United States Patent

Van Haaften

[15] **3,693,342**

[45] **Sept. 26, 1972**

[54] **TUNING-FORK TYPE ELECTRONIC CLOCK**

[72] Inventor: **Egbert Van Haaften,** Closter, N.J.

[73] Assignee: **Bulova Watch Company, Inc.,** New York, N.Y.

[22] Filed: **July 8, 1971**

[21] Appl. No.: **160,835**

[52] **U.S. Cl.** ....**58/23 TF,** 58/23 D, 310/25, 310/36, 331/157

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

[58] **Field of Search**.......58/23 R, 23 TF, 23 D, 23 V; 331/157; 84/457; 310/25, 36, 38

[56] **References Cited**

UNITED STATES PATENTS

3,425,210 2/1969 Barth..........................58/23 R

FOREIGN PATENTS OR APPLICATIONS

1,519,243 2/1968 France.....................58/23 TF

Primary Examiner—Richard B. Wilkinson
Assistant Examiner—Edith C. Simmons Jackmon
Attorney—Michael Ebert

[57] **ABSTRACT**

An electronic clock making use of an electromagnetically actuated tuning fork whose vibrations are converted into rotary motion for driving the gear train of the clock by means of a motion transformer including a V-shaped indexing element. The ends of the indexing element are attached to the tines of the fork at corresponding points thereon, and the vertex thereof is flattened to define a rectangular tongue whose edge engages the ratchet teeth of an index wheel whereby as the tines vibrate, the tongue reciprocates in a rectilinear path at right angles to the direction of vibration. The index wheel is joined to a worm gear coupled to the first wheel in the gear train, the worm gear being supported for rotation between a fixed pivot and a spring-biased pivot, whereby sufficient friction is introduced to prevent retrograde motion of the index wheel.

9 Claims, 7 Drawing Figures

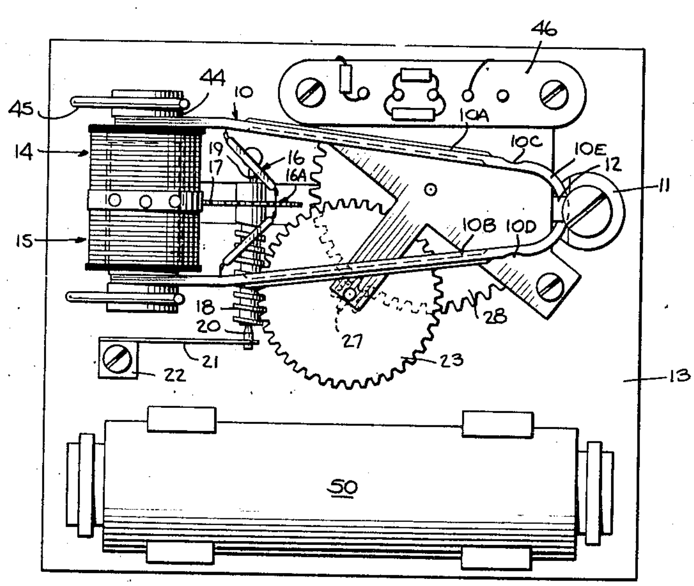


Fig.1.

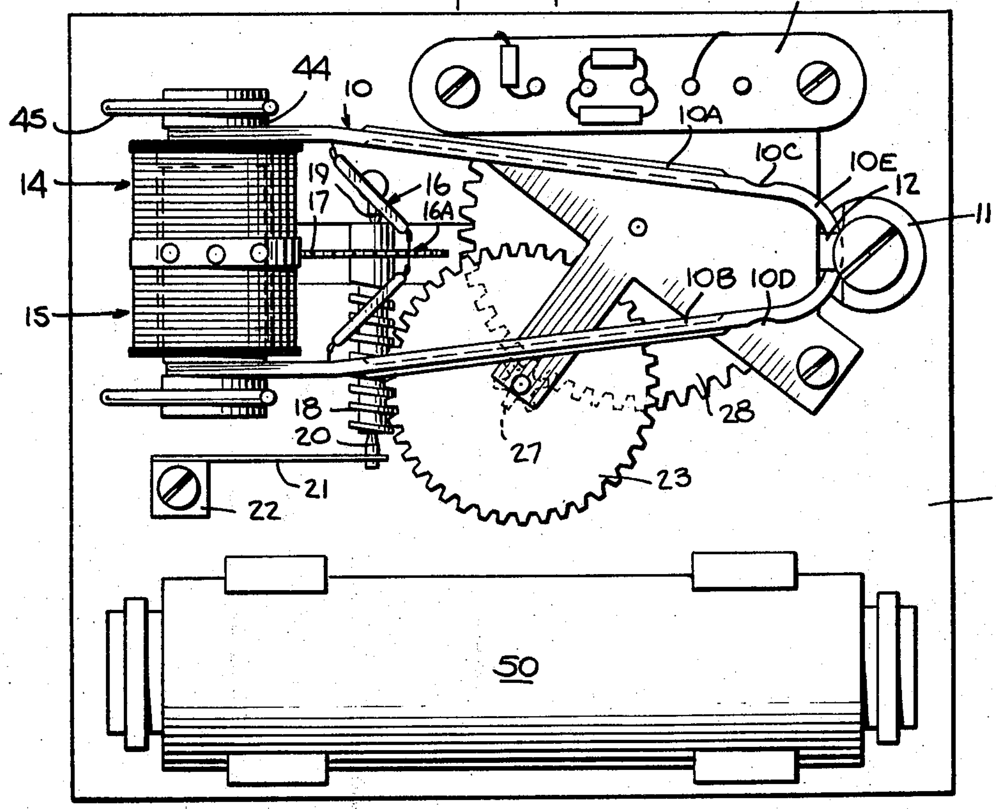
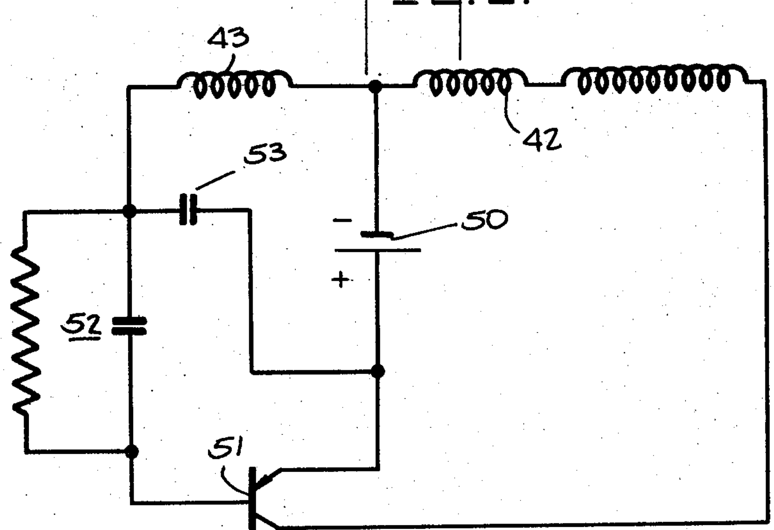


Fig.2.



INVENTOR.
EGBERT VAN HAAFTEN
BY [signature]
ATTORNEY

PATENTED SEP 26 1972 4,693,342

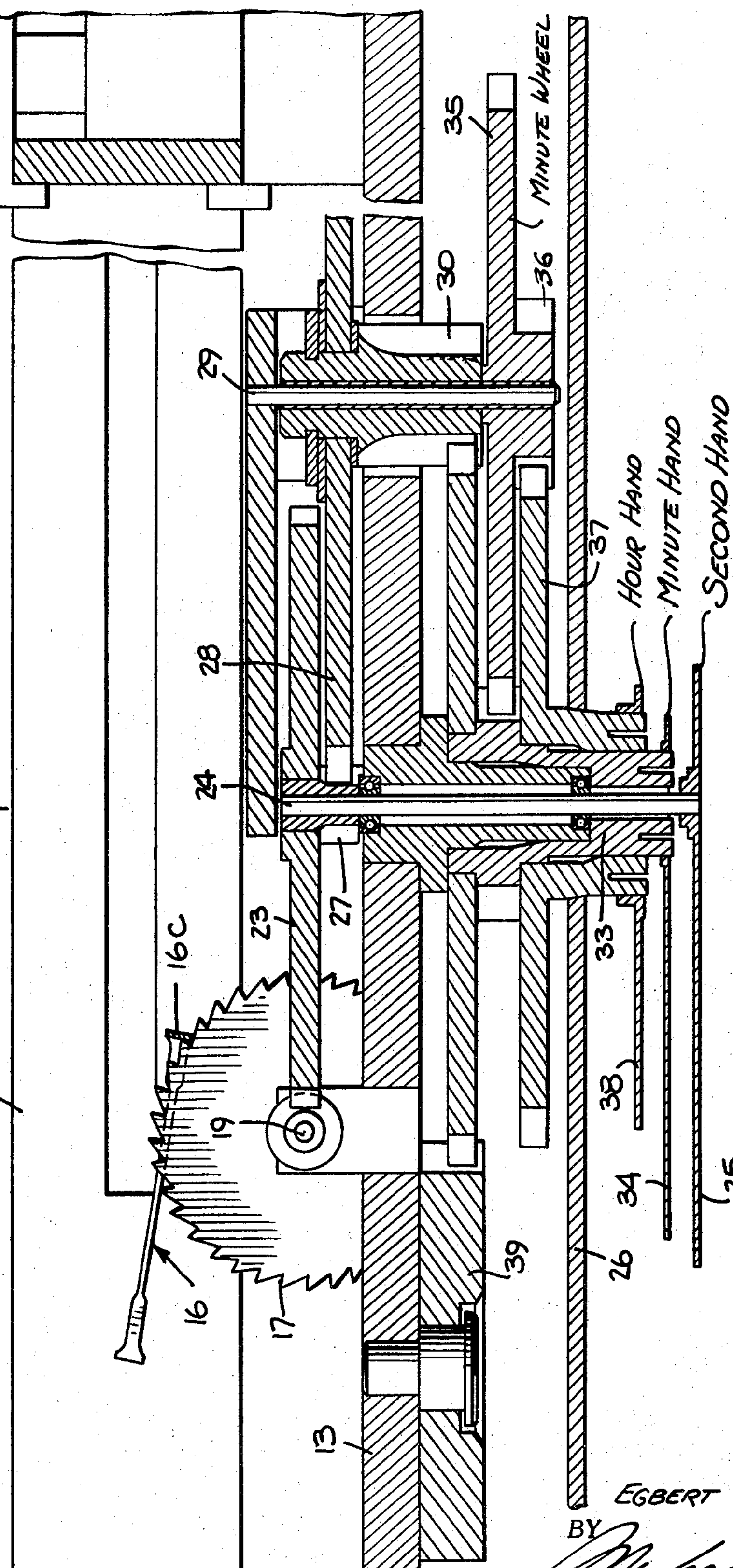
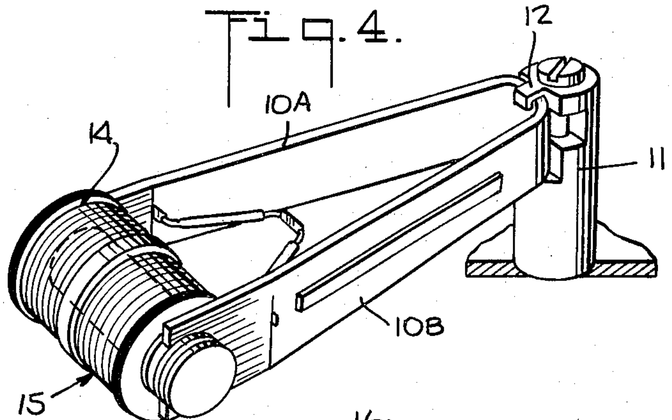


Fig. 3

INVENTOR.
EGBERT VAN HAAFTEN

BY Michael [signature]
ATTORNEY

Fig. 4.



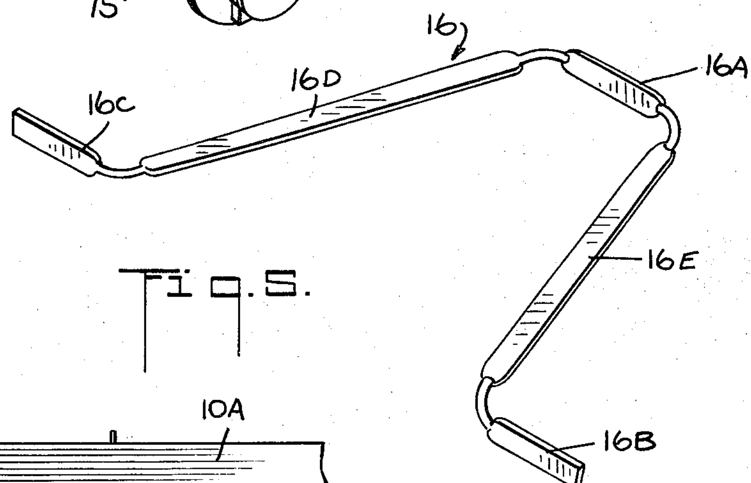


Fig. 5.

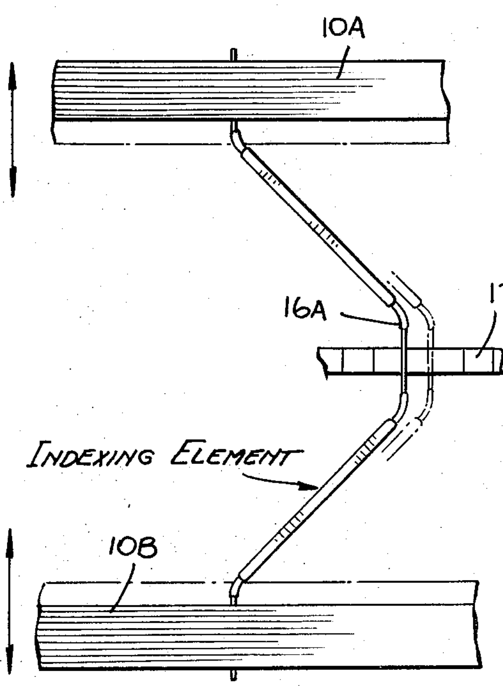
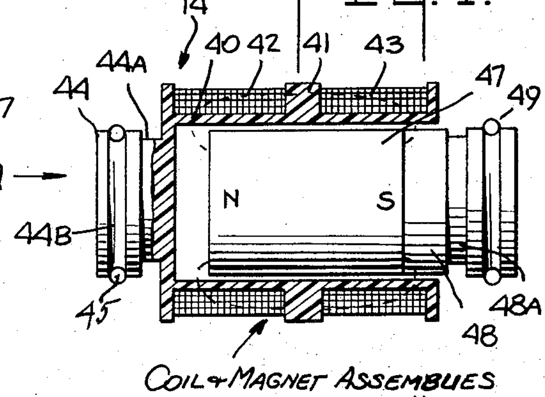


Fig. 6.

Fig. 7.



INVENTOR.
EGBERT VAN HAAFTEN
BY Michael Ebert
ATTORNEY

TUNING-FORK TYPE ELECTRONIC CLOCK

BACKGROUND OF THE INVENTION

This invention relates generally to electronic timepieces and more particularly to clocks incorporating an electromagnetically-actuated tuning fork as a time base.

By definition, a watch is a portable timepiece designed to be worn or carried on the person. Clocks on the other hand, are those devices other than watches for indicating or measuring time. Time measurement by mechanical means was first carried out by clocks employing pendulums as the timekeeping standard, and only with the introduction of the balance wheel was it possible to produce compact timepieces or watches as well as clocks. In modern spring-powered mechanical movements employing balance wheels, both clocks and watches make use of essentially the same operating components, the main distinction therebetween lying in the scale of the components and the torque produced thereby, for clocks require a greater torque to drive the relatively large time-indicating hands.

In the more recently developed field of electronic timepieces of the type in which an electromagnetically actuated tuning fork functions as the time base, the evolution of this timepiece has been the very reverse of that of mechanical timepieces, for the introduction of the tuning-fork watch preceded the development of the tuning-fork clock.

In U.S. Pat. No. 2,971,323 of Hetzel, there is disclosed an electronic timepiece suitable for a watch, and including a tuning fork having a relatively high frequency. A battery-powered transistorized drive circuit acts to sustain the vibratory motion of the fork. The reciprocating motion of the fork, which serves as a time-keeping standard, is transformed into rotary motion by means of a ratchet and pawl mechanism whose index finger is attached to one tine of the fork. The finger engages and advances a ratchet wheel provided with a pinion for operating the timepiece hands through a train of gears.

U.S. Pat. No. 3,184,981 of Bennett, Mutter, and Van Haaften discloses an improved form of a motion converter for a timepiece of the Hetzel type, whereby the ratchet wheel is caused to advance only one tooth for each forward stroke of the index finger attached to the tine, regardless of minor variations in the length of the stroke arising from changes in the amplitude of fork vibration. This is accomplished by means of an auxiliary pawl attached to the pillar plate of the timepiece, the pawl engaging the ratchet wheel at a position relative to the index finger at which the phase between the finger and pawl is several ratchet teeth plus one-half tooth. Motion converters of this type operate efficiently and reliably, and are presently used in tuning fork watches sold commercially under the trademark, "Accutron."

Electric clocks whose timing is synchronized by the frequency of the AC power source, may be manufactured and sold at low cost, for such clocks do not require motors of high quality to maintain accurate timing. But when a battery-operated clock is required in those situations where AC power is not available or where the use of external power line is undesirable, existing low-cost battery-operated clocks usually fail to afford accurate timing comparable to that of an electric clock, particularly when use is made of a balance wheel.

But when the tuning fork principle is applied to electronic timepieces in clock form, the relatively delicate index finger auxiliary pawl ratchet wheel arrangement, which requires careful adjustment, may not be suitable for a low-cost clock, particularly for clocks intended for a somewhat rugged environment such as the dashboard of a vehicle. It must be borne in mind that while clocks are larger than watches, clocks are generally marketed at a much lower cost in that watches, because of their fine workmanship, are treated as jewelry items, whereas clocks are household or industrial articles. Hence expensive mechanisms which are acceptable for fine watches cannot, as a practical matter, be used in a low-cost clock.

In an attempt to overcome these drawbacks, battery-operated tuning-fork clocks have been developed, making use of so-called magnetic escapements to convert the vibratory motion of the fork into rotary motion, rather than mechanical motion converters of the type disclosed in the above-identified patents. However, a magnetic escapement wherein a wheel having a magnetic track or teeth is associated with magnets secured to the vibrating tines of the fork, has serious disadvantages, for such escapements are inefficient and produce relatively little torque. Moreover, they are not self-starting and it is necessary to include a mechanical starter in the clock to set the wheel of the magnetic escapement into motion.

Also characteristic of existing tuning-fork watches is a tuning fork operating in conjunction with two electromagnetic transducers, one being formed by a magnetic cup attached to one tine of the fork, and associated with a stationary coil, and the other being a second magnetic cup attached to the other tine and associated with another stationary coil. This tuning fork and transducer assembly is relatively costly and a scaled-up version for a clock would result in high manufacturing costs.

SUMMARY OF THE INVENTION

In view of the foregoing, it is the main object of the invention to provide a tuning-fork type electronic clock which is accurate and reliable in operation, and which may be produced and sold at low cost.

More specifically it is an object of this invention to provide an efficient and rugged motion transformer for an electronic clock of the above-described type, which converter is capable of operating successfully under arduous environmental conditions.

Also an object of this invention is to provide a simple, low-cost electromagnetic transducer for a tuning-fork electronic clock, which transducer is composed of coil and magnet assemblies that may be readily attached to the tines of the fork.

Yet another object of the invention is to provide a tuning fork which is fabricated from a single piece of strip metal and which may be quickly installed or dismounted.

Briefly stated, these objects are attained in an electronic clock comprising a tuning fork having a permanent magnet assembly secured to one tine thereof, and a coreless coil assembly secured to the other tine thereof, the magnet being inserted in the coil to provide an electromagnetic transducer for sustaining the fork in vibration. Bridged between the tines is a V-shaped indexing element whose ends are secured to corresponding points on the tines and whose vertex is flattened to define a rectangular tongue, the lower edge of which engages the ratchet teeth of an index wheel. The tongue is caused to undergo rectilinear motion at right angles to the direction of tine vibration, thereby to drive the index wheel. The index wheel is mounted on a worm gear supported between end pivots, one of which is spring-biased to create sufficient friction preventing retrograde movement of the index wheel. The worm gear engages the first wheel in a gear train serving to drive the hands of the clock.

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 an elevational rear view of a tuning-fork type electronic clock in accordance with the invention;

FIG. 2 is a schematic diagram of the electrical circuit associated with the tuning fork in the clock;

FIG. 3 is a section taken through the clock structure;

FIG. 4 is a separate perspective view of the tuning fork and its associated electromagnetic transducer;

FIG. 5 is a perspective view of the indexing element associated with the fork;

FIG. 6 is a plan view of the indexing element and the ratchet wheel driven thereby; and

FIG. 7 is a sectional view of the electromagnetic transducer associated with the tines of the tuning fork.

DESCRIPTION OF THE INVENTION

Referring now to FIG. 1, there is shown a tuning-fork type electronic clock in accordance with the invention, comprising a U-shaped fork generally designated by numeral 10, having a pair of tines 10A and 10B. The fork is constructed of a single strip of metal having indentations at nodal points 10C and 10D adjacent the base 10E. The fork is attached to a mounting post 11 by a pair of tabs 12, each of which is bent to embrace base 10E. Mounting post 11 is anchored in pillar plate 13.

The free ends of tines 10A and 10B are provided with cut-outs to define mounting fingers for holding a coil assembly 14 and a magnet assembly 15, which together constitute the electromagnetic transducer for sustaining the fork in vibration. The operating frequency of the fork is preferably 180 Hz, for while the clock is designed for battery operation, at this frequency it becomes possible to synchronize the operation of the fork from a 60 Hz power line (60 Hz is an integral submultiple of 180 Hz), thereby providing a timepiece of high accuracy. But should AC power fail, the fork would still continue to function accurately on battery power. In practice, sync pulses may be derived inductively from the power line, thereby avoiding the need for a wired connection thereto.

The vibratory action of the fork is converted into rotary motion by a mechanical motion transformer constituted by a generally V-shaped indexing element 16, whose ends are attached at corresponding positions to tines 10A and 10B, the ends fitting into holes in the tines and being epoxied or otherwise bonded thereto. The indexing element in practice is preferably made from a single piece of stainless steel round wire having a diameter of 0.006 inches.

The round wire is flattened at the vertex of the indexing element to define a vertically oriented rectangular tongue 16A, and the ends of the element are bent outwardly and flattened to define vertically oriented feet 16B and 16C. The sides of the indexing element are also flattened to define horizontally oriented legs 16D and 16E, whereby all that remains round in the wire are the links between the legs and the feet, and the links between the legs and the tongue.

As the vibrating tines move toward and away from each other, flexure occurs in the feet 16B and 16C of the indexing element, causing tongue 16A joined to legs 16D and 16E to undergo rectilinear motion at right angles to the motion of the tines. Since both tines oscillate to an equal extent, tongue 16A will move a distance equal to the distance travelled by an individual tine at the point at which the feet (16B and 16C) are connected thereto. Thus, as best seen in FIG. 6, the tines vibrate, the tongue of the indexing element in the course of each cycle executes a forward stroke along the longitudinal axis of the fork and a return stroke along the same axis.

The lower edge of tongue 16A of the indexing element engages the ratchet teeth on an index wheel 17 such that with each forward stroke of the tongue the wheel is advanced one increment. The tuning fork has no pivots or bearings and its timekeeping action is therefore independent of the effects of friction. The amplitude of the fork tines is chosen so that the movement of tongue 16A is about one and one half times the distance between successive teeth on the index wheel. However, no pawl is used to prevent retrograde motion of the wheel. Such retrograde motion is prevented by a frictional bearing for the index wheel.

Index wheel 17 is integral with a worm gear 18, the two elements being preferably made of high-strength, low-friction plastic material, such as Delrin. The worm gear is mounted for rotation between two tapered pivots 19 and 20, which project into holes bored in the opposite ends of the worm gear. Pivot 19 is rigidly supported whereas pivot 20 is borne on the free end of a flat spring 21, mounted on a bracket 22. Spring 21 is pre-stressed to apply axial pressure against the worm gear. In practice, the pivots are formed of hardened, highly polished stainless steel and are pointed to a 20° included angle.

The direction of pitch in the worm is chosen so that as it rotates, should there be any load imposed on the index wheel and the worm integral therewith, its direction is toward the fixed pivot 19, thereby preventing the worm from moving away from the fixed pivot under load conditions. The resultant combination of forces (that of friction at the pivots and the lesser friction of the indexing element and index wheel), prevents retrogression of the wheel during the return stroke of the indexing head.

Because the teeth in the ratchet wheel are engaged by the broad lower edge of the tongue, shock or vibration causing lateral displacement of the tongue relative to the wheel will not effect disengagement therebetween. The indexing element is downwardly biased against the index wheel which also serves to present disengagement therebetween. Thus the clock is capable of uninterrupted operation under the most arduous field conditions, for the clock includes no delicate balance wheel or motion transformer that may be rendered inoperative or upset by shock forces.

Intermeshing with worm gear **18** is a worm wheel **23** mounted on a center shaft **24** whose end, as shown in FIG. **3**, terminates in the second hand **25** of the clock. The various time-indicating hands are associated with a dial plate **26**. Worm wheel **23** has sixty teeth, the worm gear having a single lead pitch. Index wheel **17** has one hundred and eighty teeth to match the 180 Hz fork frequency. With this combination, worm wheel **23** makes one revolution per minute so that the second hand completes a full turn every minute.

Also keyed to shaft **24** directly at a position below worm wheel **23** is a pinion **27** having six teeth which, in turn, drives a sixty-tooth gear **28**. Gear **28** rotates on a shaft **29** and is fitted to a 10-tooth pinion **30** through a slip clutch arrangement that permits the setting of the hands without disturbing the driving portion of the train.

The 10-tooth pinion **30** drives a 60-tooth gear **31** provided with a 16-tooth pinion **32**. Fastened to the gear assembly is a tubular shaft **33** concentric with center shaft **24** and carrying the minute hand **34**. The 16-tooth pinion **32** drives a 48-tooth gear **35** having a pinion **36** provided with 14 teeth, pinion **36**, in turn driving a 56-tooth gear **37** carrying the hour hand **38**.

Gear **35**, commonly called the minute wheel, which is combined with pinion **36**, operates on the same shaft **29** as the clutch gear **39**. This simplified arrangement is advantageous, for only one critical center distance for the gears is required, outside that of the worm and index wheel assembly. An idler gear is required in the hand-setting arrangement, but this is not critical as far as center distance is concerned.

In the above described gear train assembly, all parts thereof may be fabricated of good-grade plastic material except for the two main arbors, which are preferably of stainless steel. By using Delrin for all plastic parts and stainless steel for all metal-bearing parts, one is able to dispense with the need for a lubricant.

Coil assembly **14**, as shown separately in FIG. **7** is constituted by a tubular coil form divided by an annular partition **41** into two sections, one having a drive coil **42** wound therein, and the other a phase-sensing or pick-up coil **43**. In practice, since the drive coil has more turns than the phase-sensing coil, a portion of the phase-sensing form section may be occupied by drive coil turns, so that the drive coil is then made up of two series-connected parts.

Coil form **40** is provided with a cylindrical extension **44** projecting axially from one end thereof, which extension has one groove **44A** adapted to receive the U-shaped cut-out on the end of tine **10A**, and a second groove **44B** for accommodating a timing regulator **45**.

This regulator is in the form of an unbalanced loading mass constituted by a round piece of wire with a loop and a circular portion to fit into the coil form groove, such that by turning the regulator to different angular positions, the orientation of the unbalanced loading mass is shifted to bring about a fine adjustment in timing.

The three wires from coils **42** and **43** are connected to an electronic circuit housed in a module **46** secured to the pillar plate. The wires from coil assembly **14** run along the length of tine **10A** and are fastened thereto, the wires at the nodal point **10C** then leaving the tine to go to module **46**. Since there is virtually no motion at nodal point **10C**, negligible flexing of the wires is experienced despite the fact that the tine carrying the wires is in constant vibration.

Magnet assembly **15** is constituted by three parts, namely a permanent magnet rod **47**, a mounting plug **48**, preferably made of brass and cemented or otherwise bonded to one end of the magnet rod, and a regulator **49**. Because the plug is made of non-ferromagnetic material, the open magnetic flux path extends from the magnet rod, coaxially disposed within coils **42** and **43** through these coils, but is magnetically isolated from tine **10B** on which the magnet assembly is mounted.

Plug **48** is provided with a groove to receive the cut-out in tine **10B** and a groove **48B** to receive the regulator **49**, which is identical in form and function to regulator **45** on the coil assembly.

The electronic circuit housed in module **46** is powered by a replaceable battery cell **50**, held in a suitable socket or by clips on pillar plate **13**. The circuit, as shown in FIG. **2**, is constituted by a transistor **51**, whose emitter is connected to the positive pole of battery **50**, the negative pole thereof being connected through drive coil **42** to the collector of the transistor. The negative pole is also coupled through phase-sensing coil **43** and through a resistance-capacitance bias circuit **52** to the base of the transistor. A bypass capacitor **53** is connected between the emitter and the junction of the phase-sensing coil **43** and the RC bias circuit **52** to prevent parasitic oscillation.

In operation, when transistor **51** is rendered momentarily conductive, a current pulse derived from battery **50** flows through drive coil **43**. The resultant magnetic field produces an axial thrust on magnet assembly **15**, this action producing an equal and opposite reaction on the coil assembly **14**. Since magnet assembly **15** is mounted on tine **10B** and coil assembly **14** on tine **10A**, the tines are deflected in opposing directions.

The movement of the magnet and coil assemblies relative to each other induces a back EMF both in drive coil **42** and in phase-sensing coil **13**. Since this reciprocation is in accordance with fork motion, the back EMF assumes the form of an alternating voltage whose frequency corresponds to fork frequency (i.e., 180 Hz). The voltage induced in sensing coil **43** is applied to the base of the transistor and overcomes a bias imposed thereon by the RC circuit, thereby to control the instant or phase position in the course of each cycle when the drive pulse is to be delivered to the drive coil.

The back EMF developed in the drive coil is in series opposition to the voltage applied by battery **50** between emitter and collector of the transistor. Battery voltage has a constant value, whereas the back EMF is a function of tine amplitude. The operation of the transistor during its conductive periods is controlled in accordance with the algebraic sum of the battery and back EMF voltage applied thereto, and the amplitude of the fork vibration is thereby regulated. The behavior of this and similar circuits is explained more fully in Hetzel U.S. Pat. No. 2,971,323, commonly assigned.

The operating frequency of the fork is determined not by the fork per se, but by the combined mass of the tines and the assemblies mounted thereon. For highest operating efficiency, it is essential that symmetry exist as between the centers of gravity of the two oscillating masses with respect to the axis of symmetry of the fork. In practice, therefore, magnetic assembly **15** is made such that its mass and center of gravity substantially match that of the coil assembly **14**.

While there has been shown and described a preferred embodiment of a tuning fork clock in accordance with the invention, it will be appreciated that many changes and modifications may be made therein without, however departing from the essential spirit of the invention. For example, the indexing element, rather than being made of round wire as described herein, with flattened sections, may be made entirely of flat wire twisted at appropriate points to define the flat lip and tongue sections of the element.

I claim:

1. An electronic timepiece comprising:

A. a tuning fork having a pair of tines,

B. means operatively coupled to said fork to sustain said fork in vibration at its natural frequency, and

C. means including a motion transformer to convert the vibratory action of said fork into rotary motion for driving a gear train coupled to time-indicating hands, said means including a V-shaped indexing element whose ends are secured to the tines at corresponding points thereon, whereby the vertex of the element is caused to reciprocate in a rectilinear path substantially at right angles to the direction of tine motion, a ratchet wheel mounted on a worm gear, the teeth of said wheel being engaged by the vertex of said element whereby with each forward stroke thereof, said wheel is advanced one increment, said worm gear engaging the first wheel in said gear train and being mounted for rotation on a friction bearing introducing sufficient drag to prevent retrograde motion of the ratchet wheel on the return stroke of the vertex.

2. A timepiece as set forth in claim **1**, wherein said vertex is constituted by a rectangular tongue whose lower edge engages said teeth, said tongue lying in a plane transversely disposed relative to said rectilinear path.

3. A timepiece as set forth in claim **2**, wherein said V-shaped indexing element is formed by a piece of round wire whose ends are bent outwardly and are attached to said tines, the vertex being flattened to define said tongue.

4. A timepiece as set forth in claim **3**, wherein the sides of said element are also flattened.

5. A timepiece as set forth in claim **1**, wherein said frictional bearing is formed by two tapered pivots received in bores in the ends of said worm gear, one pivot being fixedly mounted, the other being spring-biased to urge said worm gear in the direction of the fixed pivot.

6. A timepiece as set forth in claim **5**, wherein the direction of the pitch of said worm gear is such that any load imposed on the gear is directed toward the fixed pivot, thereby preventing the worm from moving away from the fixed pivot under load conditions.

7. A timepiece as set forth in claim **1**, wherein said means to sustain said fork in vibration includes an electromagnetic transducer coupled to an electronic drive circuit, said transducer being constituted by a magnet assembly mounted on one tine of said fork and cooperating with a coil assembly mounted on the other tine.

8. A timepiece as set forth in claim **7**, wherein said magnet assembly is constituted by a permanent magnet rod secured to the associated tine by a non-ferromagnetic spacer, whereby said magnet rod is magnetically isolated therefrom.

9. A timepiece as set forth in claim **8**, wherein said spacer includes a circular groove and a timing regulator in the form of an unbalanced mass supported in said groove and including a wire loop encircling said groove.

* * * * *