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(54) HOROLOGICAL INSTRUMENT

(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 in and by the following statement:—

The present invention relates to oscillators and more particularly to an oscillatory system including an electrically driven mechanical oscillator for a horological instrument.

The improvement in battery construction and capability in recent years has provided renewed interest in horological instruments having a self-contained source of power. A clock may now be manufactured having a battery within its case, thereby avoiding the necessity of connecting the clock to an electrical outlet. Similarly, a watch may now be manufactured in which a small button type of primary battery cell is contained within the watch case and provides the power to operate the watch movement.

Various approaches have been taken by manufacturers of horological movements in applying the timekeeping ability of a mechanical oscillator to an electrical horological instrument. For example, watches have been manufactured in which one or more magnets have been mounted on a balance wheel, which carries the magnets through the fields of one or more coils. Such movements have either utilized a make-break contact carried by the balance wheel or a separate pick-up coil which triggers an electronic circuit. In another type of watch movement the balance wheel carries a coil which moves through the field of a number of permanent magnets which are fixed to the watch plate. The coil receives current either through a make-break contact or by means of two hairsprings. Various other systems have been proposed. However, generally they require that the oscillator, for example, the balance wheel or tuning fork, carry either a coil or a magnet.

When the oscillator carries a magnet there are problems presented in regard to the mag-

netic fields temporarily established in the path of oscillation by the moving magnet. The moving magnet type of horological instrument may be sensitive to external magnetic influence or external demagnetizing forces. In those horological instruments in which the oscillator carries an electric coil, it is necessary that current reach the coil. The means by which the current is carried to the moving coil, for example, the use of two hairsprings or make-break contacts, may present difficulties in regard to the expense of the movement. It is necessary to electrically isolate the coil, hairspring and contacts from other portions of the balance wheel, and such electrical isolation may be accomplished using synthetic plastic materials. However, such synthetic plastic materials may be sensitive to humidity, so that their weight increases in a humid atmosphere, causing the balance wheel to become less perfectly balanced.

In accordance with one aspect of the present invention there is provided an oscillatory system for a horological instrument said system comprising a mechanical oscillator, a coil carried by said mechanical oscillator for movement therewith, a fixed coil positioned near the path of movement of the first-mentioned coil and arranged to induce current in the first-mentioned coil, pick-up means for detecting the movement of the first-mentioned coil, an electronic circuit controlled by said pick-up means, said circuit being connected to said fixed coil to provide drive current pulses to said coil thereby impulsing said mechanical oscillator in synchronism with the movement of the first mentioned coil, and means for producing a magnetic field within which, in operation, the first-mentioned coil moves in addition to that produced by the drive current in the fixed coil.

In accordance with a further aspect of the present invention there is provided an oscillatory system for a horological instrument, said system comprising a mechanical oscillator carrying an electrically conductive coil for movement therewith, means for creating a magnetic field through which, in opera-

tion, the coil passes whereby a voltage will be induced in said moving coil, a first fixed coil, a first magnetic core inductively associated with said first fixed coil, said first core being positioned sufficiently near to the path of movement of the first-mentioned coil, so that current in the first-mentioned coil induces flux changes in said first core, an electronic circuit whose input is connected to said first fixed coil so as to be responsive to flux changes in said first fixed coil to then produce a pulse at its output, a second fixed coil connected to the output of said circuit so that upon receiving a pulse it creates a second magnetic field in the path of the first-mentioned coil and thereby drives said mechanical oscillator.

The oscillatory system in accordance with the present invention is particularly suitable for incorporation in a watch movement. A preferred embodiment has the moving coil carried by the mechanical oscillator and in the form of a single blanked turn of copper or other conductive non-magnetic material. An electric current is induced into the coil carried by the oscillator by means of current in a coil which is mounted on the frame of the movement. The induced current in the moving coil reacts with a magnetic field created by a permanent magnet or electromagnet, the permanent magnet or electromagnet also being fixed to the frame.

The mechanical oscillator, which may be a balance wheel, need be connected to the movement frame and bridge only by its pivoting and spring mechanisms, for example, in the case of a balance wheel, the balance wheel staff and its conventional hairspring. The magnetic field of the coil carried by the mechanical oscillator does not extend beyond the movement of the mechanical oscillator. Consequently, the coil carried by the oscillator will not have any adverse magnetic effects on the movement and cannot be demagnetized by external magnetic forces.

The impulsing circuit is preferably such as to enable the watch movement to be self-starting. The circuit is a self-oscillating circuit whose frequency is determined by the movement of the mechanical oscillator but which, in addition, has a self-oscillating frequency of its own for the purpose of starting the motion of the mechanical oscillator. The circuit is triggered or synchronized by the movement of the mechanical oscillator. It is possible, due to the arrangement of the coils, to provide that the indexing of the index wheel of the movement is effected by means of one of the coils fixed to the frame rather than from, as in other watches, the mechanical oscillator. This enables the mechanical oscillator to be relatively free-moving and undamped.

It will be seen that the present invention

makes possible the provision of a horological instrument utilizing an oscillator as its time base in which the oscillator is not sensitive to changes in humidity, in which the oscillator assembly is relatively simple and inexpensive; and in which magnetic shielding of the oscillator can be readily effected.

The invention will be further described with reference to the accompanying drawings which illustrate a preferred embodiment thereof. In the drawings:

Fig. 1 is a perspective view of a balance wheel type oscillator and its associated driving mechanism;

Fig. 2 is a side view taken along line A—A of Fig. 1;

Fig. 3 is a circuit diagram of the electronic circuit utilized to impulse the oscillator;

Fig. 4 is a diagram showing various wave forms in the circuit of Fig. 3; and

Fig. 5 illustrates the arrangement of the permanent magnet and lower core portion.

The oscillator system which forms the embodiment of the invention illustrated in the drawings will be described as constituting part of a watch movement, the watch movement however being illustrated and described only so far as is necessary for an understanding of the present invention. Furthermore, it will be appreciated that the invention is also applicable in connection with other horological instruments, such as balance wheel stationary clocks, balance wheel automobile clocks and pendulum wall clocks, etc.

The watch movement incorporating the present invention is shown in Fig. 1. A balance 10 is mounted on a balance staff 11. The balance staff is connected, by means of a hub, to the inner end of a conventional type of horological hairspring 12. The outer end of the hairspring 12 is connected to the frame or bridge of the watch movement (not shown). The balance 10 may be a full balance wheel or, as shown, a balance wheel comprising a cross-spoke member 13 through which the balance staff protrudes, a counter-balance portion 14 which is in the form of a partial rim and a coil 15 carried by the cross-spoke 13. The coil 15 may be constructed of many turns of fine wire which are held together by an adhesive and the coil joined to the cross-spoke 13 by an adhesive. The preferred embodiment, however, as shown in Fig. 1, is that the coil 15 is a winding consisting of a single turn. The entire balance, including the single turn winding 15, may be stamped (blanked) of a suitable non-magnetic conductive material, such as copper or phosphor bronze.

An induction coil 16 is fixed to the frame plate of the watch movement. The induction coil 16 has a centre hole through which the shank of a U-shaped magnetic core 17 is positioned. The magnetic core 17 is of a soft

magnetic permeable material such as iron. The arms of the core are formed to provide an air gap 18 through which the coil 15 moves. A drive coil 19 is also fixed to the frame of the movement. The drive coil 19 has a centre hole within which a weak permanent magnet 20 is positioned. The permanent magnet 20 is physically connected to a lower core 22 of the drive coil 19. The lower core is preferably of such a shape that maximum magnetic flux density arises at radial portions of coil 15. For purposes of illustration the lower core is shown in Figures 1 and 5 as being "U" shaped. The lower core 22 is positioned beneath the path of movement of the moving coil 15. An upper core 21 of the driving coil is positioned, for example, by adhering it to the bridge of the watch movement, above the path of movement of the coil 15. The upper core 21, like the lower core 22, is preferably of such a shape that maximum flux density arises at radial portions of coil 15. For purposes of illustration the upper core is shown in Figure 1 as being a half ring. Again, as in the case of the lower core shown in Fig. 1, the upper core is shown as only a half ring for the purpose of illustration.

An electronic circuit for impulsing the balance 10 is illustrated in Figure 3. The electronic circuit includes a battery 30 or other source of direct current. Preferably the battery 30 is positioned within the case of the movement. The positive terminal of the battery 30 is connected to one terminal of coil 16. The positive terminal of battery 30 is also connected to the cathode of a diode 31 and to the emitter 32 of a transistor 33. The collector 34 of transistor 33 is connected to the base 35 of a transistor 36. The emitter 37 of transistor 36 is connected to the anode of diode 31 and to the anode of a diode 38. The cathode of diode 38 is connected to the negative terminal of the battery 30. A resistor 39 is connected between the base of transistor 33 and the negative terminal of the battery, which may be ground. A capacitor 40 is connected between the base of transistor 33 and the base 41 of a transistor 42. The emitter 43 of transistor 42 is connected to the cathode of a diode 44 the anode of which is connected to the base 41. The emitter 43 is also connected to one terminal of the drive coil 19, to one side of the capacitor 45, and also to one terminal of the induction coil 16. The opposite terminal of the drive coil 19 is connected to one side of a capacitor 46 the other side of which is connected to the collector 47 of the transistor 36.

The operation of the device and circuit is shown in connection with the wave form diagram of Fig. 4. In Fig. 4 the x-ordinate (abscissa) is time and the y-ordinate (ordinate) is current. The legends "current I" and

"current II" refer to the current in the drive coil 19 at different times; this current is the driving impulse current. "current 16" is the current in the induction coil 16. "current 15" is the current induced into the coil 15 carried by the balance.

When the coil 15 moves within the airgap 18 formed between upper core 21 and the lower core 22 an e.m.f. is induced in the coil 15 by the permanent magnet 20. The resulting current in the coil 15 causes a magnetic field from the coil which causes a change of magnetic flux in the core 17. The change of flux in core 17 induces an emf and consequently a current change in the induction coil 16. That current change in the coil 16 acts to trigger the circuit to produce a driving impulse.

Specifically, having regard to the circuit diagram of Fig. 3, a current change at the coil 16, passes through diode 44 and capacitor 40 and triggers the transistor 33 to conduct. The battery current flows through transistor 33 and triggers transistor 36, causing current to flow through diode 38.

As soon as transistor 36 starts to conduct a rapid current change occurs in coil 19, this current flowing from the battery via capacitor 46, transistor 36, and diode 38. This current change is represented by "current I" in Fig. 4. When the current in coil 16 rises it induces a current in the coil 15 (which is a short circuit winding) of the balance wheel. The current induced in the coil 15 co-operates with the magnetic field of the cores 21 and 22 (of coil 19) to provide a driving impulse to the balance wheel.

During the driving impulse the transistor 42 is blocked by the voltage induced in coil 16. At that moment capacitor 45 is already charged via diode 38. The capacitor 46 becomes saturated and the current through the coils 16 and 19 decreases. The magnetic flux from coil 19 decreases resulting in a decreased induced voltage across coil 16. The control current from coil 16 to transistor 33 decreases lowering the control current to transistor 36. This results in decreasing the current through transistor 36 and the coils 16 and 19. The effect is regenerative, as again the induced voltage of coil 16 is reduced, until finally the transistor 36 is blocked (non-conductive). The current through coil 16 falls rapidly, the rate of fall being limited only by the inductance of the coil. The fall of current in coil 16 charges capacitor 45 to above the battery voltage. The charge on capacitor 45 ensures correct biasing of transistor 36 to enable it to conduct when triggered by transistor 33 during the drive impulse of the next oscillation. The fall in current in coil 16 induces current in the coil 15 in the opposite direction to the current which provides the drive impulse.

The transistor 42 becomes conductive by

the charging current of capacitor 40, which flows from the battery 30 by way of resistor 39. The capacitor 46 is discharged by way of transistor 42 and coil 19. The current in the coil 19 at this time, designated current II in Fig. 3, is opposite to the direction of battery current. The coil 19, with the flow of current II, induces a magnetic flux of opposite direction, relative to the flux of current I. That opposite flux co-operates with the induced reverse current of coil 15 to provide a drive impulse to the balance wheel in the same direction as the first driving impulse. The driving impulses are only provided for one direction of motion of the balance.

The circuit of Fig. 3 operates as a resistor-capacitor self-oscillating multivibrator when the balance is stopped and furnishes current impulses to the balance coil 15 at a frequency determined by capacitor 40 and resistor 39. The watch is thus self-starting.

The indexing may be from the balance wheel or from the coils. For example, a hub (plateau) fixed to the balance staff may carry a pin which indexes a fork, the fork indexing an index wheel. Alternatively the coil 16 or the coil 19 may be provided with a moving armature which indexes an index wheel in response to the current pulses in the respective coil. This alternative has the advantage that the balance will not be damped by the indexing of the index wheel.

It should be noted that the circuit of Fig. 3 may be synchronized by an external circuit instead of by the movement of the balance wheel. For example a synchronizing signal may be provided by a quartz crystal oscillator circuit whose high frequency is counted down by divider circuits.

WHAT WE CLAIM IS:—

1. An oscillatory system for a horological instrument said system comprising a mechanical oscillator, a coil carried by said mechanical oscillator for movement therewith, a fixed coil positioned near the path of movement of the first-mentioned coil and arranged to induce current in the first-mentioned coil, pick-up means for detecting the movement of the first-mentioned coil, an electronic circuit controlled by said pick-up means, said circuit being connected to said fixed coil to provide drive current pulses to said coil thereby impulsing said mechanical oscillator in synchronism with the movement of the first-mentioned coil, and means for producing a magnetic field within which, in operation, the first-mentioned coil moves in addition to that produced by the drive current in the fixed coil.

2. An oscillatory system as claimed in claim 1 wherein said pick-up means includes a first magnetic core having an air gap through which the first-mentioned coil

moves and a coil connected to the circuit and inductively associated with the core and wherein a permanent magnet is positioned near the path of movement of said first-mentioned coil.

3. An oscillatory system for a horological instrument, said system comprising a mechanical oscillator carrying an electrically conductive coil for movement therewith, means for creating a magnetic field through which, in operation, the coil passes whereby a voltage will be induced in said moving coil, a first fixed coil, a first magnetic core inductively associated with said first fixed coil, said first core being positioned sufficiently near to the path of movement of the first-mentioned coil, so that current in the first-mentioned coil induces flux changes in said first core, an electronic circuit whose input is connected to said first fixed coil so as to be responsive to flux changes in said first fixed coil to then produce a pulse at its output, a second fixed coil connected to the output of said circuit so that upon receiving a pulse it creates a second magnetic field in the path of the first-mentioned coil and thereby drives said mechanical oscillator.

4. An oscillatory system as claimed in claim 3, wherein said creating means is a permanent magnet.

5. An oscillatory system as claimed in claim 3 or 4, wherein said second fixed coil is inductively associated with a second magnetic core and said second magnetic core is positioned near the path of movement of said first-mentioned coil, and is so constructed as to concentrate the magnetic field produced by current in said second fixed coil and direct it onto said path.

6. An oscillatory system as claimed in any one of claims 3 to 5 wherein said first core is a U-shaped member the ends of whose arms form between them an air gap through which, in operation, the first-mentioned coil moves.

7. An oscillatory system as claimed in claim 6, wherein the first fixed coil embraces the first core.

8. An oscillatory system as claimed in any one of the preceding claims, wherein said first-mentioned coil is a single turn of electrically conductive non-ferro-magnetic material.

9. An oscillatory system as claimed in claim 8, wherein said mechanical oscillator is a balance which carries the single turn coil.

10. An oscillatory system as claimed in any one of the preceding claims, wherein said electronic circuit comprises a self-starting oscillator.

11. An oscillatory system as claimed in any one of the preceding claims, wherein said electronic circuit includes a multivibrator.

the charging current of capacitor 40, which flows from the battery 30 by way of resistor 39. The capacitor 46 is discharged by way of transistor 42 and coil 19. The current in the coil 19 at this time, designated current II in Fig. 3, is opposite to the direction of battery current. The coil 19, with the flow of current II, induces a magnetic flux of opposite direction, relative to the flux of current I. That opposite flux co-operates with the induced reverse current of coil 15 to provide a drive impulse to the balance wheel in the same direction as the first driving impulse. The driving impulses are only provided for one direction of motion of the balance.

The circuit of Fig. 3 operates as a resistor-capacitor self-oscillating multivibrator when the balance is stopped and furnishes current impulses to the balance coil 15 at a frequency determined by capacitor 40 and resistor 39. The watch is thus self-starting.

The indexing may be from the balance wheel or from the coils. For example, a hub (plateau) fixed to the balance staff may carry a pin which indexes a fork, the fork indexing an index wheel. Alternatively the coil 16 or the coil 19 may be provided with a moving armature which indexes an index wheel in response to the current pulses in the respective coil. This alternative has the advantage that the balance will not be damped by the indexing of the index wheel.

It should be noted that the circuit of Fig. 3 may be synchronized by an external circuit instead of by the movement of the balance wheel. For example a synchronizing signal may be provided by a quartz crystal oscillator circuit whose high frequency is counted down by divider circuits.

WHAT WE CLAIM IS:—

1. An oscillatory system for a horological instrument said system comprising a mechanical oscillator, a coil carried by said mechanical oscillator for movement therewith, a fixed coil positioned near the path of movement of the first-mentioned coil and arranged to induce current in the first-mentioned coil, pick-up means for detecting the movement of the first-mentioned coil, an electronic circuit controlled by said pick-up means, said circuit being connected to said fixed coil to provide drive current pulses to said coil thereby impulsing said mechanical oscillator in synchronism with the movement of the first-mentioned coil, and means for producing a magnetic field within which, in operation, the first-mentioned coil moves in addition to that produced by the drive current in the fixed coil.

2. An oscillatory system as claimed in claim 1 wherein said pick-up means includes a first magnetic core having an air gap through which the first-mentioned coil

moves and a coil connected to the circuit and inductively associated with the core and wherein a permanent magnet is positioned near the path of movement of said first-mentioned coil.

3. An oscillatory system for a horological instrument, said system comprising a mechanical oscillator carrying an electrically conductive coil for movement therewith, means for creating a magnetic field through which, in operation, the coil passes whereby a voltage will be induced in said moving coil, a first fixed coil, a first magnetic core inductively associated with said first fixed coil, said first core being positioned sufficiently near to the path of movement of the first-mentioned coil, so that current in the first-mentioned coil induces flux changes in said first core, an electronic circuit whose input is connected to said first fixed coil so as to be responsive to flux changes in said first fixed coil to then produce a pulse at its output, a second fixed coil connected to the output of said circuit so that upon receiving a pulse it creates a second magnetic field in the path of the first-mentioned coil and thereby drives said mechanical oscillator.

4. An oscillatory system as claimed in claim 3, wherein said creating means is a permanent magnet.

5. An oscillatory system as claimed in claim 3 or 4, wherein said second fixed coil is inductively associated with a second magnetic core and said second magnetic core is positioned near the path of movement of said first-mentioned coil, and is so constructed as to concentrate the magnetic field produced by current in said second fixed coil and direct it onto said path.

6. An oscillatory system as claimed in any one of claims 3 to 5 wherein said first core is a U-shaped member the ends of whose arms form between them an air gap through which, in operation, the first-mentioned coil moves.

7. An oscillatory system as claimed in claim 6, wherein the first fixed coil embraces the first core.

8. An oscillatory system as claimed in any one of the preceding claims, wherein said first-mentioned coil is a single turn of electrically conductive non-ferro-magnetic material.

9. An oscillatory system as claimed in claim 8, wherein said mechanical oscillator is a balance which carries the single turn coil.

10. An oscillatory system as claimed in any one of the preceding claims, wherein said electronic circuit comprises a self-starting oscillator.

11. An oscillatory system as claimed in any one of the preceding claims, wherein said electronic circuit includes a multivibrator.



12. An oscillatory system for a horological movement constructed, arranged and adapted to operate substantially as hereinbefore described and illustrated in the accompanying drawings.
13. A horological instrument including the oscillatory system as claimed in any one of the preceding claims.

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