

PATENT SPECIFICATION

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(54) SYNCHRONIZED WATCH

- (71) We, TIMEX CORPORATION, a Corporation organized under the Laws of the State of Delaware, United States of America, of Waterbury 20, Connecticut, United States of America, 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 and in and the following statement:—
- 10 This invention relates to an electrically powered wrist watch.
- The use of a quartz crystal or like oscillator of highly stable frequency in conjunction with a frequency divider to control the frequency of a "slave" device has long been known, but heretofore the application of this desirable means of control to an electric watch has posed problems.
- 20 Relatively recent example of proposals that have been made are found to be in United States Patents No. 3,212,252, 3,292,064, 3,282,042 and 3,451,210. In these, the wheels of the watch are driven by either a conventional oscillatory balance wheel or a tuning fork unit, in which oscillation frequency is relatively independent of oscillation amplitude, and which is impulsed intermittently at a controlled point in the oscillation cycle when battery current is applied to the drive of the electromagnetic motive unit; but the control of the current pulses to the drive coil involves the use of an additional pick-up or sensing coil to control a transistor as the current controlling switch, and the tie-in to the time base unit involves either a combination of signals in the transistor output or special circuitry by which pulses from the pick-up coil are combined in one way or another with the frequency-divided output of the quartz oscillator to develop a combined signal for application to the base of the transistor.
- 40 The present invention provides an electric wrist watch in which a fixed-frequency time base unit, such as that having a quartz oscillator and a frequency divider, is made operative to give better time-keeping by association in a new and simplified way with the motive unit of the watch through the use of a combination of selected particular functional units.
- 50 According to the present invention in a battery-powered electric wrist watch of the type in which the immediate source for the wheels is an oscillatory balance wheel unit including a hairspring, we provide the combination of means associated with the hairspring by which the oscillation frequency of the balance wheel unit is dependent on oscillation amplitude over a working range of oscillation frequency, an electromagnetic motive unit comprising a relatively movable drive coil and multipolar permanent magnet for imparting an impulse to the balance wheel when current flows in the drive coil, one of said elements of the motive unit being mounted for motion with the balance wheel, a battery for supplying direct current to said drive coil, a switch connected in a series loop including said drive coil and battery and comprising a conductive element moving with the balance wheel and a resilient conductive member adapted to be engaged briefly by said moving conductive element to establish a conductive state of brief duration at a predetermined point in the motion of the balance wheel, a triode transistor having a control electrode and having its two other electrodes connected in said series loop to pass current of said loop when the transistor is in a conductive state, and a time base unit comprising a piezoelectric crystal oscillator unit and a frequency divider network having its output directly connected to the control electrode of said transistor to apply thereto a train of discrete pluses of fixed width and frequency to render said transistor intermittently conductive, whereby the duration of current flow in said coil upon each closure
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of said switch is determined by the coincidence of its conductive state with that of said transistor thereby to control the amplitude and through it the frequency of said balance wheel oscillations.

Also according to the present invention we provide a wrist watch comprising a power source, a high frequency quartz crystal oscillator activated by the power source, a divider to reduce the frequency of the high frequency oscillator, a transistor switch connected to the divider output to be intermittently operated thereby, a contact spring connected in series with the transistor, a balance wheel assembly including a balance wheel having a low frequency of oscillation which is dependent on amplitude of oscillation, stationary magnet means, a drive coil mounted on the balance wheel for interaction with said magnet means, and contact means engaged by the spring during the oscillation of the balance wheel to supply drive pulses to the coil thereby synchronizing the balance wheel with a sub-harmonic frequency of the quartz crystal oscillator, and, time display means operated by the balance wheel assembly.

A preferred simplified and effective system using such a time base unit in a battery-powered wrist watch combines such a unit with selected particular functional units for the D.C. battery-powered motive unit of the watch comprising the following:—

1. For the direct transmission of driving forces in the known way to the wheels of the watch, a balance wheel unit of the kind in which the frequency of oscillation is made to be dependent on oscillation amplitude, as for example by an arrangement of the usual regulating pins in such close physical relation to the helical hairspring that they bear upon it variably to change the natural frequency of oscillation as the amplitude of oscillation varies, such a balance wheel unit being known *per se* from United States Patent No. 2,183,062;

2. An electromagnetic motive unit for the balance wheel which consists of a drive coil and a permanent magnet, the coil preferably but not necessarily serving as the mobile element and therefore, being the element mounted on the balance wheel; such a motive unit being either of the unidirectional impulse type using two poles of opposite polarity to generate simultaneous impulses on the two sides of the coil, once in each full oscillation, as in United States Patent No. 2,976,435 (and c.f. Patent No. 2,183,062 above), or of the bidirectional type as in French Patent No. 1,277,507, using three poles and a double-action contact, but with the same two-pole action in a given direction once in each half-oscillation according to the principle of Fery set forth in French Patent No. 677,304

of 1928 and its additions Nos. 36,026 and 36,434;

3. A switch which is in a series loop with the battery and the drive coil and which is closed briefly, to give a conductive state, at a particular point or points in each half or full oscillation, by the engagement of a conductive pin on the balance wheel or its staff with the free end of a resilient fixed contact, as in Patents identified in paragraphs 1 and 2 above; and

4. A triode transistor having a control electrode and two other electrodes which are connected in the series loop including the battery, the drive coil and the switch, thus creating with the switch an AND unit in the sense that current flows in the loop only when both the contactor and the transistor are conductive, the transistor having its control electrode, i.e. its base, directly connected to the frequency divider output to receive a train of pulses of stable frequency which make the transistor intermittently conductive for time periods of fixed duration.

With this system, stabilization of the timekeeping is effected by the action of the AND network in fixing the duration (width) of the pulses of current applied to the drive coil of the motive unit. The duration of those pulses of constant D.C. voltage determines the amplitude of oscillation, which in turn controls oscillation frequency because of the special amplitude-frequency characteristic given to the balance wheel assembly. As oscillation frequency varies (watch running too fast or too slow), the duration of the current pulses in the coil varies because of the resulting change in phase between the varying-duration conductive periods of the switch and the fixed-duration conductive periods of the transistor, with consequent change in the duration of their coincident conductive periods.

Synchronizing systems have been known before in which the duration of impulsion of a driven unit was varied by variation of the coincident conduction periods of two devices which were placed in the power supply line to a drive coil and which had intermittent conductive periods, the conductive periods of one such device being determined by the driven motive unit and those of the other such device being determined by a reference signal. See United States patent No. 2,183,062, referred to above, in which a switch worked intermittently by a balance wheel was in series with a rectifier that passed the half-waves of a received alternating current supply of power for driving the motive unit.

Also, United States Patent No. 3,207,965, Figs. 10-14, describes a master and slave system in which the master oscillator is of

the tuning fork type driven by intermittent application of direct current to a drive coil 14 through a transistor TR-1 controlled by pulses generated in a sensing coil 13 associated with the fork; and the synchronized "receiver" or slave unit, either an oscillatory or rotary motive unit, is driven by coils 34-36 which are in parallel with the master drive coil 14 and which receive current during the coincident conductive periods of the transistor TR-1 at the master oscillator and a device (either another transistor TR-2 or a "circuit breaker") worked by the receiver's motive unit (as through pick-up coil 37), there being in some cases a frequency divider between the master unit and the receiver unit. See also the French Patents of Hatot No. 1,092,411 (Fig. 12); the 6th Addition No. 73,591 thereto; and Fig. 38 of the 3rd Addition No. 80,213 to No. 1,090,564.

A preferred embodiment of wrist watch according to the present invention will now be described by way of example, reference being made to the accompanying drawings, in which:—

Figure 1 is a schematic diagrammatic representation of the main elements of a wrist watch in accordance with the present invention, and especially a balance wheel and its hairspring and regulating pins as adapted to make the natural frequency of oscillation of the balance dependent on its amplitude of oscillation over a working range of oscillation frequency;

Figure 2 is a side view of a portion of the structure shown in Figure 1;

Figure 3 is a schematic diagram of the electrical system including the motive unit for the balance wheel, an AND network and a time base unit;

Figures 4A to 4C illustrate respectively the relative closure or conductive intervals of the switch and the transistor, and of the current supplied to the drive coil during the intervals when the two are simultaneously closed, i.e., are both conductive; and

Figure 5 is a qualitative chart of oscillation frequency versus amplitude for the balance wheel assembly of Figures 1 and 2.

The drawings illustrate only as much of the structure of the synchronized watch as is necessary to provide an understanding of the principles of the invention. Watch structure not illustrated, such as dial train driven by the balance wheel and time display means, may be conventional.

Referring now to the drawings, and initially to Fig. 3, the synchronized watch of the present invention includes a high frequency oscillator 10 which serves as a time base or source for timing signals receiving energy from a local source 15, preferably the battery 15 which supplies drive current to the motor of the watch. The oscillator 10

may be a quartz crystal oscillator having a frequency substantially of 49,000 Hz or any other suitable high frequency. The crystal oscillator 10 provides a very stable high frequency signal to the frequency divider 11.

The frequency divider 11 comprises a plurality of dividing circuits, preferably of the complementary metal-oxide semiconductor type, which divide down the high frequency pulse rate from the oscillator 10 to some lower multiple of the balance wheel frequency. An output frequency substantially of 6 Hz would be satisfactory for a synchronizing signal being fed to AND circuit 12. In a 3 beat watch, for example, the divider output frequency would then be twice the balance wheel frequency.

The AND circuit 12 comprises a transistor 13 having its base 14 (Fig. 1) connected to the divider 11. The collector 16 is connected in series with a switch 17 while the emitter 18 (Fig. 1) is coupled to ground via the battery 15. To lessen the current drain of the circuit, a field effect transistor may be used in this instance. Transistor 13 and switch 17 comprise an AND arrangement for feeding drive pulses to a coil 19.

The pertinent portions of the watch of the present invention are shown in Figs. 1 and 2. The watch includes a front frame 31 having a dial ring 32 mounted thereon and a balance bridge 33 which is spaced apart from the frame 31. A balance wheel staff 34 is journaled in a bearing 36 in the front frame 31 and a bearing 37 in the balance bridge 33. The balance wheel staff 34 carries a balance wheel 21 which includes the electric coil 19 of round, trapezoidal, or other shape, consisting of many turns of fine wire. A magnet 25 is mounted on the dial ring 32 on one side of the coil while a magnetic shunt 38 is positioned below the coil 19.

A hairspring 39 is coupled to the balance staff 34 for controlling the movement of the balance wheel 21 which includes a contact pin 41 mounted thereon. The pin 41 is connected to one end of the coil 19 by lead 42 while the other lead 43 from the coil 19 is connected to the balance wheel 21 at 44.

A contact spring assembly 46 as described and claimed in our Patent Specification No. 1,316,392 is mounted adjacent the balance wheel 21 and includes a body portion 47 of an insulating material, a spring contact arm 48 for engaging the battery 15 and a contact spring 49 forming one contact of the switch 17. The contact spring 49 is joined to the body 47 by mounting means 51 while the contact arm is joined thereto by means 52. The spring 49 extends at a right angle to its base 53 while an intermediate portion is held by damping arm 54. The free end portion of the spring 49 contacts pin 41 during the rotation of the balance wheel 21.

In operation, a synchronizing pulse is fed

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to drive coil 19 creating a magnetic field which interacts with the field of the magnet 25. This interaction of magnetic fields imparts an impulse to the balance 21. The magnet 25 is usually a single piece of ceramic forming in effect, three magnets and creating three magnetic fields through which the coil 19 oscillates. The three magnetic fields are arranged with alternating polarities, for example, South-North-South, at the magnet face to provide bidirectional impulse to the balance 21. The contact spring 49 and contact pin 41 are positioned with respect to the magnets to provide self-starting.

The balance 21 acts against the restoring force of a non-linear spring 39 which can be selected or adjusted by regulator means so that the amplitude of the balance wheel 21 increases with frequency, thus affecting the contact closure period of switch 17. Alternatively, the spring 39 can be selected to provide a balance wheel isochronism characteristic wherein the amplitude decreases with frequency. As a more practical alternative, a conventional linear spring may be employed with a special regulator (not shown) to provide the desired non-linear isochronism characteristic.

The contact spring 49 intermittently engages contact pin 41 mounted on the oscillatory balance 21 to complete the circuit path through transistor 13 to coil 19. The output of the divider 14 is fed to the drive coil 19 in the form of a variable width pulse only during the time interval that the switch 17 is closed and the transistor 13 is activated to feed pulses thereto.

Referring to Figures 3 and 4A, 4B and 4C, the transistor 13 operates under the control of the divider output to provide a series of synchronizing pulses P_1 of fixed and highly stable frequency and duration shown in Figure 4B. The divider 11 reduces the frequency of the high frequency quartz oscillator to the 10 to 6 Hz range from an input frequency in the 49 KHz range. Current flows in the drive coil 19 only when the transistor 13 is turned on and switch 17 is closed. Switch 17 and transistor 13 thus comprise an AND circuit to control the drive pulses to the coil 19 by regulating the pulse width.

The contact closed duration P_2 illustrated in Figure 4A and the current pulse duration P_3 in Figure 4C vary with the motion of the balance wheel 21. Thus, if the balance wheel 21 speeds up, the pulse duration P_2 will tend to become narrower whereas if the balance wheel 21 slows down, the pulse duration P_2 will tend to become wider. The current pulse P_3 to the drive coil 19 is that portion of the pulse P_1 which coincides with the pulse P_2 . Therefore, if the wheel 21 speeds up, the current pulse P_3 becomes narrower be-

cause the contact closure terminates earlier in relation to P_1 . The current pulse P_3 is, consequently, varied in width to provide more or less driving energy to the balance wheel 21 in accordance with the duration of the pulse passed during the closure of switch 17.

The balance wheel 21 is coupled in a non-linear arrangement under control, for example, of a selected hairspring 39 or a hairspring having a non-linear characteristic imparted thereto by a special regulator wherein the frequency of the balance varies with amplitude. The changes in pulse width fed to the coil 19 causes changes in the mechanical amplitude of the balance wheel 21 which due to the non-linearity of the mechanical system cause the balance wheel 21 to return to the synchronized frequency. The curve of one such system, Frequency versus Amplitude, is plotted in Figure 5.

To summarize, the improved wrist watch described above comprises a quartz oscillator 10 and divider unit 11 which are coupled with selected functional units. An oscillatory balance wheel 21 having a frequency of oscillation dependent upon amplitude of oscillation is one such unit while another is an electromagnetic motive unit which drives the balance wheel 21. The drive pulses to impel the balance wheel 21 are controlled both as to duration and timing by the AND-function effect of a switch 17 in series with a transistor 13. The output divider 11 makes the transistor portion of the AND arrangement intermittently conductive for periods of fixed duration. The resultant current pulse varies with the speed of the balance wheel because the switch closure terminates earlier or later in relation to the pulses from transistor 13. The balance wheel 21 which drives the wheels of the watch is thereby synchronized with pulses from quartz oscillator 10.

The present invention, as described above, thus provides an extremely accurate synchronized watch with functions under the control of synchronizing pulses from a quartz oscillator.

WHAT WE CLAIM IS:—

1. In a battery-powered electric wrist watch of the type in which the immediate power source for the wheels is an oscillatory balance wheel unit including a hairspring, the combination of: means associated with the hairspring by which the oscillation frequency of the balance wheel unit is dependent on oscillation amplitude over a working range of oscillation frequency, an electromagnetic motive unit comprising a relatively movable drive coil and multipolar permanent magnet for imparting an impulse to the balance wheel when current flows in the drive coil, one of said elements of the motive unit being mounted for motion with

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to drive coil 19 creating a magnetic field which interacts with the field of the magnet 25. This interaction of magnetic fields imparts an impulse to the balance 21. The magnet 25 is usually a single piece of ceramic forming in effect, three magnets and creating three magnetic fields through which the coil 19 oscillates. The three magnetic fields are arranged with alternating polarities, for example, South-North-South, at the magnet face to provide bidirectional impulsion to the balance 21. The contact spring 49 and contact pin 41 are positioned with respect to the magnets to provide self-starting.

The balance 21 acts against the restoring force of a non-linear spring 39 which can be selected or adjusted by regulator means so that the amplitude of the balance wheel 21 increases with frequency, thus affecting the contact closure period of switch 17. Alternatively, the spring 39 can be selected to provide a balance wheel isochronism characteristic wherein the amplitude decreases with frequency. As a more practical alternative, a conventional linear spring may be employed with a special regulator (not shown) to provide the desired non-linear isochronism characteristic.

The contact spring 49 intermittently engages contact pin 41 mounted on the oscillatory balance 21 to complete the circuit path through transistor 13 to coil 19. The output of the divider 14 is fed to the drive coil 19 in the form of a variable width pulse only during the time interval that the switch 17 is closed and the transistor 13 is activated to feed pulses thereto.

Referring to Figures 3 and 4A, 4B and 4C, the transistor 13 operates under the control of the divider output to provide a series of synchronizing pulses P_1 of fixed and highly stable frequency and duration shown in Figure 4B. The divider 11 reduces the frequency of the high frequency quartz oscillator to the 10 to 6 Hz range from an input frequency in the 49 KHz range. Current flows in the drive coil 19 only when the transistor 13 is turned on and switch 17 is closed. Switch 17 and transistor 13 thus comprise an AND circuit to control the drive pulses to the coil 19 by regulating the pulse width.

The contact closed duration P_2 , illustrated in Figure 4A and the current pulse duration P_3 in Figure 4C vary with the motion of the balance wheel 21. Thus, if the balance wheel 21 speeds up, the pulse duration P_2 will tend to become narrower whereas if the balance wheel 21 slows down, the pulse duration P_2 will tend to become wider. The current pulse P_3 to the drive coil 19 is that portion of the pulse P_1 which coincides with the pulse P_2 . Therefore, if the wheel 21 speeds up, the current pulse P_3 becomes narrower be-

cause the contact closure terminates earlier in relation to P_1 . The current pulse P_3 is, consequently, varied in width to provide more or less driving energy to the balance wheel 21 in accordance with the duration of the pulse passed during the closure of switch 17.

The balance wheel 21 is coupled in a non-linear arrangement under control, for example, of a selected hairspring 39 or a hairspring having a non-linear characteristic imparted thereto by a special regulator wherein the frequency of the balance varies with amplitude. The changes in pulse width fed to the coil 19 causes changes in the mechanical amplitude of the balance wheel 21 which due to the non-linearity of the mechanical system cause the balance wheel 21 to return to the synchronized frequency. The curve of one such system, Frequency versus Amplitude, is plotted in Figure 5.

To summarize, the improved wrist watch described above comprises a quartz oscillator 10 and divider unit 11 which are coupled with selected functional units. An oscillatory balance wheel 21 having a frequency of oscillation dependent upon amplitude of oscillation is one such unit while another is an electromagnetic motive unit which drives the balance wheel 21. The drive pulses to impel the balance wheel 21 are controlled both as to duration and timing by the AND-function effect of a switch 17 in series with a transistor 13. The output divider 11 makes the transistor portion of the AND arrangement intermittently conductive for periods of fixed duration. The resultant current pulse varies with the speed of the balance wheel because the switch closure terminates earlier or later in relation to the pulses from transistor 13. The balance wheel 21 which drives the wheels of the watch is thereby synchronized with pulses from quartz oscillator 10.

The present invention, as described above, thus provides an extremely accurate synchronized watch with functions under the control of synchronizing pulses from a quartz oscillator.

WHAT WE CLAIM IS:—

1. In a battery-powered electric wrist watch of the type in which the immediate power source for the wheels is an oscillatory balance wheel unit including a hairspring, the combination of: means associated with the hairspring by which the oscillation frequency of the balance wheel unit is dependent on oscillation amplitude over a working range of oscillation frequency, an electromagnetic motive unit comprising a relatively movable drive coil and multipolar permanent magnet for imparting an impulse to the balance wheel when current flows in the drive coil, one of said elements of the motive unit being mounted for motion with





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the balance wheel, a battery for supplying direct current to said drive coil, a switch connected in a series loop including said drive coil and battery and comprising a conductive element moving with the balance wheel and a resilient conductive member adapted to be engaged briefly by said moving conductive element to establish a conductive state of brief duration at a predetermined point in the motion of the balance wheel, a triode transistor having a control electrode and having its two other electrodes connected in said series loop to pass current of said loop when the transistor is in a conductive state, and a time base unit comprising a piezoelectric crystal oscillator unit and a frequency divider network having its output directly connected to the control electrode of said transistor to apply thereto a train of discrete pulses of fixed width and frequency to render said transistor intermittently conductive, whereby the duration of current flow in said coil upon each closure of said switch is determined by the coincidence of its conductive state with that of said transistor, thereby to control the amplitude and through it the frequency of said balance wheel oscillations.

2. A battery-powered wrist watch in accordance with Claim 1 wherein the means associated with the hairspring comprises a regulator which causes the frequency of the balance wheel to increase with amplitude of oscillation.

3. A battery-powered wrist watch in accordance with Claim 1, wherein the electromagnetic motive unit comprises a drive coil mounted on the oscillatory balance wheel and a multipolar magnet of ceramic material mounted oppositely the coil on a stationary member.

4. A battery-powered wrist watch in accordance with Claim 1, wherein the battery is further coupled to and supplies power to the crystal oscillator unit.

5. A battery-powered wrist watch in accordance with Claim 1, wherein the switch comprises a pin mounted on the balance wheel and a spring contact mounted at one end in an insulating block and engaging the pin with its other free end.

6. A battery-powered wrist watch in accordance with Claim 1, wherein the transistor comprises a field effect transistor.

7. A battery-powered wrist watch in accordance with Claim 1, wherein the piezoelectric crystal oscillator has a frequency of substantially 49,000 Hertz and the divider output has a frequency of substantially 6 Hertz.

8. A wrist watch comprising a power

source, a high frequency quartz crystal oscillator activated by the power source, a divider to reduce the frequency of the high frequency oscillator, a transistor switch connected to the divider output to be intermittently operated thereby, a contact spring connected in series with the transistor, a balance wheel assembly including a balance wheel having a low frequency of oscillation which is dependent on amplitude of oscillation, stationary magnet means, a drive coil mounted on the balance wheel for interaction with said magnet means, and contact means engaged by the spring during the oscillation of the balance wheel to supply drive pulses to the coil thereby synchronizing the balance wheel with a sub-harmonic frequency of the quartz crystal oscillator, and, time display means operated by the balance wheel assembly.

9. A watch in accordance with Claim 8 further including a hairspring coupled to the balance wheel and regulator means associated therewith to impart a non-linear isochromism characteristic to the balance wheel wherein the frequency of the balance wheel varies with amplitude.

10. A watch in accordance with Claim 8 wherein, the quartz crystal oscillator has an output frequency of substantially 49,000 Hertz and, the balance wheel has a frequency of substantially 6 Hertz.

11. A watch in accordance with Claim 8 wherein, the divider comprises a plurality of complementary MOS circuits.

12. A watch in accordance with Claim 8 wherein the transistor is a field effect transistor.

13. A watch in accordance with Claim 8 wherein the contact means comprise a contact pin mounted on the balance wheel and connected to one end of the drive coil, and the contact spring comprises an elongated spring member fixedly mounted at one end and having a damped intermediate portion, the free end portion thereof engaging the contact pin in a predetermined manner during the oscillation of the balance wheel.

14. A watch in accordance with Claim 1, wherein the electromagnetic motive unit comprises a magnet mounted on the balance wheel and a stationary drive coil for interaction with the magnet.

15. A synchronized watch substantially as hereinbefore described with reference to the accompanying drawings.

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