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ELECTRONICALLY CONTROLLED STOP-WATCH

Original Filed Jan. 17, 1962

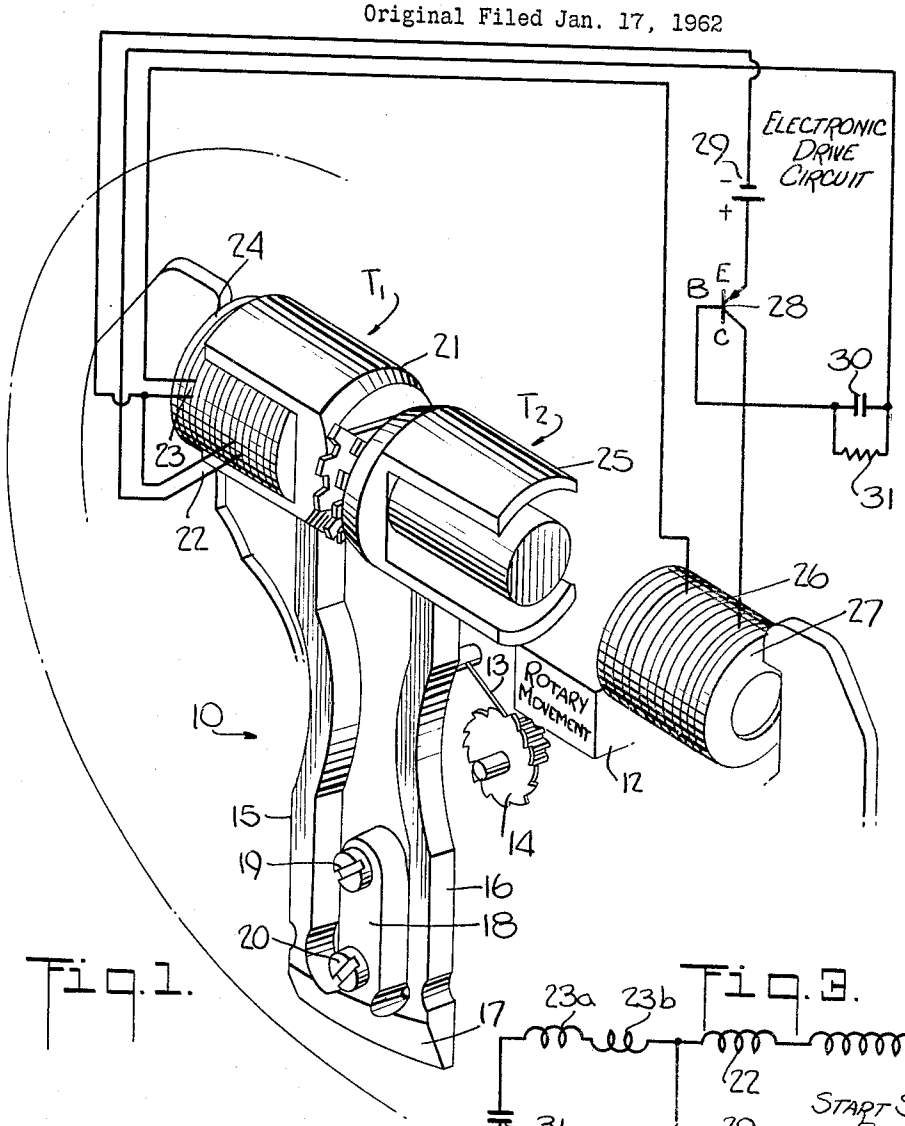

Fig. 1.

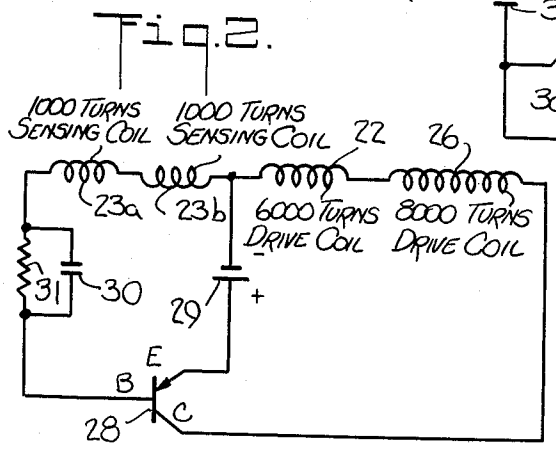

Fig. 2.

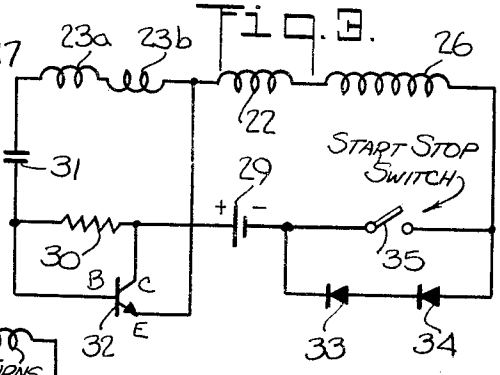

Fig. 3.

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ELECTRONICALLY CONTROLLED STOP-WATCH

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Original application Jan. 17, 1962, Ser. No. 166,838, now Patent No. 3,149,274, dated Sept. 15, 1964. Divided and this application July 15, 1964, Ser. No. 382,705

6 Claims. (Cl. 58—39.5)

My invention relates generally to electronically controlled timepieces, and more particularly to an electronically operated stop-watch of high efficiency. This application is a division of my co-pending application Serial No. 166,838, filed January 17, 1962, now Patent No. 3,149,274.

In my Patent 2,971,323, there is disclosed a device making use of a tuning fork having a predetermined natural frequency, the fork being pulsed electromagnetically by means of a battery-operated transistor circuit which excites the fork into vibration and sustains the motion thereof.

This motion is transferred to a rotary gear train by means of a pawl secured to one tine of the fork, the pawl advancing a ratchet or index wheel which drives the train. The drive circuit for the tuning fork is constituted by a drive coil electromagentically coupled to the tuning fork and connected to a transistor amplifier whose operation is controlled by a phase-sensing or pick-up coil similarly coupled to the tuning fork, the alternating voltage induced in the sensing coil by the vibration of the fork being applied to the transistor to render it conductive periodically and thereby produce drive pulses in the drive coil.

It is the main object of this invention to provide an electronically-operated timepiece of the tuning-fork type, which may be caused to stop and start, whereby the timepiece is adapted to serve as a stop-watch.

Also an object of the invention is to provide an electronic stop-watch wherein the desired stop or start action takes place in a fraction of a second.

More specifically, it is an object of the invention to provide a battery-operated electronic circuit for driving a tuning-fork timekeeping standard, the vibrations of the fork being translated into rotary motion by means of a pawl attached to one tine of the fork, the pawl driving a ratchet wheel coupled to the gearworks of the timepiece. The amplitude of fork vibration is controlled as a function of battery voltage. In order effectively to decouple the fork from the ratchet wheel and thereby stop the watch, means are provided to reduce the battery voltage applied to the electronic circuit to a degree which maintains the tuning fork in vibration but lowers the amplitude of such vibration to a point insufficient to cause the pawl to drive the ratchet wheel. To cause resumption of watch operation, the amount of voltage applied to the electronic circuit is restored to its normal value.

Thus the operation of the tuning fork is not arrested when stopping the timepiece, and when starting the timepiece the drive of the gearworks is caused to resume in a fraction of a second.

A further significant feature of the invention resides in the use of a grounded collector silicon transistor drive circuit which has an extremely low leakage current, thereby minimizing power losses.

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 representation in perspective of the basic components of an electronic timepiece in accordance with the invention;

FIG. 2 is the electrical circuit diagram of the timepiece; and

FIG. 3 shows a modified electrical circuit diagram for the timepiece which includes a stop-watch arrangement in accordance with the invention.

Referring now to FIG. 1 of the drawing, the major components of the timepiece are a timekeeping standard constituted by a tuning fork **10** and an electronic drive circuit **11** therefor, and a rotary movement **12** of conventional design including a gear train for turning the hands of the timepiece, which may be a clock, a watch or any other timing mechanism, such as a time-delay switch. Because of the exceptional accuracy of the device, a switching action may be caused to occur within predetermined months, days, hours or minutes, or fractions thereof, spaced from a given starting instant. The gear train is driven by means of a pawl **13** connected to one tine of the fork and engaging a ratchet wheel **14** coupled to the rotary movement. The tuning fork has no pivots or bearings and its timekeeping action is therefore independent of the effects of friction.

Tuning fork **10** is provided with a pair of flexible tines **15** and **16** interconnected by a relatively inflexible base **17**, the base having an upwardly-extending stem **18** secured to the pillar plate of the timepiece 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 first and second transducers T_1 and T_2. Transducer T_1 is constituted by a magnetic element **21** secured to the free end of tine **15**, the element coacting with a drive coil **22** and a pick-up or phase sensing coil **23**. The two coils are wound on an open-ended tubular carrier **24** affixed to a sub-assembly mounting form secured to the pillar plate. The second transducer T_2 includes a magnetic element **25** secured to the free end of tine **16** and coacting with a drive coil **26** wound by a tubular carrier **27**.

The electronic drive circuit **11** comprises a transistor **28**, a single-cell battery **29** and an R-C biasing network formed by condenesr **30** shunted by resistor **31**. Transistor **28** which may be of the germanium junction PNP type, is provided with base, emitter and collector electrodes designated B, E and C, respectively.

The base B is coupled through the R-C network **30–31** to one end of phase-sensing coil **23**, the other end of which is connected to one end of drive coil section **22**. The main drive coil section **26** is connected in series with drive coil section **22** to collector electrode C of the transistor.

Emitter E is connected to the positive terminal of battery **29**, the negative terminal thereof being connected to the junction of drive coil **22** and phase-sensing coil **23**. Thus battery **29** is connected serially through both drive coils **22** and **26** between the emitter and collector of the transistor, the collector being negative relative to the emitter. Battery **20** should be of the type providing a highly stable voltage (i.e., 1.3 volts) for almost the full duration of its usable life.

The interaction of the electronic drive circuit **11** 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 operation, an energizing pulse applied to the drive coils of the transducers will cause an axial thrust on the associated magnetic element in a direction determined by the polarity of the pulse in relation to the polarization of the permanent magnet therein and to an extent depending on the energy of the pulse. Since

the magnetic element is attached to a tine of the tuning fork, the thrust on the element acts mechanically to excite the fork into vibration.

The resultant movement of the magnetic element relative to the fixed coils induces a back e.m.f. in the drive coils and in the case of transducer T_1, in the phase-sensing coil as well. Since the magnetic element reciprocates in accordance with the fork motion, the back e.m.f. will take the form of an alternating voltage whose frequency corresponds to the fork frequency. The voltage picked up by the sensing coil is applied to the base of the transistor to control the instant during each cycle when the driving pulse is to be delivered to the drive coils. The behavior of the drive circuit is more fully explained in my earlier patent, above identified.

The two transducers are of like design except that transducer T_1 includes a phase-sensing coil **23** as well as a drive coil **22**. The construction and behavior of the transducers is similar to that of a dynamic permanent magnet speaker, save that the moving element is the magnet and not the coil.

In the circuit shown in FIGS. 1 and 2, the arrangement is of the grounded emitter type. In the alternative circuit shown in FIG. 3, the circuit is of the grounded collector type and makes use of a silicon high common emitter connection current amplification factor transistor amplifier **32**. The advantage of the silicon transistor over the germanium type is that it is free of leakage current and works well from −60° C. to 100° C. with a power efficiency of 75% or more. This reduces the power consumption of the timepiece and also makes it operative in extremely hot and cold climates without loss of accuracy.

A very reliable start and stop feature can be incorporated in this circuit by the use of two silicon diodes **33** and **34** interposed between the negative terminal of battery **29** and drive coil **26**, the diodes being serially connected and shunted by an on-off switch **35**.

In the event the battery voltage applied to the transistor is lowered, a point will be reached at which the resultant amplitude of the fork operation and pawl movement is insufficient to advance the ratchet wheel, even though the fork still vibrates. Assuming that the diodes each have a knee voltage of .4 volt, in series the diodes will begin to conduct at .8 volt. With switch **35** open (stop postion), the voltage applied to the transistor oscillator is the battery voltage (1.32) minus .8 volt, which will ordinarly reduce the amplitude below the normal amount to a level at which the ratchet wheel will no longer be driven. When the switch is closed, the diodes are shunted out and normal operation is resumed.

Thus the operation of the fork is not arrested when stopping the watch but is only diminished somewhat in amplitude. The gear train, however, is decoupled from the tuning fork.

While there has been shown a preferred embodiment of the invention, it will be appreciated that many modifications may be made therein without departing from the essential spirit thereof expressed in the annexed claims.

What I claim is:

1. In an electronic timepiece provided with a tuning fork and gearworks for operating time indicators, said gearworks having a ratchet wheel which is actuated by a pawl engaging the teeth thereof and attached to one tine of said fork whereby as said pawl reciprocates said wheel is caused to turn; an electronic circuit for sustaining the vibrations of said tuning fork and comprising:

(A) a voltage source having a predetermined potential value,

(B) a transistor having a control element,

(C) an electromagnetic drive coil operatively coupled to said tuning fork and electrically connected to said source through said transistor to apply actuating pulses to said fork to sustain vibratory motion thereof when said transistor is rendered periodically conductive, the amplitude of fork vibration being a function of the potential of said source;

(D) an electromagnetic pickup coil operatively coupled to said tuning fork and electrically connected to the control element of said transistor to derive control pulses from said tuning fork at a rate determined by the vibratory rate thereof and to apply said control pulses to said control element to render said transistor periodically conductive; and

(E) means including a switch to reduce the potential of said source below its predetermined value to a degree lowering the amplitude of fork vibration to a point insufficient to drive said ratchet wheel, whereby the timepiece action is stopped while said fork remains in vibration.

2. In a timepiece as set forth in claim **1**, wherein said transistor is of the silicon type.

3. In a timepiece as set forth in claim **1**, wherein said voltage source is a battery having a highly stable output for substantially the full duration of its useable life.

4. In a timepiece as set forth in claim **1**, wherein said transistor includes base, emitter and collector electrodes, the control voltage being applied to said base electrode while the collector and emitter electrodes are serially connected with said voltage source and said drive coil.

5. In a timepiece as set forth in claim **1**, wherein said switch is interposed between said drive coil and said voltage source and is shunted by a unidirectional device whereby when said switch is closed the device is shorted out and the full potential of said source is applied, whereas when said switch is opened, the potential is dropped by said device to the point insufficient to effect actuation of said ratchet wheel.

6. In a timepiece as set forth in claim **5**, wherein said unidirectional device is constituted by two silicon diodes connected in series.

No references cited.

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