United States Patent

Imahashi

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[54] ELECTRIC TIMEPIECE

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[52] **U.S. Cl.**.....**58/23,** 310/8.1, 331/109, 331/182

[51] **Int. Cl.**.....**G04c 3/00,** H04r 17/00, H03b 3/02

[58] **Field of Search**.....58/23, 23 A, 23 V, 23 TF; 331/109, 182; 310/8.1

[56] **References Cited**

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Assistant Examiner—Edith C. Simmons
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[57] **ABSTRACT**

An electric timepiece having a vibrator, electrostrictive elements for energizing a vibrator and detecting the vibration thereof, and a driving circuit for energizing the vibrator the impedance of which is changed to keep the amplitude of vibrations constant when such vibrations exceed a desirable predetermined value.

6 Claims, 4 Drawing Figures

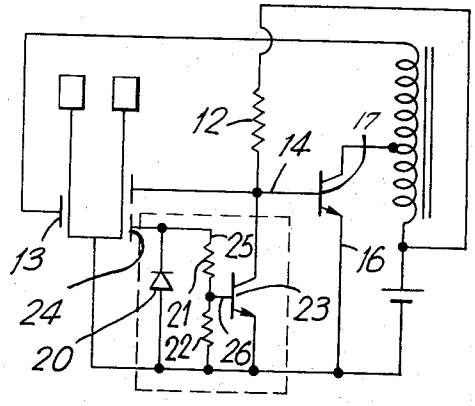
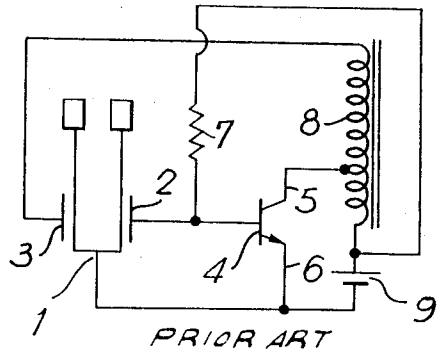


FIG. 1



PRIOR ART

FIG. 2

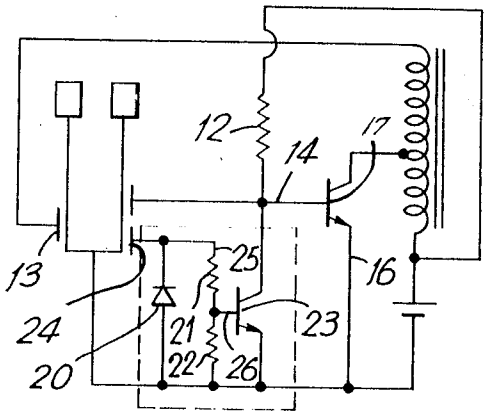


FIG. 3

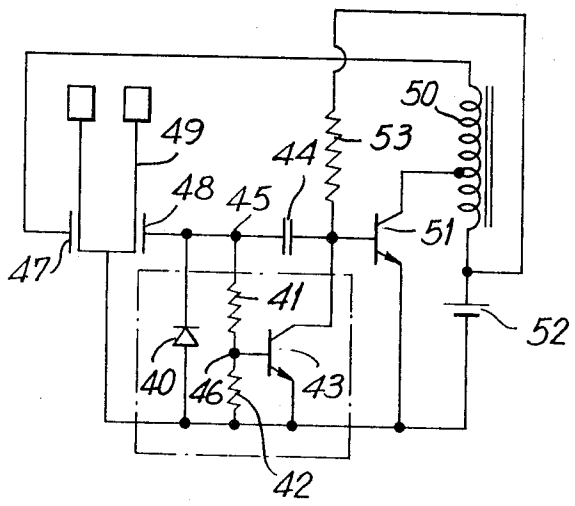
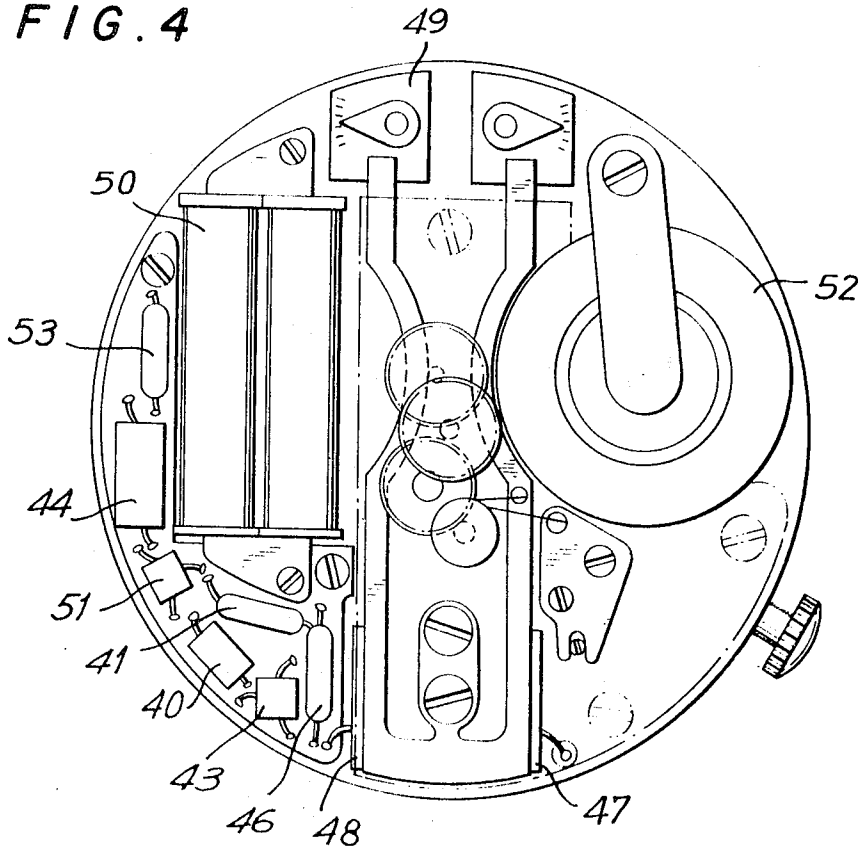

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FIG. 4


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ELECTRIC TIMEPIECE

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 shows an oscillating circuit of the conventional type of electrostrictive vibrator;

FIG. 2 shows an oscillating circuit of the electrostrictive vibrator according to the invention;

FIG. 3 shows another embodiment of the oscillating circuit of the electrostrictive vibrator according to the invention;

FIG. 4 shows a schematic view of an electric watch including an electrostrictively driven tuning fork according to the invention.

DETAILED DESCRIPTION OF THE INVENTION

The present invention relates to an electric timepiece wherein a mechanical vibrator is electrostrictively driven and its oscillating phase is detected electrostrictively.

An object of the present invention is to provide an electric timepiece wherein the amplitude of the mechanical vibrator is maintained relatively constant independent of the outer disturbance and variation of the load applied to the vibrator.

Up to the present time oscillating circuits for electrostrictive vibrator as shown in FIG. 1, have been known. In FIG. 1, 1 is a mechanical vibrator; 2 a detecting electrode for electrostrictively detecting oscillating phase; 3 a driving electrode for electrostrictively driving the vibrator. Furthermore, 4, 5, and 6 are base, collector and emitter of the transistor respectively. Also, 7 is a leak resistance of the base; 8 a step-up transformer, and 9 a dry cell.

Generally in an electrostrictively driven mechanical vibrator, it is necessary to apply constant current through the driving electrode to control the amplitude within a desirable predetermined value. In other words, it is necessary to drive the oscillator at constant current. For the above purpose a circuit for reversing the impedance from constant voltage to constant current is required to be connected between the driving source and the vibrator. Said circuit comprises such passive elements as an inductance coil and capacitor and is connected between the driving source and the driving electrode of the vibrator.

When the vibrator is driven by the oscillating circuit as shown in FIG. 1, the amplitude of the vibrator is unstable, and changes greatly due to the change of the load applied to the vibrator. The amplitude variation of a mechanical vibrator is caused by the variation of the load applied to the vibrator and the shock applied from the outside. In order to keep the amplitude of the vibrator constant under this condition, it is necessary to detect amplitude variation of the vibrator to control the phase difference between oscillating phase and driving phase and/or driving energy of the vibrator. That is to say, constant current is applied through the vibrator by controlling impedance. The oscillating circuit of this type oscillates relative to the vector composed of the inductances, capacitances and resistances of the mechanical vibrator and driving circuit respectively. By controlling any of these components, the compound vector varies. As a result, impedance of the driving circuit varies. Therefore, by controlling any component in the driving circuit for a vibrator, oscillation is maintained constant. The driving element may be used in connection with the control element or they may be provided independently. In the former case, if the driving element is non-linear, it is possible to form an oscillating control circuit sensitive to outer disturbance. Generally, the driving circuit may be constituted by providing a control element sensitive to amplitude variation of the vibrator and suitable for controlling impedance of the driving circuit, in addition to the driving element.

A first embodiment of the oscillating system according to the invention comprises a control circuit formed by diode, resistor and transistor and a driving circuit formed by a transistor, coil, resistor and condenser.

In the embodiment shown in FIG. 2, a special circuit is added to the ordinary oscillating circuit to oscillate the oscillator at constant amplitude.

The present invention provides means to short-circuit between the base and emitter of the driving transistor when the voltage exceeds a desirable predetermined value in order to prevent the amplitude from increasing. When the amplitude of the vibrator decreases due to external disturbance, the driving phase shifts so that high efficiency driving energy is supplied to the vibrator and increases the amplitude of said vibrator. The part encircled by the dotted line in the figure performs the operation of keeping the amplitude constant. The part outside of the dotted line, functions similarly to the one shown in FIG. 1. Without the circuit encircled in the dotted line, the electric circuit operates quite the same as in FIG. 1, with no operation for keeping the amplitude constant.

Referring now to the circuit shown in FIG. 2, 24 is a detecting electrode that detects the amplitude and 12 is a leak resistor of the driving transistor. In the electrode of this electrostrictive material, the voltage is induced in proportion to the amplitude of the vibrator. If the amplitude of the vibrator increases and a negative peak voltage at point 25 exceeds over 0.7V, current flows through the silicon diode 20 and charges electrostatic capacity in the detecting electrode 24 for controlling the amplitude. As a result, the average voltage at point 25 increases. The voltage at point 25 is divided by the resistors 21 and 22 and induced at point 26. Current is applied through the silicon transistor 23 when the positive peak voltage at point 26 exceeds 0.7V. In other words, if the voltage induced in the detecting electrode proportional to the amplitude exceeds the predetermined value, current is applied through the transistor 23. As a result, base 14 and emitter 16 of the transistor 17 are short-circuited, and the driving electrode 13 steps down abruptly and the amplitude does not increase. When the amplitude of the vibrator decreases die to outer disturbance, current does not flow through the transistor 23. Thus the transistor 17 is switched on and sufficient current flows to apply sufficient driving voltage to the driving electrode 13 and the amplitude increases.

FIG. 3 shows another embodiment of the oscillating circuit according to the invention. In this embodiment, it is so designed that the detecting electrode for maintaining the oscillation and the detecting electrode for controlling the amplitude are common. The operating principle is similar to the example shown in FIG. 2. 40 is a diode for maintaining the induced voltage at point 45 constant. Also, 41 and 42 are divider resistors for maintaining the voltage at point 46 constant. Also, 43 is a transistor that is switched on when the amplitude exceeds the predetermined value. Furthermore, 44 is a condenser for cutting off the DC component. Condenser 44 controls the amplitude of the vibrator by controlling the driving phase of the vibrator in the following manner. The electrostrictively driven vibrator is driven in normal condition with a minor deviation from the best driving phase condition. When the load is applied to the vibrator, said vibrator is driven in a condition where the highest efficiency is attainable.

FIG. 4 shows a schematic view of an electric watch having the electrostrictively driven tuning fork as a time standard. Also, 47 is an electrostrictive element that drives the tuning fork 49. Also 48 is an electrostrictive element that detects the vibration of the fork. Also, 50 is a step-up transformer coil. Also, 51 is a driving transistor that maintains the oscillation of the vibrator. Furthermore, 52 is a dry cell.

Although in the conventional method, it is difficult to drive an electrostrictive vibrator at constant current and to keep the amplitude constant, the present invention solves this prior art problem and provides a controlling circuit for an electrostrictive vibrator which operates to decrease the amplitude when it exceeds a predetermined value and no control power is applied to the vibrator in normal condition. In the conventional type of electromagnetically driven vibrators, fabrication of the magnets and coils is not easy. On the other hand, it is possible to make thin watches of simplified construction using the electrostrictive watch according to our invention, which watch is made by pasting electrostrictive element with adhesives.

What is claimed is:

1. An electric timepiece having gear trains comprising, a time standard vibrator coupled to said gear trains for the direct driving thereof; an electrostrictive element coupled to said vibrator for driving said vibrator; and electrostrictive element coupled to said vibrator for detecting the vibration of said vibrator; a driving circuit for driving said vibrator including each of said electrostrictive elements; and control means provided on the input side of said driving circuit for controlling the operation of said driving circuit and for cutting off said driving circuit when the amplitude of vibrations of said vibrator reaches a predetermined level, said control means including detecting circuit means incorporating said detecting electrostrictive element and rectifying means connected to said detecting electrostrictive element, said control means being operative in response to the output of said rectifying means.

2. An electric timepiece comprising a vibrator; an electrostrictive element coupled to said vibrator for driving said vibrator; driving means for driving said vibrator including a driving transistor and said driving electrostrictive element; control means including a control transistor and a rectifying diode coupled to said vibrator for producing a signal responsive to the amplitude of vibrations of said vibrator, said rectifier diode being coupled to said control transistor for switching said control transistor to prevent the driving of said vibrator by said driving means when the amplitude of said vibrator reaches a predetermined value.

3. An electric timepiece as recited in claim 2, wherein the collector and emitter electrodes of said control transistor are connected to the base and emitter electrodes of said driving transistor; said timepiece including an electrostrictive element coupled to said vibrator for detecting the vibration of said vibrator coupled to the input terminal of said control transistor, said rectifying diode being connected between said detecting electrostrictive element and the emitter electrode of said control transistor.

4. An electric timepiece as recited in claim 3, including a condenser connected between said detecting electrostrictive element and the base electrode of said driving transistor, whereby said detecting electrostrictive element serves to maintain the oscillation of the vibrator.

5. An electric timepiece as recited in claim 3, including divider means, said detecting electrostrictive elements being connected to said input terminal of said control transistor through said divider.

6. An electric timepiece having gear trains comprising, a time standard tuning fork coupled to said gear trains for the direct driving thereof; an electrostrictive element coupled to said tuning fork for driving said tuning fork; an electrostrictive element coupled to said tuning fork for detecting the vibration thereof; a driving circuit having a driving transistor coupled to said driving electrostrictive element for driving said tuning fork; a control transistor connected between the base and emitter of said driving transistor; a leak resistor for supplying base bias voltage to said driving transistor; a condenser for regulating the driving phase of said tuning fork, said condenser being connected between said detecting electrostrictive element and a base electrode of said driving transistor; a battery; a transformer coil connected between the collector electrode of said driving transistor and said battery; a divider connected between said detecting electrostrictive element and the input terminal of said control transistor for dividing the detected voltage to supply a control signal to said control transistor; and a diode connected between said detecting electrostrictive element and an emitter electrode of said control transistor for controlling the operation of said control transistor to cut off driving of said tuning fork when the amplitude of vibration thereof reaches a predetermined level.

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