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Baumgartner et al.

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[54] **MINIATURIZED MOVEMENT FOR AN ELECTRONIC TIMEPIECE**

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[51] **Int. Cl.**...........................**G04c 3/02,** H02k 33/00

[58] **Field of Search**.....58/23, 23 BA, 116 M; 310/25

[56] **References Cited**

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[57] **ABSTRACT**

A miniaturized movement for an electronic watch having a tuning-fork resonator which is sustained in vibration by an electrodynamic transducer constituted by magnetic elements borne by the tines of the fork and a stationary coil disposed in the air gaps of the magnetic elements. The coil is mounted on a module having embedded therein the components of the electronic drive circuit associated with the coil, the coil being inserted in the air gaps through an entrance which makes it possible to assemble or disassemble the transducer without interfering with the tuning fork.

7 Claims, 5 Drawing Figures

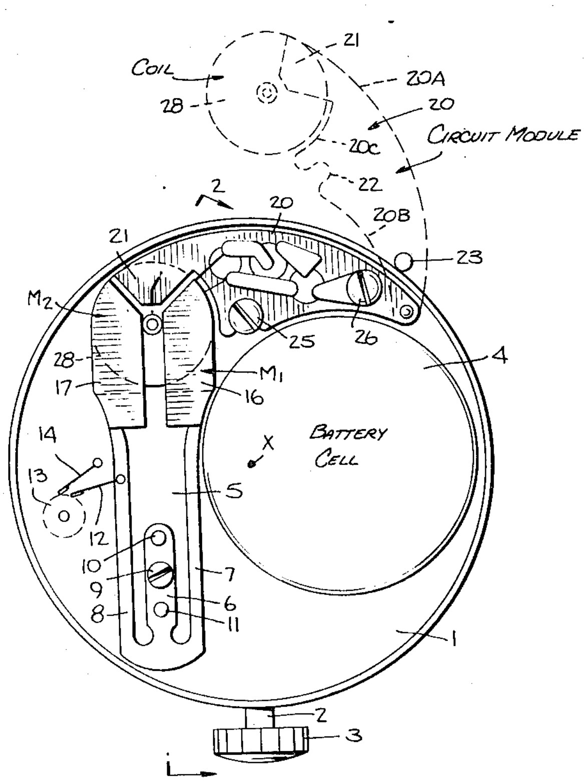

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Fig.1.

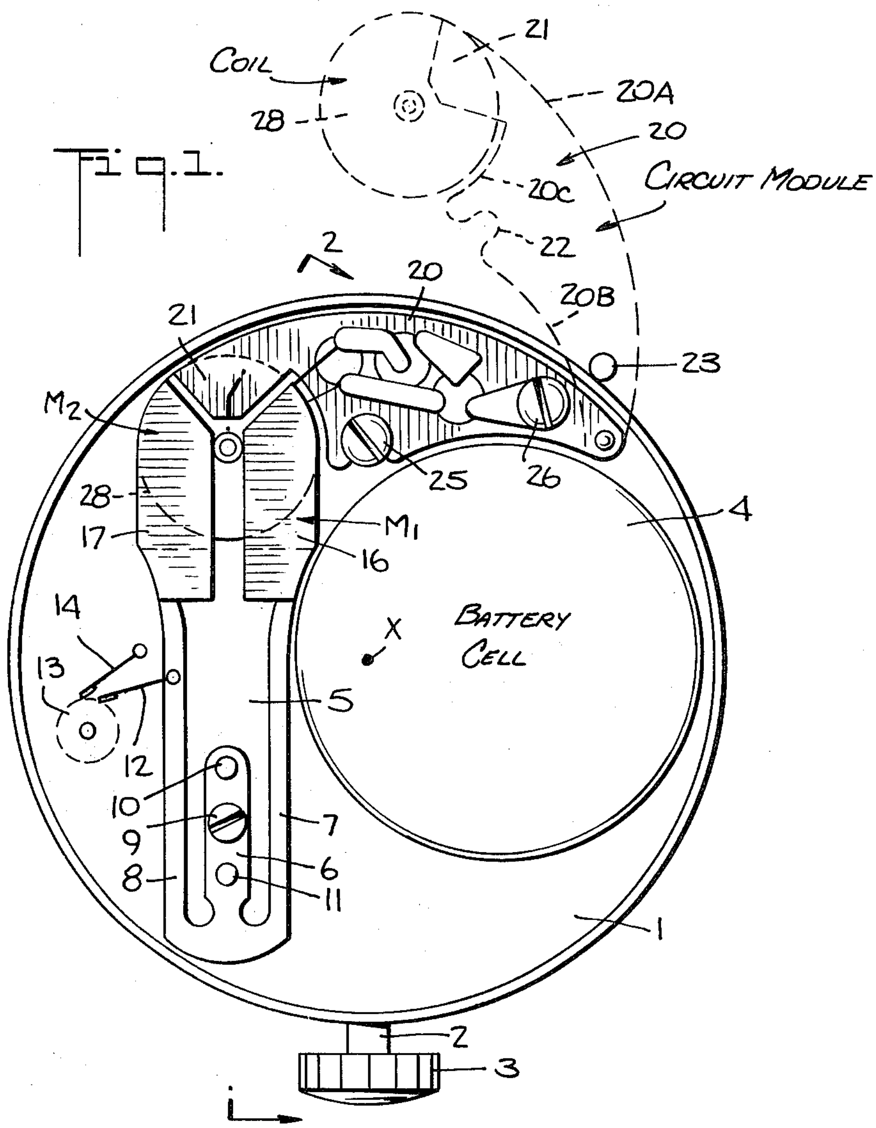

Fig.2.

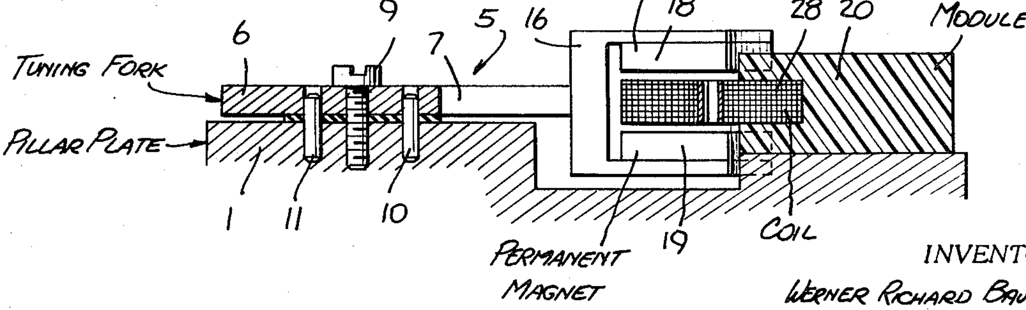

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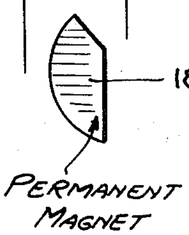
FIG. 1A.



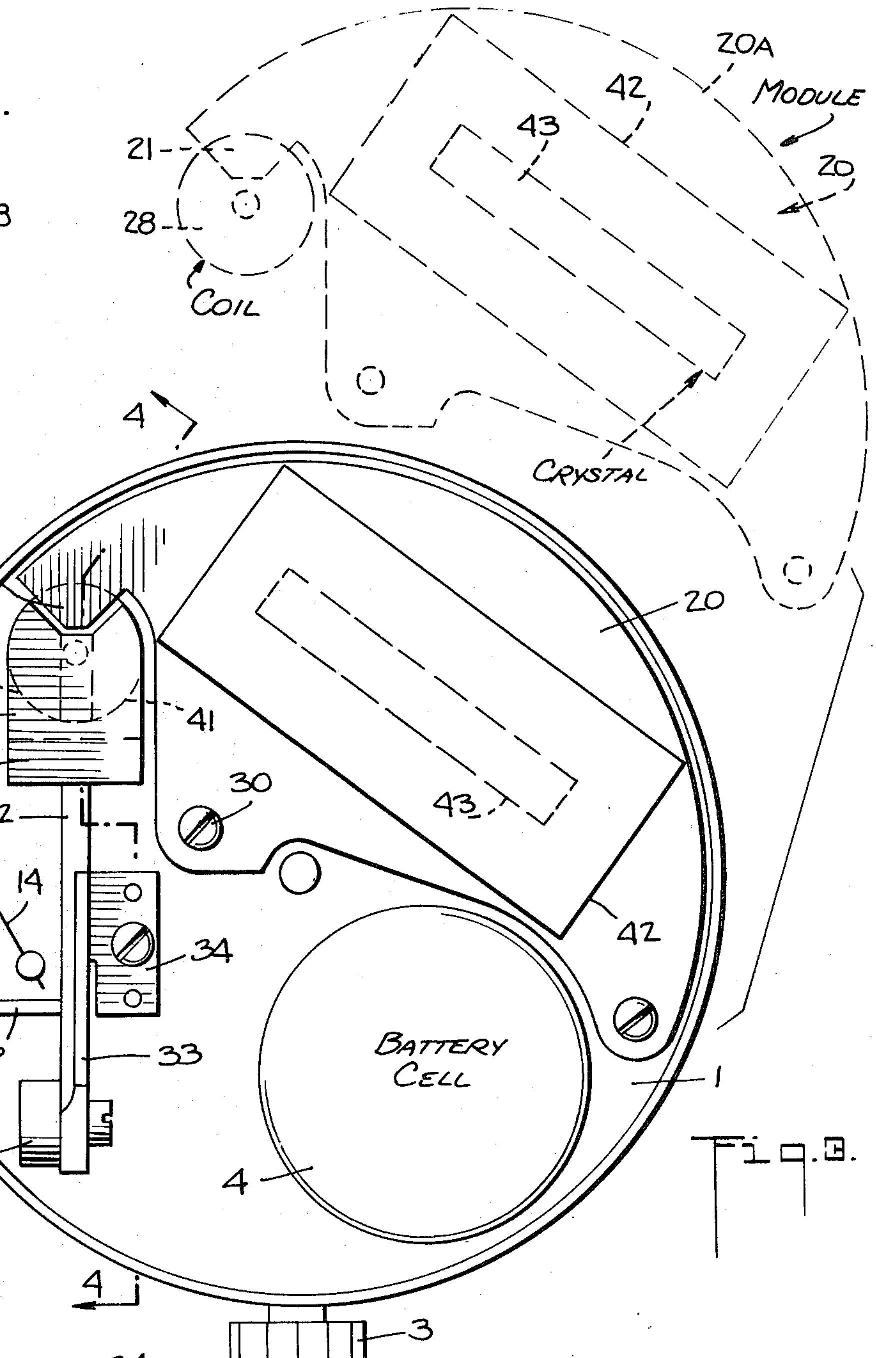


FIG. 3.

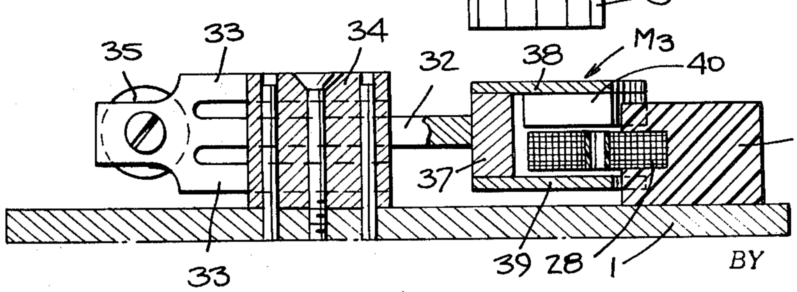


FIG. 4.

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MINIATURIZED MOVEMENT FOR AN ELECTRONIC TIMEPIECE

RELATED APPLICATION

This application is related to the commonly assigned co-pending application Ser. No. **2819**, now U.S. Pat. No. 3,628,323 filed Jan. 14, 1970, entitled "Miniaturized Electronic Watch."

This invention relates generally to battery-operated electronic timepieces, and more particularly to a miniaturized electronic watch including a tuning-fork resonator which is sustained in motion by an electrodynamic transducer constituted by a magnetic element borne by the fork and vibrating with respect to a stationary coil coupled to an electronic drive circuit.

In electronic timepieces of the type disclosed in U.S. Pat. No. RE26,322, a battery-energized transistor drive circuit acts to sustain the vibratory motion of a tuning fork. This motion is transferred by a pawl and ratchet mechanism to a rotary movement including a gear train and dial pointers or hands.

In tuning-fork electronic watches of the type heretofore known, the structural arrangement has been such as to preclude a reduction in the diameter and other dimensions of the watch movement to a degree making it possible to house the movement within a lady's watch case. Though such watches have been made in relatively large models having masculine appeal, it has not hitherto been feasible to miniaturize the dimensions to a point rendering the watch acceptable to ladies.

In seeking to miniaturize an electronic timepiece of the tuning-fork type, one is mainly confronted with two problems. One of these problems involves optimum exploitation of available space to accommodate the necessary components of the watch. The other problem relates to the ease of assembly and disassembly of certain watch components. To some extent, the solution to one problem is incompatible with the solution to the other, for if one succeeds in tightly packing the watch components within a very limited space, this usually renders it difficult to carry out assembly and disassembly operations.

In an electronic watch in which the tuning fork is sustained in vibration by an electrodynamic transducer, the transducer is constituted by magnetic elements borne by the fork and cooperating with a stationary coil connected to an electronic drive circuit. It is possible, using modern technology, to package the electronic circuit in an integrated microelectronic module. However, it is important, for purposes of assembly or servicing, to be able to install or remove the module and its associated coil without interfering with or disturbing other parts of the watch movement and without the need to bend or spread apart the tines of the fork in order to put the coil in place or remove it.

SUMMARY OF THE INVENTION

In view of the foregoing, it is the main object of this invention to provide a miniaturized electronic watch movement including a tuning fork sustained in vibration by means of an electrodynamic transducer whose coil is connected to an electronic drive circuit, the coil and electronic drive circuit being physically combined in a module which may be readily installed or removed without physically disturbing the tuning fork or other components of the movement.

Among the significant advantages of the invention is that it facilitates replacement of the electronic assembly without having to de-solder coil wires or other electrical connections and without the need to bend or otherwise interfere with the tines of the fork.

More specifically, it is an object of this invention to provide a tuning-fork watch movement wherein the tines of the fork bear C-shaped magnetic elements whose air gaps lie in a plane parallel to the oscillatory plane of the fork and are adapted to accommodate a pancake-shaped transducer coil, also lying in a plane parallel to the pillar plate, the coil being supported on a removable module incorporating the associated electronic circuit whereby the coil may readily be slipped in and out of the air gaps without disturbing the tuning fork or any other mechanical components of the movement.

Briefly stated, these objects are accomplished in a watch movement including a tuning fork having two vibrating tines, the vibratory action of the fork being converted into rotary motion to operate the hands of the timepiece. Mounted on the free ends of the tines are C-shaped magnetic elements which define air gaps lying in a plane parallel to the oscillatory plane of the fork, the air gaps accommodating a pancake-shaped coil which is mounted on a removable module incorporating the components of an electronic drive circuit associated with the coil, the entrance to the air gaps being disposed at the free ends of the magnetic elements whereby the coil may readily be introduced or withdrawn therefrom.

OUTLINE OF THE DRAWING

For a better understanding of the invention, as well as other objects and further features thereof, reference is made to the following detailed description to be read in conjunction with the accompanying drawing, wherein:

FIG. 1 is a schematic plan view of one preferred embodiment of an electronic timepiece movement in accordance with the invention, the dial, the case and the wheels for driving the hands being omitted for purposes of simplicity;

FIG. 1A is a plan view of one of the permanent magnets included in the magnetic elements forming part of the structure shown in FIG. 2;

FIG. 2 is a section taken in the plane indicated by line 2—2 in FIG. 1;

FIG. 3 is a plan view of another preferred embodiment of an electronic timepiece movement in accordance with the invention; and

FIG. 4 is a section taken in the plane indicated by line 4—4 in FIG. 3.

DESCRIPTION OF THE INVENTION

Referring now to FIGS. 1 and 2, there is shown one embodiment of an electronic watch movement in accordance with the invention, the diameter of the movement being relatively small, thereby making it possible to incorporate the movement in the casing of a ladies-model watch.

The movement is provided with a circular pillar plate 1 which, in the usual manner, supports a setting stem 2 having a crown 3. Placed within a circular recess in pillar plate 1 is a round, single-cell battery 4. The battery is so placed that a point on its periphery substantially coincides with the border of pillar plate **1**.

The dial train components supporting the hands of the watch (i.e., hour wheel, cannon pinion and center second pinion), which turn with respect to a geometric axis X passing through the center of the pillar plate, all lie above the top surface of battery **4** in the manner disclosed and illustrated in the above-identified copending application.

Mounted on pillar plate **1** is a mechanical resonator in the form of a tuning fork having tines **7** and **8** and a reentrant stem **6** which is attached by a screw **9** to the pillar plate. The fork position is maintained by pins **10** and **11** which penetrate pillar plate **1**, the oscillating plane of the fork being parallel to the pillar plate. Tines **7** and **8** extend upwardly from the common base of the fork, the tines curving out slightly at their free ends, such that the concave portion of tine **7** complements the curvature of battery **4** which is directly adjacent thereto. The axis of symmetry Y of fork **5** is relatively distant from the geometric axis X passing through the center of pillar plate **1**, which geometric axis also passes through battery cell **4**.

Supported on tine **8** is an index finger **12** which engages the teeth of an index wheel **13**, the wheel driving the hands of the watch in the manner illustrated in said copending application. Retrograde motion of wheel **13** is prevented by a pawl **14** anchored on the pillar plate.

Borne on tines **7** and **8** and vibrating therewith are respective magnetic elements M_1 and M_2, the elements cooperating with a stationary pancake-shaped coil **28** to provide an electrodynamic transducer. This coil, which may be made up of drive and sensing windings, is supported from a nose **21** formed on a plastic module **20** which encapsulates the associated electronic assembly. The circuit of the coil and electronic drive system is disclosed in greater detail in said copending application. Coil **28** lies in a plane parallel to pillar plate **1** as well as to the plane of oscillation of fork **5**.

Magnetic elements M_1 and M_2 are each constituted by C-shaped ferromagnetic frames **16** and **17**, respectively. As best seen in FIG. 3, mounted on the inner walls of the arms of frame **16** of magnetic element M_1 are permanent magnets **18** and **19** which establish a magnetic field extending perpendicularly through coil **28**. Magnetic element M_2 has an identical arrangement.

Coil **18** is received in the air gap defined by the permanent magnets borne by magnetic elements M_1 and M_2. As shown in FIG. 1A, the magnets borne by magnetic elements M_1 and M_2 are contoured to encircle the entire coil except for an open segment having about a 90 degree dimension at the free end of the elements.

Since the magnetic elements oscillate in phase opposition, the magnetic fields created by the permanent magnets borne thereby must be polarized in the same direction. The permanent magnets are fabricated of a material producing strong fields, and this, coupled with the fact that the lines of flux cut through virtually the entire coil, gives rise to an electrodynamic transducer of very high efficiency.

The contours of plastic module **20** are such that its convex outer border **20A** conforms to the curvature of pillar plate **1**, whereas its concave inner border **20B** follows the related curvature of battery **4** and its end border matches the curvature of magnetic element M_1.

Thus the shape of module **20** is constituted by three arcs and is generally triangular.

In order to simplify assembly, check-out and service, generally triangular module **20** pivots at its apex about a pin **24** affixed to pillar plate **1**. Module **20** is held in its operative position by screw **25** which passes through a notch **22** in the module and a screw **26** which passes through a hole **23** therein. This makes it possible to swing out module **20**, as indicated by dotted lines in FIG. 1, thereby separating coil **28** from magnetic elements M_1 and M_2.

Thus it becomes possible to replace or repair the electronic circuit and coil assembly without having to disassemble, loosen or spread apart the tines of the tuning fork. In addition to this practical advantage, the arrangement affords a highly compact package which makes possible the design of miniaturized watches.

Referring now to FIGS. 3 and 4, there is shown another embodiment of an electronic watch movement which differs from that shown in FIGS. 1 and 2, mainly in the fact that the operating frequency of the mechanical resonator is regulated by a quartz crystal frequency standard.

In this arrangement, plastic module **20** is similar to that in FIGS. 1 and is provided with a nose **21** supporting coil **18**. Module **20** also carries a container **42** enclosing a quartz crystal **43**, the components of the electronic circuit being embedded in the module. Module **20** is held to pillar plate **1** by screws **30** and **31**. The module may be removed to occupy the position shown in dotted lines, thereby making possible quick assembly and disassembly.

The mechanical resonator includes a relatively stiff oscillating arm **32** which is affixed to a block **34** by means of elastic reeds **33**, the block in turn being mounted on pillar plate **1**. The resonant frequency of the resonator is maintained relatively low by means of two weights borne by arm **32**. One of these weights is constituted by a C-shaped magnetic element M_3 consisting of a spacer **37** of non-magnetic material, two plates **38** and **39** of magnetically soft alloys, and two permanent magnets **40** and **41**.

The permanent magnets have the same shape as magnet **18** shown in FIG. 1A and partially cover coil **28**, which is disposed in the air gap defined thereby. The permanent magnets have opposite polarities with respect to coil **28** and generate a magnetic field whose lines of flux extend perpendicularly to the plane of coil **28**.

The other end of oscillating arm **32** bears a counterweight **35**. The arm and its flexible reeds serve as a low-frequency resonant vibrator whose frequency is synchronized by pulses derived, after suitable frequency division, from the crystal standard. Alternatively the low-frequency resonator may be phase-locked with the frequency of the high-frequency crystal standard.

The vibratory motion of arm **32** is converted into rotary motion by means of index finger **12** extending from a post **36** affixed to arm **32** and engaging index wheel **13** in such a manner as to minimize the adverse effect of accelerations in the phasing of the index mechanism which also includes pawl **14** to prevent retrograde motion of wheel **13**.

As in the case of FIG. 1, all electronic components other than battery **4** are incorporated in module **20** shown in FIG. 3. In order to disassemble the electrical system, it is necessary only to break the connection to the battery, for all other component connections are borne by the module.

Since one terminal of the battery cell is normally connected to the pillar plate, this terminal may be connected to the electronic drive circuit in the module by way of one of screws **30** or **31**. The second terminal of the battery may be connected to the electronic circuit by a contact spring (not shown) extending from the module and adapted to engage the second battery terminal, thereby making it possible to readily replace the module. It is also advantageous to design the contact spring so that it is pivoted about its point of connection on the module, thereby facilitating replacement of the battery cell.

While there have been shown and described preferred embodiments of a miniaturized electronic timepiece in accordance with the invention, it will be appreciated that many changes and modifications may be made therein without departing from the spirit of the invention.

We claim:

1. An electronic timepiece movement provided with a pillar plate which is receivable within a casing, and a battery cell supported on said plate, said movement comprising:

A. a mechanical resonator mounted on said plate and adapted to vibrate in a plane parallel to the plate, said vibration being converted into rotary motion to drive the hands of the timepiece,

B. an electrodynamic transducer constituted by a C-shaped magnetic element secured to said resonator and having at least one permanent magnet affixed thereto to define an air gap which lies in a plane parallel to said pillar plate, said gap having an entrance at the free end of said element, and a pancake-shaped coil receivable within said air gap, and

C. a module removably mounted on said pillar plate and incorporating an electronic drive circuit energized by said cell and associated with said coil to supply pulses thereto to sustain said resonator in vibration, said coil being supported by said module and projecting from one end thereof, the other end of said module being pivotally supported on said pillar plate, whereby said module and coil may be removed by swinging said module on its pivot without interfering with said resonator.

2. An electronic timepiece movement provided with a pillar plate which is receivable within a casing, and a battery cell supported on said plate, said movement comprising:

A. a mechanical resonator in the form of a tuning fork mounted on said plate and having tines adapted to vibrate in a plane parallel to the plate, said vibration being converted by a motion transformer into rotary motion,

B. an electrodynamic transducer constituted by a C-shaped magnetic element secured to each tine of said resonator and having at least one permanent magnet affixed thereto to define an air gap which lies in a plane parallel to said pillar plate, said gap having an entrance at the free end of said element, and a pancake-shaped coil receivable within said air gap, the C-shaped magnetic elements being symmetrically disposed with respect to said coil,

C. a module removably mounted on said pillar plate and incorporating an electronic drive circuit energized by said cell and associated with said coil to supply pulses thereto to sustain said resonator in vibration, said coil being supported by said module, whereby said module and coil may be removed without interfering with said resonator and,

D. time-indicating hands driven by said motion transformer, the hands rotating about a geometric axis passing the rough center of said pillar plate, the axis of symmetry of said fork being displaced from said center.

3. A movement as set forth in claim **2**, wherein one point on the periphery of said cell substantially coincides with the border of the pillar plate and the diametrically opposed point on the periphery of said cell is adjacent one tine of the fork, the dial train components of the movement being disposed above the plane defined by the top surface of the power cell.

4. A movement as set forth in claim **3**, wherein the upper ends of the fork tines are curved outwardly, the curvature of one of the tines following the curvature of the battery cell adjacent thereto.

5. A movement as set forth in claim **2**, wherein said module profile is formed by three arcs to define a generally triangular body, the outer arc matching the curvature of the pillar plate, the inner arc that of the battery and the end arc that of the magnetic element on the adjacent tine.

6. A movement as set forth in claim **5**, wherein said module is pivoted at its apex whereby one may swing the module away from the pillar plate.

7. A movement as set forth in claim **2**, wherein said module also includes a piezoelectric crystal standard to synchronize the operation of the resonator.

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