shown. This frequency divider circuit is of common design and may comprise a successive stages of flip-flops, although not shown on account of its very popularity. End terminal 220 is connected to the positive side of the battery block, although the connecting lead has been omitted only for simplicity. The negative side of the battery is earthed although not shown.

The main feature and operation of the aforementioned oscillator circuit assembly is as follows:

As seen from FIG. 14, the arrangement comprises the crystal oscillator 611' and the temperature compensator are inserted in series to each other and between the input and the output of the amplifier, so as to represent a circuit loop.

A general representative temperature characteristic curve of a low frequency three-terminal crystal oscillator is shown at 225. The peak point is shown at 226. This curve is similar to a parabola. As an important requirement for the temperature compensator, it is first required that the compensator must set the allowable peak temperature as desired. Next, the oscillation frequency must be compensated substantially in parabolic mode.

Now considering the parallel arrangement of the resistance value, R_T , of thermistor 213 and the capaci-

tor value, C , of condenser, then the impedance Z will be:

$$Z = \frac{R_T}{1 + (\omega \cdot C \cdot R_T)} - j \frac{1}{\omega \left(C + \frac{1}{\omega^2 \cdot C \cdot R_T^2} \right)} \quad (1)$$

$$= R_e - j \frac{1}{\omega \cdot C_e}$$

where,

R_e : equivalent resistance; and

C_e : equivalent capacitance;

The characteristic of thermistor can generally be expressed by the following formula:

$$R_T = R_C \cdot \exp B \left[\left(\frac{1}{T} \right) + \left(\frac{1}{T_C} \right) \right] \quad (2)$$

Therefore, it will be seen that the value R_T varies exponentially with the temperature.

From the formula (1), the value C_e varies from C to α with R_T . On the other hand, when the capacitance connected in series with the crystal oscillator, the oscillation frequency will vary therewith as is commonly known, and the relation can be expressed in terms of R_T as its parameter.

Now expressing:

Qq = sharpness of resonance of crystal oscillator;

rq = ineffective resistance of crystal oscillator;

ri = input resistance of amplifier circuit;

ro = output resistance of amplifier circuit;

$\Delta\phi$ = phase angle;

then, the frequency deviation will be:

$$\Delta f/f \approx \Delta\phi/2Q_0 \quad (3)$$

where,

$$Q_0 = \frac{Qq}{1 + \frac{ri + rc + Re}{rq}} \quad (4)$$

it is clear from the formula (4), Q_0 , and thus, the oscillation frequency will varies with R_e , as shown at 227 in FIG. 18.

Since R_e has a maxima at $R_T = 1/\omega C$, the variation of oscillation frequency relative to $\log R_T$ will become as at 228 in FIG. 18. The effect of the temperature compensator 213; 214 will then be an addition of these both curves 227 and 228, as shown at 229 which has its minima at 230, and varies in proximity thereof substantially parabolically relative to $\log R_T$.

As clear from the formula (2) representing the characteristic of the thermistor, the value of $\log R_T$ varies linearly with temperature variation, and thus, the oscillation frequency varies, after all, parabolically therewith.

With variation of C , the value of C_e and R_e therewith, thus the curves 227 and 228 will vary. Thus, at the same time, the resultant curve 229 will be subject to variation. It will thus be seen that the point of maxima can be shifted in its position and the curvature in proximity thereof can also be varied.

In performing the temperature compensation, the curve 229 which is complementary to the characteristic of the crystal oscillator is found out at first, and then a point R_T' which corresponds to the point of its maxima 230. And a proper combination of thermistor and C is selected out so that the said value of R_T' may be at-

tained at the maximum allowable temperature of crystal oscillator. On the other hand, since the characteristic of the thermistor has a specific functional system as shown by the foregoing formula (2), an exact and precise compensation could not be realized. In order to perform a rather precise compensation, ri in the formula (4) may preferably be watched upon for varying the value thereof. Or more specifically, the input impedance of the amplifier, ri , can be easily varied by alteration of the bias resistance R_{B1} in formula (3). The effects of the variation of bias resistance R_{B1} in formula (3) are shown by the curves 231 and 232, thereby providing the chance of alteration of the variation rate in the compensation effect.

More specifically, the variation rate in the compensation effect can be modified generally as a whole by varying the value of R_{B1} to a larger degree, the more effective will be its effect, especially at higher temperatures which means a substantially advantage in the technical field concerned. On the contrary, a decrease of the value of R_{B1} , the compensation effect may be made weak as a whole. Therefore, by selecting proper value of R_{B1} , a curve such as at 243 may be obtained so as to be substantially ideal.

The realization of proper modification of the center frequency to occasional demands can be made independently by use of a variable trimmer condenser as at 222. So far as the variable range is within reasonable limits, the aforementioned compensation curve can be shifted substantially in the parallel mode.

In order to make variable the input impedance ri of the amplifier, there may be several different methods. As a representative example, the first stage emitter resistor 212 can be made variable for that purpose.

According to the novel principles set forth above, the temperature compensation of the crystal oscillator can be performed electrically and continuously and the oscillator can be made substantially shock-proof. For this purpose, the compensation can be realized without loss of the power which fact is highly advantageous in the case of smaller timepieces, especially electronic watches wherein power consumption must be kept as small as possible. In addition, the compensator is highly simple in its design and very small in its dimensions. In place of or in addition to thermistor or condenser, R_{B1} can be utilized for execution of intentional modification of the curvature of the characteristic curve, and in a rather strict degree compensation as desired.

Since one side of the variable trimmer condenser may be earthed, an improved stability of the thus adjusted center frequency is provided.

Finally referring to FIGS. 15 and 16, the balance motor assembly is more fully described.

In these drawings, numeral 515 represents a balance wheel arbor; 516 a hair spring collet; 517 a hair spring; 518 and 519 balance wheels made of magnetic material; 520 - 527 axially magnetized pseudo-elliptical permanent magnets, the longitudinal axis 530 of each of which directs tangentially to rotational circle of the balance wheel motor. 528 and 529 represent a pair of diametrically opposite, substantially elliptical drive coils which are stationarily mounted as connectionally. As seen, each of the longitudinal axes of these elliptical coils directs tangentially to the rotational directions of the balance wheel motor. These coils 528 and 529 are connected in series or parallel to each other, although

the connection diagram has been omitted only for simplicity.

Vertically registered permanent magnet pairs 520; 521, 522; 523, 524; 525, and 526; 527 arranged to interlink with said drive coils 528; 529 with proper idle gaps, as seen from FIG. 16, all of said coils being fixedly mounted on the magnetic balance wheels 518 and 519 as shown in FIG. 16. These balance wheels are fixedly attached to the balance wheel arbor 515.

Nearly at the top of the arbor 515, collet 516 is fixedly attached which mounts in turn fixedly the outer end of hair spring 517, while the outer end of the spring is fixedly attached to balance bridge 3 (see, especially FIG. 2).

In comparison with the comparative conventional one, using circular permanent magnets and coils, the improved embodiment of the balance wheel motor provides the areas through which the effective magnetic fluxes penetrate are substantially broader and the mutual magnetic coupling degree between the coils; on the one hand, and the permanent magnets, on the other, can be improved appreciably. In this way, disadvantageous effects of outside shocks to the desired correct oscillating movement of the balance wheel motor can be avoided to an appreciable degree.

The embodiments of the invention in which an exclusive property or privilege is claimed are as follows:

1. In a small electronic timepiece, especially a watch, comprising a piezo-electric crystal oscillator as a time base means thereof, a frequency divider for dividing the oscillation frequency fed from said oscillator, and a balance wheel motor for conversion of the frequency divided electric signal fed from said divider into a corresponding mechanical oscillative movement for driving a time-keeping gear train of said timepiece, the improvement wherein said oscillator comprises a piezo-electric oscillation crystal bar which is suspended in the interior of a totally enclosed and evacuated cylindrical container by suspension means at a position along its length defining a nodal point near at least one of the ends of the bar, said suspension means comprising at least two wire mounts each of which is formed at its intermediate portion into a shock-absorbing coil and suspended between two of four rigid supporting pillars fixedly mounted in said container, on the one hand, and the crystal bar, on the other hand, and wherein said container is mounted through a resilient sleeve tightly covering substantially the whole length of said container, thereby providing a doubled shock-absorbing means.

2. A small electronic timepiece as claimed in claim 1, wherein at a position in proximity to that of said shock-absorbing wire mount, a resilient stopper is provided for preventing excess amplitude oscillation of said crystal bar and is attached fixedly to at least one of said supporting pillars.

3. A small electronic timepiece as claimed in claim 2, wherein said resilient stopper comprising a bendable wire and a buffering pad attached fixedly at the inner ends of said supporting pillars positioned in close proximity of said crystal bar.

4. A small electronic timepiece, as claimed in claim 1, wherein said crystal bar has a rectangular cross-section and wherein two of the four piezo-electrode-bearing side surfaces of said crystal bar bear unipolar piezo-electrodes of opposite polarities and each of the

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remaining two side surfaces bears a pair of piezo-electrodes of opposite polarities.

5. A small electronic timepiece as claimed in claim 1, said resilient sleeve is made of silicone rubber.

6. A small electronic timepiece as claimed in claim 1, wherein a frequency adjusting means is provided at an electronic oscillator cooperating with said piezo-electric oscillation crystal bar resiliently suspended, said adjusting means comprising a plurality of condenser elements having steppingly varying capacitance value for rough adjustment of said frequency, and a plurality of trimmer capacitance elements having continuously varying capacitance values for fine adjustment of said frequency.

7. A small electronic timepiece as claimed in claim 15

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1, wherein said piezo-electric crystal oscillator comprises an electronic oscillator circuit having a temperature compensating circuit inserted in a feedback line connected between the output side and the input side of said oscillator circuit, said compensating circuit comprising a thermistor and a capacitor connected in parallel to each other.

8. A small electronic timepiece as claimed in claim 7, further including means for adjustment of the input impedance of said electronic oscillator circuit, said means being preferably an adjustable resistor inserted in the base-collector passage of a first stage transistor included in said electronic oscillator circuit.

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