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Burckhardt et al.

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[54] **RESONATOR FOR A TIMEPIECE**

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[30] **Foreign Application Priority Data**

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[52] **U.S. Cl.** .... **58/28 R;** 58/23 TF; 331/175

[51] **Int. Cl.** **G04c 3/02;** G04c 3/04; H03d 3/00

[58] **Field of Search**.... 58/23 R, 23 D, 23 TF, 28 A, 58/28 B, 28 D, 107, 23 V; 331/175

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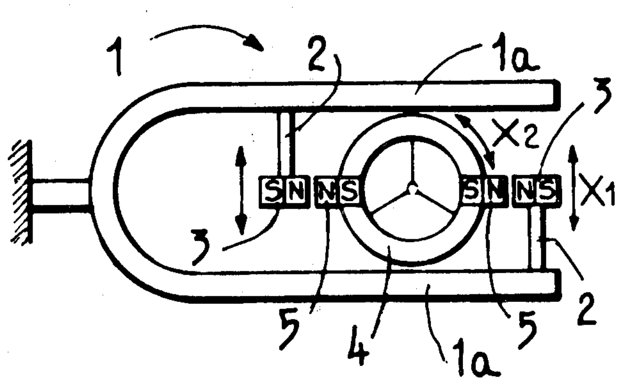
[57] **ABSTRACT**

A resonator for a timepiece includes a first oscillating device which oscillates at a first low frequency and a second oscillating device which oscillates at a second higher frequency. Each oscillating device includes at least one magnet which moves in accordance with a moving member of its respective oscillating device. The movement of the magnets produces a non-linear magnetic field between the oscillating devices which transmits the energies of one oscillating device to the other for synchronizing the low frequency oscillating device to the higher frequency oscillating device.

8 Claims, 6 Drawing Figures



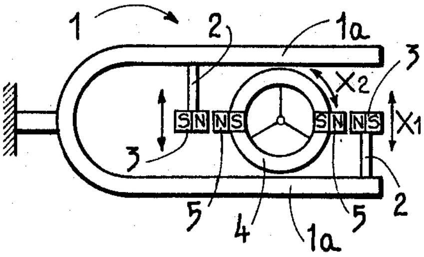


FIG. 1

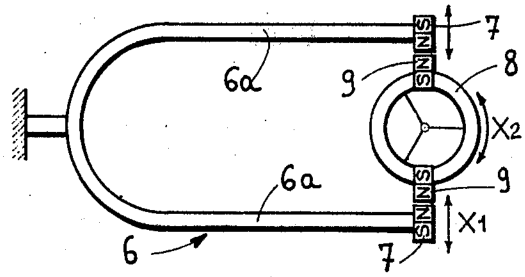


FIG. 2

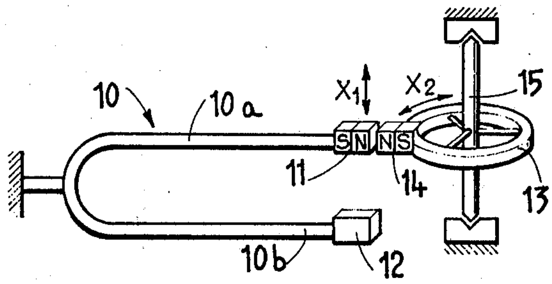


FIG. 3

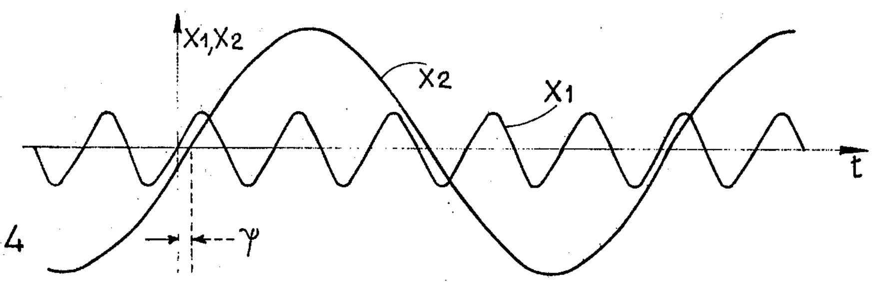


FIG. 4

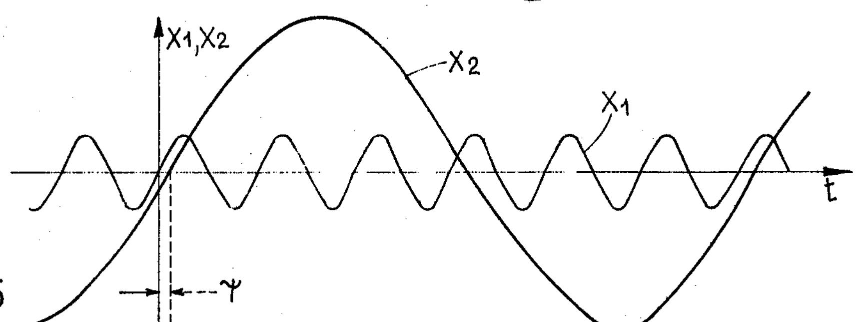


FIG. 5

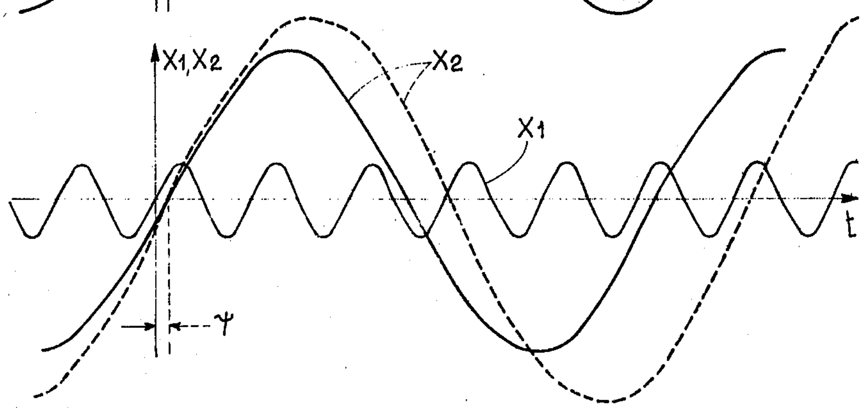


FIG. 6

RESONATOR FOR A TIMEPIECE

The present invention relates to a resonator for a timepiece comprising two oscillating devices the proper frequencies and the virtual energies of which are different, the energy transmitting themselves from one to the other by a connecting means having a non linear characteristic, so that the low frequency oscillating device, the virtual energy of which is the lowest, will be synchronized by the high frequency oscillating device the virtual energy of which is the highest.

Such resonators are based on the fact that the high frequency oscillating device has a quality factor substantially higher than the other device, that permits it to synchronize this latter.

In the known realizations of these resonators, the transmission of the energy from one of the oscillating devices to the other is effected by the shock of a vibrating mass of one of these devices against a vibrating mass of the other. The sensitiveness to the outer accelerations of such a type of transmission is obviously great and its fiability weak, so that the object of the invention is to remove these drawbacks.

The resonator according to the invention is characterized by the fact that the two oscillating devices comprises each at least one magnet moving with the vibrating member of the respective oscillating device, the magnetic fields produced by the said magnets constituting the connecting means between the two oscillating devices ensuring the transmission of their energies.

One distinguishes, in the applications of the above mentioned resonator, the two following cases:

1. Frequency division

The high frequency oscillating device is a driving one and pilots the low frequency oscillating device the oscillations of which represent the time and are counted by a time display for presenting the time.

2. Frequency multiplication

The low frequency oscillating device is a driving one and ensures the maintaining of the oscillations of the high frequency oscillating device which, by a feed-back effect, synchronizes it at its turn, the oscillations of the low frequency oscillating device representing the time and being counted and displayed by a time display for presenting the time.

The drawing shows, by way of example, three embodiments of the object of the invention which can all the three be used according to one or the other of the two types of operation which have been indicated hereabove.

FIGS. **1** and **2** are plan views of two embodiments of a resonator for a timepiece provided with a tuning-fork and with a balance-wheel.

FIG. **3** is a perspective view of a third embodiment of a resonator for a timepiece also provided with a tuning-fork and with a balance-wheel, and

FIGS. **4** to **6** are diagrams of the oscillations of the two oscillating devices of each of the three resonators of FIGS. **1** to **3** respectively.

In the example of FIG. **1**, the high frequency oscillating device is a tuning-fork **1** the two arms **1***a* of which carry each a stem **2** at the end of which is secured a permanent magnet **3**. The stem **2** of one of the arms **1***a* is situated at the vicinity of its end while the stem **2** of the other arm is situated at the vicinity of its root. The low frequency oscillating device is constituted by a balance-wheel **4** carrying two permanent magnets **5** diametrically opposed. The arrangement is such that, when the balance-wheel **4** occupies its position of equilibrium (point zero), the four magnets **3** and **5** are placed on a same diameter of the balance-wheel **4** which coincides with the medium axis of this tuning-fork **1**. Thus, the magnets **3** carried by the tuning-fork move tangentially with respect to the balance-wheel; the polarity of the several magnets is such that they act on one another, by pairs, by repulsion.

The diagram of the respective oscillations of the two oscillating devices is represented in FIG. **4**.

One knows that, if X_1 is the amplitude of the oscillations of the tuning-fork **1** and ω its proper frequency, one has the relation $X_1(t) = X_{10} \sin \omega t$ where X_{10} is the maximum amplitude of tuning-fork **1**, and that, if X_2 represents the amplitude of the oscillations of the balance-wheel **4** and Ω its proper frequency, one has $X_2(t) = X_{20} \sin (\Omega t - \tau)$ where τ represents the value of the dephasing of the two oscillating devices and X_{20} represents the maximum amplitude of balance wheel **4**.

One sees from the diagram of FIG. **4** that the frequencies ratio ω/Ω is 5. It must be, in the case of the embodiment of FIG. **1**, of 3, 5, 7, etc..., that is to say a uneven whole number.

In the example of FIG. **2**, the high frequency oscillating device is a tuning-fork **6** the arms **6***a* of which carry each, at their ends, a permanent magnet **7**. The low frequency oscillating device is constituted by a balance-wheel **8** carrying two permanent magnets **9**, diametrically opposed. The arrangement is such that, when the balance-wheel **8** occupies its position of equilibrium (point zero), the four magnets **7** and **9** are placed on a same diameter of the balance-wheel **8**, which is perpendicular to the median axis of the tuning-fork **6**. Thus, the magnets **7** carried by the tuning-fork move radially with respect to the balance-wheel; the polarity of the several magnets is such that they act on one another, by pairs, by repulsion.

The diagram of FIG. **5** is similar to this one of FIG. **4**, but is related to the embodiment of FIG. **2**.

One sees, according to this diagram, that the frequencies ratio ω/Ω is of 6. It must be, in the case of the embodiment of FIG. **2**, of 2, 4, 6, etc..., that is to say an even whole number.

In the example of FIG. 3, the high frequency oscillating device is a tuning-fork **10** one of the arms **10***a* of which carries, at its end, a permanent magnet **11** and the other arm **10***b* of which carries a counterweight **12** the weight of which is equal to the weight of the magnet **11**. The low frequency oscillating device is constituted by a balance-wheel **13** carrying a permanent magnet **14**. The arrangement is such that, when the balance-wheel **13** occupies its position of equilibrium (point zero), the two magnets **11** and **14** are situated opposite one another. The direction of the displacements of the magnet **11** of the tuning-fork **10** is parallel to the axis, designated by **15**, of the balance-wheel **13**; the polarity of the two magnets **11** and **14** is such that they act on one another by repulsion.

The diagram of FIG. **6** is similar to this one of FIGS. **4** and **5** but is related to the embodiment of FIG. **3.** One sees that, in this embodiment, one can have two different oscillating modes for the balance-wheel, one represented by the curve X_2 in full line and the other represented by the curve X_2 in dotted line, the frequencies ratio ω/Ω being of 5 for the first one and of 6 for the second one. This ratio must be, in the case of the embodiment of FIG. 3, of 2, 3, 4, 5, etc..., that is to say an even or uneven whole number.

It is to be noted that, in all the examples represented, the interaction of the magnets is a repulsion. In the case this interaction would be a pull, the dephasing would merely change of sign.

It is also to be noted that the three relative positions of the directions of oscillation such as disclosed and represented are particular cases, but that it would be possible to use intermediary relative directions.

What we claim is:

1. Resonator for a timepiece comprises two oscillating devices the proper frequencies and the virtual energies of which are different, the energy transmitting themselves from one to the other by a connecting means having a non linear characteristic, so that the low frequency oscillating device, the virtual energy of which is the lowest, be synchronized by the high frequency oscillating device the virtual energy of which is the highest, characterized by the fact that the two oscillating devices comprise each at least one magnet moving with the vibrating member of the respective oscillating device, the magnetic fields produced by the said magnets constituting the connecting means between the two oscillating devices ensuring the transmission of their energies.

2. Resonator as claimed in claim **1**, arranged in such a way as to realize a frequency division, characterized by the fact that the high frequency oscillating device operates as a driving element and synchronizes the low frequency oscillating device the oscillations of which are counted for displaying time.

3. Resonator as claimed in claim **1**, arranged in such a way as to realize a frequency division, characterized by the fact that the low frequency oscillating device operates as a driving element and ensures the maintaining of the high frequency oscillating device which, by a feed-back effect, pilots it at its turn, the oscillations of the low frequency oscillating device being counted for presenting time.

4. Resonator as claimed in claim **1**, characterized by the fact that the high frequency oscillating device comprises at least a vibrating blade, the low frequency oscillating device being constituted by a balance-wheel.

5. Resonator as claimed in claim **4**, characterized by the fact that the high frequency oscillating device is constituted by a tuning-fork.

6. Resonator as claimed in claim **4**, characterized by the fact that the arrangement is such that the magnet carried by the vibrating blade moves tangentially with respect to the balance-wheel.

7. Resonator as claimed in claim **4**, characterized by the fact that the arrangement is such that the magnet carried by the vibrating blade moves radially with respect to the balance-wheel.

8. Resonator as claimed in claim **4**, characterized by the fact that the arrangement is such that the magnet carried by the vibrating blade moves parallely to the axis of the balance-wheel.

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