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(54) ELECTRONIC HOROLOGICAL MOVEMENT

(71) We, TIMEX CORPORATION, a Corporation organised 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 in and by the following statement:—

The present invention relates to horology and more particularly to an electronic horological movement.

In the horological industry a distinction is sometimes made between "electronic" movements and "electric" movements. Literally, all electronic movements are electric in the sense that they utilize electricity, in contrast to a mainspring or some other source of power. However, conventionally it is understood that electric movements are those that have an electrical switching function performed by a physical electrical make and break contact. Electronic movements replace that contact by an electronic device such as a solid-state transistor.

It is believed that electric horological movements, such as watches, will fail due to the corrosion or wearing away of the contact mechanism, particularly by electric arcing at the contact points. The problem of such wear has been attempted to be solved, in contact electric watches, by the use of precious metals at the contacts, and expensive and complex contact damping mechanisms. A contact electrical horological movement, having an oscillator of a frequency of 3 Hz, will open and close its contacts 10,8000 times an hour, or over 94 million times a year. If the contacts should fail or make irregular contact, the watch may cease to function as an accurate timekeeper, or stop. Repairs of the contacts may be relatively difficult and expensive.

[Price 25p]

Electronic movements, compared to electric movements using contacts, are generally more expensive, delicate and complex. Nevertheless, they are often preferred because some electronic devices, such as transistors, are relatively reliable over a long period.

Electronic horological movements which are electromechanical usually utilize one or more coils which interact with one or more magnetic fields, the fields usually being created by permanent magnets. It may be preferable that the magnets are fixed and that the coil is carried by a mechanical oscillator. A moving magnet may present difficulties in regard to balancing of the oscillator and may cause stray magnetic fields. If the coil is carried by the oscillator, there must be some way to make electric contact with its terminals. It has been suggested that the movement have two hairsprings, both of which would carry current. The use of two hairsprings, even when one is a light auxiliary spring, results in a delicate construction which may be difficult to balance and expensive to manufacture.

It is an objective of the present invention to present an electronic horological movement which is relatively sturdy, reliable and low in cost.

In accordance with the present invention there is provided an electronic horological movement including a frame, a source of electrical power, an electronic circuit connected thereto and providing a pulse of predetermined duration, an electric coil carried by a mechanical oscillatory assembly, means creating a fixed magnetic field through which the coil is moved in an oscillatory manner, conductive means electrically connected to the coil and carried by the oscillatory assembly to oscillate therewith an electrically conductive hairspring connected between the frame and the oscillator assembly and electrically connected to the

coil, and a conductive spring electrically connected to an output terminal of the electronic circuit and having a portion positioned to be intermittently contacted by the said conductive means in its path of oscillation, wherein the electronic circuit provides a pulse to the coil, which pulse starts after the making of the contact between the spring and conductive means and which terminates before the ending of the said contact.

A preferred embodiment of the electronic horological instrument is a watch having a balance wheel and a single hairspring; the balance wheel is an oscillator. The balance wheel is mounted upon a staff which has a hub to which the inner end of the hairspring is attached. The balance wheel carries an electrical coil having two terminals and a conductive pin. One terminal of the coil is connected to the pin and the other terminal to the inner end of the hairspring. A spring blade is fixed at one of its ends and cantilevered in position to contact the pin for a predetermined portion of the full oscillation of the pin. An electronic circuit, connected to a power source, provides a pulse to the coil through the contact between the spring blade and the pin.

The angle of contact between the spring blade and pin, and the duration of that contact, is predetermined so that the contact begins before, and ends after, the pulse to the coil. This ensures that there will be no electrical current through the spring blade and pin at the time of the making or breaking of the physical contact. As there will be no voltage or current across the blade and pin when such making or breaking occur, there is no arcing and the wear and corrosion of the contacts is reduced. The contact made by means of the spring blade and pin substitutes for the second hairspring employed in other types of electronic horological instruments. Compared to the second hairspring, the spring blade and pin are relatively simple, inexpensive and sturdy and do not present any difficulty in regard to the balancing of the balance wheel.

The present invention will now be further described with reference to the accompanying drawings which illustrate by way of example a preferred embodiment thereof.

In the drawings:—

Fig. 1 is a plan view of a watch according to the present invention, shown partly cut away;

Fig. 2 is a side cross-sectional view of the balance wheel and its associated hairspring, shunt and magnet;

Fig. 3 is a cross-sectional view taken along the line 3-3 in Fig. 2, showing the magnet and balance wheel;

Fig. 4 is a plan view of the spring blade

and balance wheel pin;

Fig. 5 is a cross-sectional view taken along the line 5-5 in Fig. 4;

Figs. 6 and 7 are schematic diagrams of suitable alternative electronic circuits used in the watch and;

Figs. 8 and 9 are diagrams of the timing of the oscillator and of the pulse, respectively.

The following description of the present invention is given in connection with an embodiment in the form of a wrist watch. However, it will be understood that the invention is also applicable to other types of horological instruments such as pocket watches, automobile clocks and table clocks.

As shown in Fig. 1, the watch 10 includes a case 11 having a bezel 12 to which a strap may be attached. The top of the watch is covered by a crystal 13 of plastics or glass. The crystal 13 covers a dial 14 upon which time indicia 15 are printed. The watch 10 has the conventional type of rotatable hands and includes a seconds hand 16, a minutes hand 17, and an hour hand 17a. The power for the operation of the movement is furnished by a small battery cell 18 within the watch case 11. A link 19 connects one terminal of the battery 18 to an electronic circuit 20. The other terminal of the battery is grounded to the case. The electronic circuit has an output line 21 which is connected to a flat spring blade 22.

The time base of the watch is an oscillatable balance wheel 23 which is fixed to a balance wheel staff 24. The balance wheel 23 carries an electric coil 25, consisting of many turns of fine wire. Preferably the coil 25 is round, as seen in plan view, although other shapes such as a sector shape may be used. The balance wheel staff 24 has a plate 26 fixed to it. The plate 26 has a pin 27 which co-operates with a fork 28 to oscillate the fork back and forth between end positions. The fork, in turn, operates an index wheel 29, which is the first wheel of a conventional gear train 30. The gear train 30 rotates the hands 16, 17 and 17a.

As shown in Figs. 2 and 3, the balance wheel staff 24 pivots between bearings in a bottom frame 30 and a top bridge member 31. The coil 25 on the balance wheel moves through the magnetic fields created by axially poled permanent magnets 32, 33 and 34, which are positioned on a bottom shunt 35. The fields may, alternatively, be created by coils or by axially poled zones of a single ceramic ferrite magnetic member. A top shunt 36 is positioned above the balance wheel and is fixed either to the bridge or frame. A hub 37 fixed to staff 24 is connected to the inner end of a conventional flat hairspring 38 whose

outer end is connected to a metal pin 39. Pin 39 is mounted in the metal bridge 31. One end of the coil 25 is grounded through the hairspring 38 to the pin 39.

- 5 As shown in Figs. 4 and 5, a contact to the coil is made through a pin 41 carried by the plate 26. The pin 41 is embedded in a tubular non-conductive plastics insert 43 and connected by a wire 44 to the coil 25. The spring blade 22 is cantilevered from the conductor 45 (21) being fixed thereto for example by soldering. Conductor 45 is embedded in a plastic member 40, which is attached to the frame.
- 10 A suitable electronic circuit 20 is shown in Fig. 6 and is similar to that described in the United States Patent No. 3,046,460. The circuit includes a complementary pair of transistors; PNP transistor 46 and NPN transistor 47, a capacitor 48, and resistors 49, 50, 51 and 52, contacts 53, and a switch 56. The switch 56 is used to stop the watch when setting the watch hands and to prevent the watch from running before it is sold. The switch 56 connects and disconnects the battery to the coil. The contacts 53 indicate the contact between the spring blade 22 and the pin 41.

- An alternative, and preferred, circuit is shown in Fig. 7. The circuit is similar in some respects to the circuit of Fig. 6, but does not utilize a switch similar to switch 56 of Fig. 6. The circuit of Fig. 7 includes complementary transistors 46a and 47a, capacitor 48a, resistors 49a, 50a, 51a and 52a, and contacts 53a.

Suitable values for the components of the circuits of Figs. 6 and 7 are given below.

- 40 Resistor 57a — 100 K ohms
Resistors 49 and 49a — 4.7 Megohms
Resistors 50 and 50a — 1.2 K ohm
Resistors 51 and 51a — 82 K ohms
Resistors 52 and 52a — 18 K ohms
- 45 Battery 18 — 1.5 volt
Capacitor 48 — 0.15 μ f
Capacitor 48a — .22 μ f
Coil 25 — 2200 turns

- 50 In addition, the circuit of Fig. 7 has a diode 54 between a terminal of resistor 52a and a terminal of contact 53a, and a capacitor 55 (suitable value 1.0 μ f), between the same terminal of resistor 52a and the negative side of battery 18.

- In operation, before the watch is sold, or during hand setting, the balance wheel is pivoted so that its contact pin is not touching the contact spring. The setting stem of the watch (not illustrated in the drawings) may have a pin or arm which, when the stem is pulled outwardly, holds the balance wheel in position with its hairspring partially wound. The release of the balance wheel, when the setting stem is

pushed inward, starts the watch. The contact spring contacts the pin on the balance wheel, i.e., switch 53a is closed.

Once the contacts 53a are closed, the capacitor 48a is charged and the circuit, which is a relaxation oscillator, will produce an output pulse.

The circuit of Fig. 6, even with the contacts 53 open, will consume power, the current flowing through the emitter and base of transistor 46. That current drain required the circuit to have the separate switch 56. In contrast, the circuit of Fig. 7 avoids an appreciable current drain when the contacts 53 are open and does not have a separate switch to disconnect the battery from the circuit.

In the circuit of Fig. 7, when contacts 53a are closed and then opened, the capacitor 55 is charged. The charge remains on capacitor 55, the resistor 57a preventing its leaking off rapidly. Diode 54 by-passes resistor 57a to allow rapid charging of the capacitor 55. The charge on capacitor 55 makes the voltage at the emitter of transistor 46a almost equal to the battery voltage, thereby presenting a bias condition similar to that found in Fig. 6. The circuit operates in the same manner as the circuit in Fig. 6 as long as capacitor 55 is periodically recharged through the closure of contacts 53a. If the balance wheel is stopped so that contacts 53a are open, capacitor 55 eventually discharges, causing the circuit to cease operation and current to stop flowing.

The diode 54 and the capacitor 55 eliminate the need for the switch 56 in the circuit of Fig. 6 to cut-off stand-by current drain, for example, before the watch is sold.

Other types of drive circuits may be used with the contact system of the present invention.

Fig. 8 shows the closure period during an oscillation of the balance wheel. The coil 25 is in successive positions I, II and III during the clockwise portion of its oscillation. The contacts 53a contact, both during the clockwise and the counterclockwise portions of the full oscillation, is closed for 110°. The pulse 60, of 15°, occurs on the clockwise movement only when the coil 25 is over magnets 34 and 33 (position I). The pulse 61, of 15°, occurs on the counterclockwise movement only when the coil 25 is over the magnets 33 and 32 (position III).

Fig. 9 shows a typical voltage waveform for a contact closed period. Some contact bounce may occur near the leading edge of the closure and near the break, but these breaks do not affect timekeeping and do not deteriorate the contact performance since there is virtually no current flowing

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at these times.

If the contact closed angle is wide enough and positioned properly to include a complete half sinusoid of induced voltage, as shown in Figs. 8 and 9, the circuit has been found to operate satisfactorily.

WHAT WE CLAIM IS:—

1. An electronic horological movement including a frame, a source of electrical power, an electronic circuit connected thereto and providing a pulse of predetermined duration, an electric coil carried by a mechanical oscillatory assembly, means creating a fixed magnetic field through which the coil is moved in an oscillatory manner, conductive means electrically connected to the coil and carried by the oscillatory assembly to oscillate therewith, an electrically conductive hairspring connected between the frame and the oscillator assembly and electrically connected to the coil, and a conductive spring electrically connected to an output terminal of the electronic circuit and having a portion positioned to be intermittently contacted by the said conductive means in its path of oscillation, wherein the electronic circuit provides a pulse to the coil, which pulse starts after the making of the contact between the spring and conductive means and which terminates before the ending of the said contact.

2. A horological movement as claimed in claim 1 wherein the oscillatory assembly consists of a balance wheel fixed to a balance wheel staff.

3. A horological movement as claimed in claim 1 or claim 2 wherein the conductive means is a conductive pin.

4. A horological movement as claimed in any one of the preceding claims, wherein the spring is a flat cantilevered metal spring blade.

5. A horological movement as claimed in any one of the preceding claims, wherein the movement is a watch movement within case and the source of power is a battery cell within the case.

6. A horological movement as claimed in any one of the preceding claims, wherein the magnetic field is a combination of three fields created by three axially and alternately poled magnets.

7. A horological movement as claimed in any one of claims 1 to 5, wherein the magnetic field is a combination of three fields created by three axially and alternately poled zones in a single ceramic magnetic member.

8. A horological movement as claimed in any one of the preceding claims, wherein there is provided a capacitor the charging of which is effected through the contact between the spring and conductive means, the capacitor when charged assisting in the energising of the electronic circuit, the electronic circuit being inoperative when the capacitor is discharged.

9. An electronic horological movement substantially as hereinbefore described with reference to the accompanying drawings.

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