United States Patent

Kanazawa et al.

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[54] **BALANCE WHEEL ASSEMBLY OF A BATTERY-DRIVEN TIMEPIECE**

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Sept. 29, 1969 Japan 44/77676

[52] **U.S. Cl.**.....**58/28 D,** 58/117, 74/1.5

[51] **Int. Cl.**.....**G04c 3/04,** G04b 15/14, F16h

[58] **Field of Search**.....58/28, 28 A, 28 B, 28 D, 107, 58/110; 74/1.5

[56] **References Cited**

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[57] **ABSTRACT**

This invention concerns with a drive balance wheel assembly for use in an electronic timepiece, an impulse pin being fixedly mounted to steppingly drive an escape wheel.

This improvement comprises the arrangement of said impulse pin so as to have an offset angle, 20° or more, relative to the common diameter of the balance and escape wheels for compensating unavoidable amplitude reduction as met with consumption of a source battery fitted in the timepiece.

2 Claims, 6 Drawing Figures

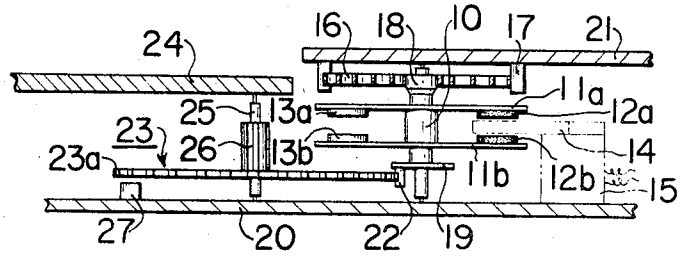


FIG. 1

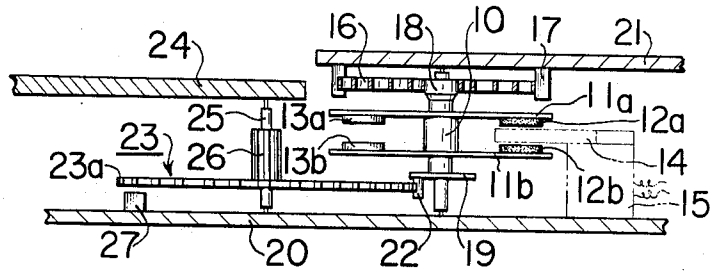


FIG. 2

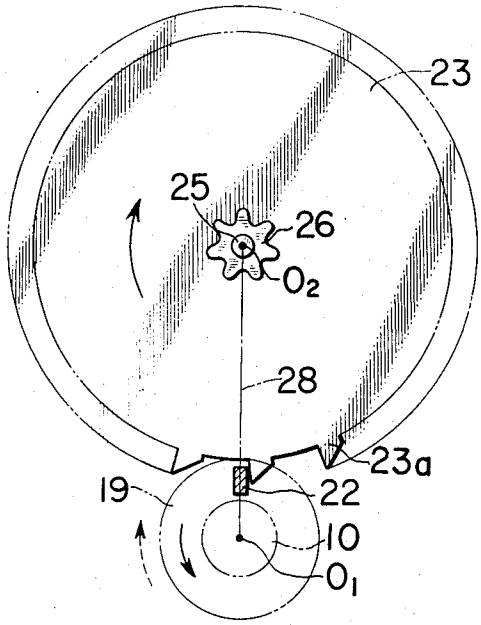


FIG. 3

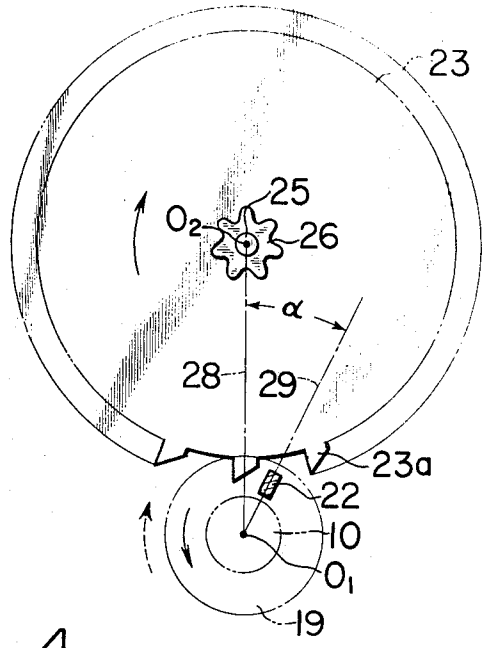
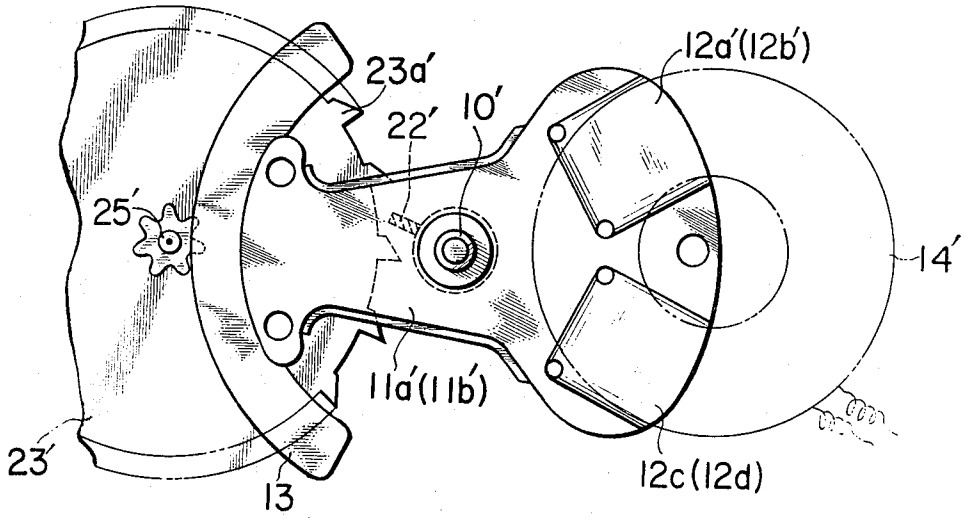
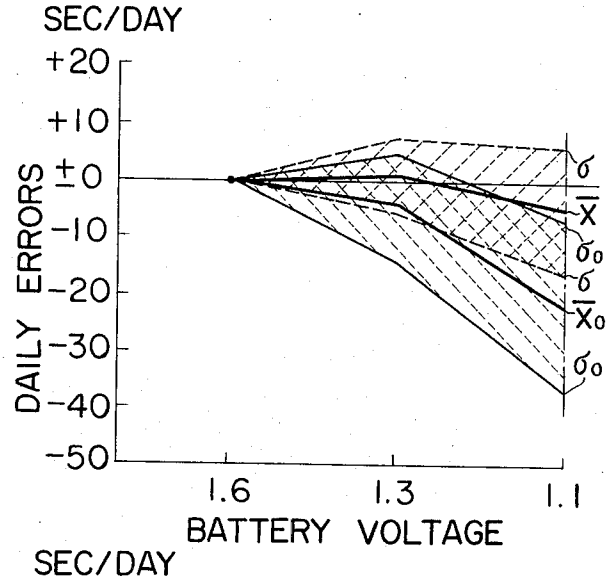


FIG. 4

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-10
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-40
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DAILY ERRORS
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1.3
1.1
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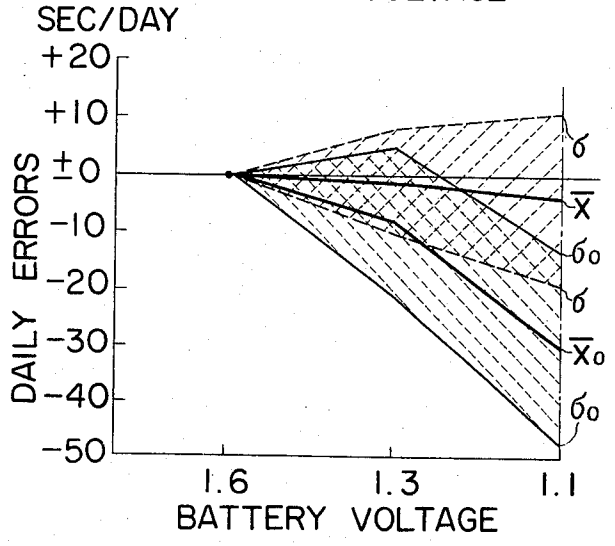
σ
X̄
σ₀
σ
X̄₀
σ₀

FIG. 5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DAILY ERRORS
1.6
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1.1
BATTERY VOLTAGE
σ
X̄
σ₀
σ
X̄₀
σ₀

FIG. 6

BALANCE WHEEL ASSEMBLY OF A BATTERY-DRIVEN TIMEPIECE

This invention relates to improvements in and relating to a balance wheel for use in a battery-driven electronic timepiece, wherein an impulse pin mounted on the balance wheel drives an escape wheel.

It is commonly known that the drive battery used in an electronic timepiece will be subjected to gradual voltage reduction as it consumes its power during extended use of the timepiece.

With reduction of the applying voltage thus caused, the operating amplitude of the balance wheel will naturally be subjected to a corresponding gradual reduction, resulting in a corresponding alteration in the regular stepping movement of the timepiece.

In order to overcome such a conventional drawback of balance wheel amplitude reduction, a certain brake means is additionally fitted to the mechanism at the cost of an increased power consumption.

As an alternative way, the hair spring is controlled in its winding angle which results, however, in considerable additional time and cost in the timepiece manufacture.

As a still further counter measure, a provision of magnetic brake means is made in close proximity of the balance wheel, so as to perform a similar job for improving the isochronism of the timepiece.

THe main object of the invention is to provide an improved balance wheel, capable of providing a highly stabilized isochronism in the operation of the timepiece fitted therewith, even when the balance wheel is subjected to amplitude variation caused by the battery consumption in the above-mentioned sense.

In order to fulfill the aforementioned object, the drive balance wheel according to this invention is so designed and arranged that the impulse pin fixedly mounted on the wheel for driving an escape wheel is positioned so as to establish a central angle of 20° or more on the balance wheel as measured from the common diameter to the said both wheels and with the balance wheel kept at its neutral position.

These and further objects, features and advantages of the invention will become more apparent when read the following detailed description of the invention by reference to the accompanying drawings illustrative of substantially a preferred embodiment of the invention.

In the drawings:

FIG. **1** is an axial sectional view of a preferred embodiment of the drive balance wheel according to the invention wherein, however, the driven escape wheel is also shown.

FIG. **2** is an enlarged schematic plan view of a conventional roller of a balance wheel, an impulse pin fixedly mounted thereon and a driven escape wheel, shown in such position of the balance wheel which is held in its stationary or neutral position.

FIG. **3** is a similar view to FIG. **2**, showing the improved structure according to this invention.

FIG. **4** is a rather specific and still further enlarged plan view of a modified shape of a drive balance wheel embodying the principles of the invention, wherein the driven escape wheel, sensing and driving permanent magnets mounted on the balance wheel and a stationary coil assembly adapted for cooperation with these permanent magnets are shown additionally.

FIGS. **5** and **6** are isochronic performance curves of a drive balance wheel according to this invention.

Referring now to FIG. **1** of the accompanying drawings, numeral **10** denotes a balance wheel arbor which is rotatably mounted with its both ends by conventional timepiece plate **20** and a conventional balance bridge **21** which are shown only partially on account of their very popularity and for simplicity of the drawing. A pair of balance wheel discs **11**a and **11**b are fixedly attached at their centers to the arbor **10** and carry thereon a plurality of permanent magnets **12***a* and **12***b* and counter weights **13***a* and **13***b*, said magnets being arranged to electromagnetically cooperate with a stationary coil means **14** which is fixedly mounted on the plate **20** through a mounting means **15**. Although not shown, the coil means **14** consists of a sensing coil element and a drive coil element which are compoundly wound into a single coil mass. These coil means **14** and mounting means **15** are shown in chain dotted lines and substantially by their respective outlines only for simplicity. The said coil elements are connected electrically with a conventional electronic drive circuit, not shown, and a battery, again not shown, for transmitting sensed electric signals to and receiving drive currents from the electronic circuits when the balance wheel is kept in its oscillatory movement, as will be more fully described hereinafter. The balance wheel is provided with a conventional hair spring **16** with its ends fixedly attached to conventional stud **17** and collet **18**.

In close proximity to the lower end of the arbor **10**, the latter is fixedly attached with a mounting disc **19** which mounts fixedly in turn an impulse pin **22**.

An escape wheel **23** having peripheral ratchet teeth **23***a* is rotatably mounted by its arbor **25** between a second bridge **24**, only partially shown, and the plate **20**, said teeth being positioned in the acting area of the impulse pin **22** when the escape wheel **23** rotates.

The escape arbor **25** is formed with an escape pinion **26** which is operatively connected with a conventional movement gear train, for driving the latter, although not shown.

A positioner magnet **27** for the escape teeth **23**a is mounted fixedly on the plate **20**.

The centers of the balance wheel and thus the balance wheel arbor **10** and the escape shaft **25** are denoted in FIGS. **2** and **3** at O_1 and O_2, respectively; the common diameter connecting these centers is shown by a chain-dotted line **28**, respectively.

When the balance wheel is kept stationary and in its neutral position illustrated by way of example in FIGS. **2** and **3** for the case of the conventional and the inventive arrangement, respectively, the impulse pin **22** will occupy the position on the common diameter in the conventional case and at certain angularly offset position relative to the latter. According to our practical experiments, this offset angle "alpha" should be 20° or larger.

As was referred to hereinbefore, the electronic timepiece of the above kind employing the escape wheel, the balance wheel amplitude will be subjected to a gradual reduction with reduction of the battery voltage, and this kind of amplitude reduction will naturally and adversely affect upon the isochronic performance of the timepiece. The thus caused isochronic error depends upon various factors such as escape error, winding angle of hair spring, eccentric mounting of the latter, shift of the center of gravity, and the like.

According to the prior technique, these erroneous factors have been attempted to be remedied independently and separately. However, it is naturally impossible to realize a complete compensation of these various factors as a whole, thus remaining always a certain degree of residual error which will appear as the isochronic error making the timepiece performance correspondingly inferior.

According to the present invention, the escape error which constitutes a main error of these various errors is so advantageously controlled that all the remaining errors may substantially be cancelled out.

By mounting the impulse pin in an angularly offset position by a certain angle "alpha", as measured at the neutral position of the balance wheel relative to the escape wheel, as was specifically referred to hereinbefore, the escape error will increase gradually for a certain constant amplitude of the balance wheel oscillation, and the thus resulted error is, as ascertained by our practical experiments, intimately related with increase of the offset angle of the impulse pin.

On the other hand, any person skilled in the art may well recognize that there is an exponential relationship between the balance wheel amplitude reduction in the above sense and the isochronic characteristic curve of the timepiece. According to our experimental knowledge, the escape error caused to appear in a latent sense in the arrangement according to this invention by the offset arrangement of the impulse pin takes always in the shape of an exponential curve of substantially similar nature as before, yet in the opposite or compensating sense. This latent error can be negative or positive, as the case may be, relative to the common diameter to the both balance and escape wheels. Under conditions according to the present invention the impulse pin is positively offset from the the common diameter to that which has been shown and described hereinabove.

By determining the isochronic curve for each commercialized timepiece model by experiments, a certain offset angle and its positive or negative sign for the impulse pin can also be determined upon performing several minor experiments, so as to substantially cancel out the overall error.

In this way, a highly favorable overall isochronic performance characteristic for a specific timepiece model can easily be provided.

FIGS. **5** and **6** represent isochronic error curves for the impulse pin mounted at nil and 20° of the offset angle as hinted in FIGS. **2** and **3**, respectively, as being caused by the battery voltage variation.

The curve shown in FIG. **5** was obtained with the balance wheel arbor in its vertical position, while that shown in FIG. **6** was obtained with the arbor positioned in its horizontal position.

In the conventional arrangement shown in FIG. **2**, the escape error would be substantially nil by the provision of the impulse pin on the common diameter.

The isochronic curves shown in FIGS. **5** and **6** represent each an appreciable inclination of change with gradual reduction of the source voltage, representing in the mean (see $\overline{X}_0$) a daily stepping error of between about 20–30 seconds. In these figures, "σ" denotes a standard deviation.

In contrast thereto, in the case of the escape arrangement shown in FIG. **3** according to the invention, wherein, as was referred to hereinbefore, the impulse pin **22** is positioned at an offset angle of about **20** degrees, the daily stepping error $\overline{X}$ in the mean has been substantially improved to about **5** seconds. In this figure, "σ" represents again a standard deviation.

More specifically, since the escape arrangement shown in FIG. **2** has a negative isochronic characteristic curve as ascertained by practical experiments, it is necessary to a positive escape error for cancelling out the said negative error. Therefore, by positioning the impulse pin **22** so as to have a clockwise offset angle relative to the common diameter **28**, the pin **22** will turn in the direction shown by the small arrow and apply an impulse force onto one of the escape teeth **23a** of the escape wheel at a position beyond the newly established neutral position **29** of the balance wheel during the forward oscillation stroke of the latter. During the reverse stroke of the impulse pin **22**, it will apply an impulse force onto one of the escape teeth **23a** at a position in advance of the neutral position.

It should be noted that, in this case of the inventive escape arrangement, the escape wheel **23** will perform a certain return movement, not only in the forward oscillation stroke of the balance wheel shown by the small solid arrow, but also in the reverse oscillation stroke of the same wheel in the direction opposite to that, as shown by the dotted arrow. However, thanks to the positioning of a positioning magnet **27** cooperative with one of the escape teeth **23***a* which is thus magnetically attracted, the escape wheel **23** will be returned to the original position upon performing said slight reverse movement. The drive force exerted by the impulse pin **22** onto the escape teeth **23***a* in the forward direction shown by the arrow is selected to be larger than that applied by the pin in the reverse direction. Thus, with the offset angle of the impulse pin shown in FIG. **3**, the applying force by the pin is larger than that which will be applied after passage of the pin through the neutral position **29**. This will result in the development of a positive escape error which can effectively compensate the aforementioned negative isochronic characteristic.

The initial rotational direction and the offset angle (alpha) of the impulse pin **22** is determined based upon the isochronic characteristic as determined for the offset angle selected to nil. In practice, however, it will suffice to set the compensation for the case of the minimum usable source voltage such as, for instance, 1.1 volts in the case of FIGS. **5** and **6**.

FIG. **4** illustrates a modification from that shown and described hereinabove wherein modified balance wheels proper **11***a*′ (**11***b*′) are fixedly attached to a balance arbor **10**′ and carry thereon permanent magnets **12***a*′ (**12***b*′) and **12***c* (**12***d*) adapted to electromagnetically cooperate with coil assembly **14**′. In diametral opposition to these permanent magnets, a unified and arcuated counter weight mass **13** is fixedly mounted on the balance wheel. At the lower end part of the balance arbor **10**′, there is provided an impulse pin **22**′ fixedly attached thereto as before. This impulse pin **22**′ is also positioned with an offset angle amounting to 20° or more, relative to the common diameter of the balance wheel and the escape wheel. Numeral **23**′ denotes the

conventional escape wheel of conventional design and having its arbor **25'** rotatably mounted as before, although not specifically shown, between the second bridge and the timepiece plate as at **24** and **20** in the foregoing embodiment.

The same or similar constituent parts in the present modification are shown, irrespective of modified configuration thereof, by the respective same references as those employed in the foregoing so that no further analysis would be necessary for better understanding of the present modification.

The functional mode of the modification is similar to that of the foregoing embodiment.

It will be clearly seen from the foregoing that according to the novel teachings of the invention, separate and independent removal of occational fluctuations of the winding angle of hair spring **16** and the reduction in battery voltage can be obtained by mounting the impulse pin **22** of the mounting disc **19** at a positive angle relative to the common diameter **28** between the escape wheel **23** and the mounting disc **19**, which will cause an occasional alteration in the position of the center of gravity which will influence the isochronic error of the drive balance wheel acting as the timebase of the above kind of battery-driven timepeice, can be substantially obviated.

With the balance wheel kept in its stationary or neutral position, in the case of the timepiece according to this invention, the impulse pin is kept in no physical contact with the escape tooth, the balance wheel can be started at the beginning stage of the balance wheel oscillation practically under no load, thus providing a smooth and effective starting characteristic being attained without use of any mechanical starter means and capable of providing a favorable and repid development of the oscillation amplitude.

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

1. In a drive balance wheel assembly for use in an electronic timepiece having an impulse pin fixedly mounted on the balance wheel arbor for driving cooperation with an escape wheel, and a mounting plate for rotatably supporting said balance wheel arbor and escape wheel, the improvement comprising said escape wheel having a plurality of ratchet teeth equally spaced around the outer periphery thereof, said ratchet teeth having two parallel radial edges, the outermost edge of each radial tooth forming an acute angle with the edge of said tooth on the side in the direction of rotation of said escape wheel, said impulse wheel being formed as a rectangular pillar mounted perpendicularly on said balance wheel for engagement with said ratchet teeth in both directions of rotation of said balance wheel arbor, said impulse pin being positioned so as to establish a central angle of 20° or more on the balance wheel as measured ahead of the common diameter to said both wheels with the balance wheel kept at its neutral position, and a permanent magnet mounted on said plate between said plate and the ratchet teeth of said escape wheel for cooperation with the planar surface of each ratchet tooth to position said escape wheel as it is indexed by the engagement of said impulse pin with each of said ratchet teeth.

2. The improvement as claimed in claim **1**, characterized by that said impulse pin is mounted fixedly on a mounting disc which is fixedly mounted in turn on the arbor of said balance wheel.

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