Feb. 2, 1965 | M. HETZEL | 3,167,905

MOTION TRANSFORMERS FOR ELECTRONICALLY CONTROLLED TIMEPIECE

Filed July 16, 1963

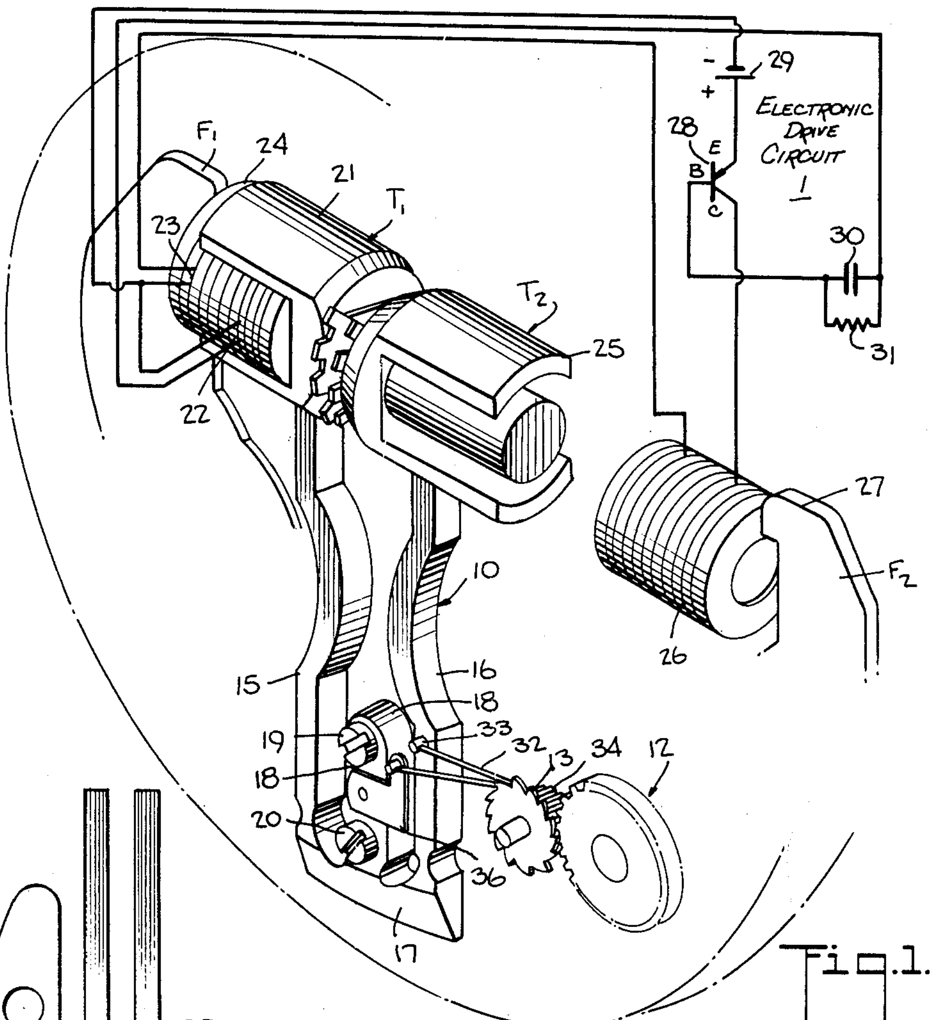

Fig.1.

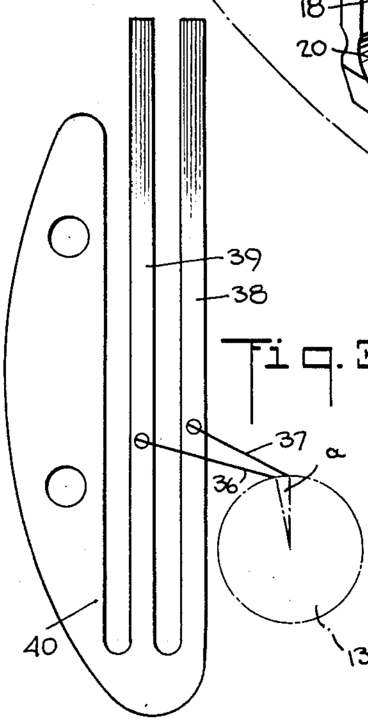

Fig.3.

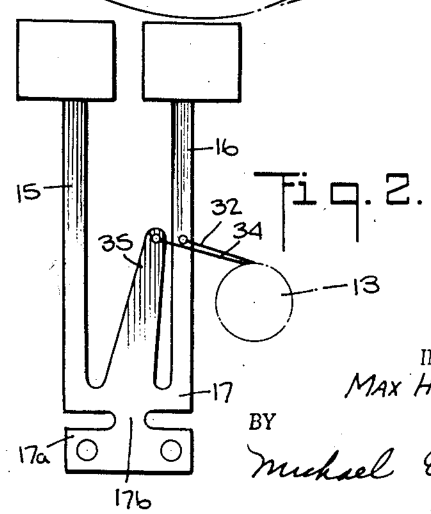

Fig.2.

INVENTOR.
MAX HETZEL

BY Michael Ebert

ATTORNEY

United States Patent Office

3,167,905
Patented Feb. 2, 1965

3,167,905

MOTION TRANSFORMERS FOR ELECTRONICALLY CONTROLLED TIMEPIECE

Max Hetzel, New Hyde Park, N.Y., assignor to Bulova Watch Company, Inc., New York, N.Y., a corporation of New York

Filed July 16, 1963, Ser. No. 295,406
1 Claim. (Cl. 58—23)

This invention relates generally to electronically controlled timepieces which incorporate electromagnetically actuated tuning forks, and more particularly to improved motion transformers for converting the reciprocating movement of the tuning fork into rotary motion for driving the gear train of the timepiece.

In ordinary electric watches, make-and-break contacts are mechanically operated by the oscillation of the balance wheel. Each time these contacts close, battery current flows in a coil to electromagnetically impulse the balance wheel. Such mechanically operated make-and-break contact systems are subject to wear as well as to deterioration and contamination of the delicate contact points which must open and close an electric circuit without fail 216,000 times a day. The slightest sparking will cause rapid deterioration of these contacts and early failure of the watch.

In my United States Patents 2,971,323; 3,070,951; 2,960,817; 3,057,147; 2,949,727; 2,929,196; 2,908,174; 2,900,786, and 2,888,582, I disclose an electronically controlled timepiece which does away with a balance wheel and escapement, as well as with make-and-break contacts. My timepiece employs a self-sufficient timekeeping standard formed by a tuning fork whose vibratory motion is sustained electromagnetically by a battery-energized transistor circuit. This motion is transmitted to a rotary movement including the usual gear train and dial pointers by means of an index finger attached to one tine of the fork, the finger advancing a ratchet or index wheel which drives the gear train.

In the co-pending application of Bennett et al., Serial No. 89,896, filed January 16, 1961, now abandoned, there is disclosed a motion transformer for a timepiece of the type described in my patents, the transformer including a jewel-tipped index finger which engages the teeth of an index or ratchet wheel so that the oscillations of the tine transmit turning impulses to the wheel. Operating in conjunction with the index wheel is a pawl whose design is similar to that of the index finger, the pawl being pivotally attached to the pillar plate of the timepiece. The index finger and pawl are both tensioned downwardly such that when the finger is retracted by the tine, the resultant reverse torque produces a backup which is arrested by the pawl, the pawl being phased several teeth plus one-half tooth from the finger and being positioned in advance thereof, in the direction of wheel rotation.

One important problem which arises in a ratchet system of the type disclosed in said co-pending application, is with respect to the phase relationship between the pawl and the index finger. While this relationship may be initially adjusted to a desired fixed value, it may be upset by the twisting of the pillar plate on which the pawl is mounted. Any deviation from this phase relationship lowers the strobe range and impairs the reliability and operation of the ratchet system. Twisting of the pillar plate frequently occurs when inserting and clamping the watch movement in a watch casing.

Accordingly, it is the principal object of this invention to provide a motion transformer in which the phase relationship between the ratchet wheel and the drive elements therefor is maintained constant, regardless of twisting of the pillar plate.

More specifically, it is an object of the invention to

provide a motion transformer for a tuning-fork timepiece wherein an index wheel is driven by a pair of push-pull actuated index fingers attached to the respective tines of the fork.

Still another object of the invention is to provide a motion transformer for a tuning fork timepiece wherein the index wheel is driven in one direction by an index finger secured to one tine of the tuning fork, reverse movement of the wheel being prevented by a pawl secured to a stationary portion of the tuning-fork, whereby twisting of the pillar plate has no influence on the phase relationship of the pawl and finger.

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 like components in the several figures are identified by like reference numerals.

In the drawing:

FIG. 1 is a schematic representation, in perspective, of the basic components of an electronic timepiece including a motion transformer in accordance with the invention;

FIG. 2 shows another preferred embodiment of a motion transformer in accordance with the invention; and

FIG. 3 shows a push-pull drive system in accordance with the invention.

Referring now to the drawing, the major components of a timepiece in accordance with the invention are a time-keeping standard constituted by a tuning fork **10** and an electronic drive circuit **11** therefor, a rotary movement of conventional design including a gear train **12** for turning the hands of the timepiece, and a motion transformer including an index wheel **13** operatively intercoupling the fork **10** and the rotary movement **12** and acting to convert the vibratory action of the fork into rotary motion.

All of the electrical components of the drive circuit are mounted on sub-assembly units or modules attached to a disc-shaped metallic pillar plate **14** which may be supported within a watch casing of standard design or within any other type of housing, depending on the use to which the timepiece is put.

Tuning fork **10** is provided with a pair of flexible tines **15** and **16** whose feet are interconnected by a relatively inflexible base **17**, the base being provided with an upwardly extending stem **18** secured to the pillar plate by suitable screws **19** and **20**. The central area of the pillar plate is cut out to permit unobstructed vibration of the tines.

The tuning fork is actuated by means of a first transducer T_1 constituted by a magnetic element **21** secured to the free end of tine **15**, the element coacting with a drive coil **22**, and a phase sensing coil **23**. Drive coil **22** is wound on an open-ended tubular carrier **24** affixed to a sub-assembly mounting form F_1 which is secured to pillar plate **14**. Coils **22** and **23** may be wound in juxtaposed relation on carrier **24** or the phase sensing coil **23** may be wound over drive coil **22**.

A second transducer T_2 is provided, constituted by a magnetic element **25** secured to the free end of tine **16** and coacting with a drive coil **26** wound on a tubular carrier **27**.

The electronic drive circuit **11** of the tuning fork comprises a transistor **28**, a single-cell battery **29**, and an R–C biasing network constituted by a condenser **30** shunted by a resistor **31**. Transistor **28** is provided with base, emitter and collector electrodes represented by letters B, E and C, respectively.

The base electrode is coupled through the R–C bias network **40–41** to one end of the phase-sensing coil **23**, the other end of the coil being connected to one end of the drive coil section **22**. The drive coil **26** is connected in a series with drive coil **22** to the collector electrode C of the transistor.

The emitter electrode E is connected to the positive terminal of the battery **29**, the negative terminal thereof being connected to the junction of drive coil **22** and phase-sensing coil **23**. Thus the battery is connected serially through both drive coils **22** and **26** between the emitter and collector electrodes of the transistor, the collector being negative relative to the emitter.

The transistor is preferably of the germanium junction type, and the polarity of the battery connection is shown as it exists when the transistor is of the PNP type. Obviously for other types of junction and point contact transistors made of such materials as silicon or germanium, the battery connections are arranged in accordance with the particular requirements.

The interaction of the electronic drive circuit and the tuning fork is self-regulating and functions not only to cause the tines to oscillate at their natural frequency, but also to maintain oscillation at a substantially constant amplitude. In practice, the amplitude of oscillation of the tines will be maintained at a substantially constant value or quickly returned to this value in the event of a mechanical disturbance. The electrical behavior of this circuit is set out more fully in the above-identified patents.

A tuning fork is a high "Q" mechanical oscillator and will vibrate at a natural frequency determined by the dimensions of the tines and the loading thereon which, in this instance, is determined by the mass of magnetic elements attached to the free ends. The rate at which the timepiece movement is driven is directly proportional to the operating frequency of the vibrator, so that the accuracy of the timepiece may be regulated by predetermining the operative frequency of the tuning fork. In practice, a fork vibrating at 360 cycles per second may be used.

The vibratory motion of the tuning fork is converted by a motion transformer into rotary motion. This transformer is constituted by a ratchet and pawl mechanism operated by the tuning fork to drive index wheel **13**. The index wheel **13** acts as the actuator for the rotary movement **12** and it is therefore essential that this wheel be advanced by the vibratory fork at a constant rate. This is effected by means of an index finger **32** which is soldered or otherwise attached to a post **33** secured at one end to tine **16**, post **33** having a constriction therein to provide a bending neck.

The index finger is in the form of a light leaf spring, and carries a tip which may be a precious or semi-precious stone, such as sapphire. The tip engages the teeth of index wheel **13** so that the oscillations of the tine transmit turning impulses to the wheel. The shaft of the wheel **13** is provided with a pinion which intermeshes with the first gear in the gear train **12**.

Operating in conjunction with the index wheel **13** is a pawl **34** whose design is similar to that of the index finger, the pawl being attached to a post **35** mounted on a bracket **36** secured to stem **18** intermediate screws **19** and **20**. The index finger and pawl are both tensioned downwardly, the jewelled tips thereof being parallel with the teeth of the index wheel. The tension is such that when the finger is retracted, there is sufficient reverse torque to cause the wheel to reverse direction. This backup, however, is arrested by pawl **34**, which is phased several teeth plus one-half tooth from the finger and is positioned in advance thereof in the direction of wheel rotation.

The necessary phase adjustment between the finger and pawl can be effected by pivoting the ratchet wheel with its bearings around the center of the first gear train wheel, or by pivoting bracket plate **36**, so that this adjustment can be made. In either case, the phase adjustment, once made, will be maintained, for the relationship is not distorted by twisting of the pillar plate, the pawl being independent of the pillar plate and being connected to a rigid portion of the fork.

In the modification shown in FIG. 2, a similar result may be accomplished by a fork structure mounted on the pillar plate by a base extension **17*a*** connected to the base **17** by a yieldable neck portion **17*b***, the fork being provided also with an upwardly extending, non-vibrating stem **18*a***. The stem **18*a*** is inclined toward tine **16**, and the pawl **34** is mounted thereon rather than on the pillar plate, thereby shortening the length of the pawl. Thus in the embodiments of FIGS. 1 and 2, the pawl position relative to the index finger is not affected by twisting of the pillar plate, for the pawl and finger are both mounted on the fork.

Instead of having a ratchet finger fixed on one tine of the fork and a pawl fixed on the pillar plate or on a non-vibratory portion of the fork, it is possible, as shown in FIG. 3, to do away with the pawl entirely and to drive the ratchet wheel **13** in a push-pull manner. This is accomplished by two index fingers **36** and **37**, each fixed to one tine of a tuning fork so that the fingers vibrate at the same amplitude and frequency in opposing phase. The angle alpha (α) between the two finger directions is equal to the angle between the two radii going through the center of the ratchet wheel and the jewelled tips of the fingers. This last condition is necessary to ensure that the jewels lie flat on the ratchet wheel teeth.

For the same ratchet wheel, the amplitude of one finger need be only half as large as it is for the ratchet and pawl system. With this push-pull system, the inertia power will be only one-fourth of the ratchet and pawl system, but since there are twice as many strokes, the total lost power is one-half that of the ratchet and pawl system. In effect, therefore, the ratchet wheel appears to have only half the thickness of the wheel in the ratchet and pawl system. Obviously, twisting of the pillar plate has no influence on the phase relationship of both jewels when these jewels engage the wheel at closely spaced points. Because both fingers are mounted on the tuning fork, movement of the wheel axle with respect to the foot of the fork does not significantly change the phase between fingers.

The fork construction shown in FIG. 1 does not lend itself to push-pull operation of the ratchet wheel, in that the fork tine separation is too great, as a result of which the length of one finger is far in excess of the other, and it is not possible to run the fingers in almost parallel paths. In order to facilitate a push-pull drive, the electromagnetically-operated fork in FIG. 3 is composed of two closely spaced tines **38** and **39** whose feet are joined to a base support **40** mounted on the pillar plate of the timepiece, the base running parallel to the tines. In this way, the two fingers **36** and **37** connected to the base **40** extend in substantially parallel paths to the wheel **13**. Similar results may be obtained with S or Z-shaped forks, or other symmetrical or asymmetrical configurations, which make it possible to extend index fingers of substantially the same length to an index wheel to effect push-pull operation thereof.

While there have been shown preferred embodiments of motion transformers 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 as defined in the annexed claim.

What is claimed is:

A timepiece comprising:

(A) a gear train for turning the hands of the timepiece,

(B) a tuning fork having a pair of vibrating tines attached at their roots to a yoke and extending upwardly therefrom and a mounting base lying to one side of said tines, said base being attached at one end to said yoke and extending upwardly therefrom, said tines being closely adjacent each other,

(C) means sustaining said tines in vibration,

(D) and a motion transformer for converting the vibrations of the tines into rotary motion for driving said gear train, said transformer including a ratchet wheel coupled to said train and a pair of fingers of substantially the same length attached to the respective tines and engaging said wheel at different points thereon to drive same in double-acting relation.

References Cited by the Examiner

FOREIGN PATENTS

579,298 7/24 France.

(Note.—The specification pages are numbered 576,298 except for page 2 which carries No. 570,298.)

LEO SMILOW, *Primary Examiner.*

JOSEPH P. STRIZAK, *Examiner.*