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(54) METHOD OF AND SYSTEM FOR DETERMINING THE RATE OF AN ELECTRONIC TIMEPIECE

(71) We, CITIZEN WATCH CO., LTD., a Japanese corporate body of 1-9-18, Nishi-shinjuku, Shinjuku-ku, Tokyo, Japan, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to a method of, and a system for, determining the operating speed or rate of an electronic timepiece which has a time indicator which makes use of an electro-optical display element such as a liquid-crystal, light emitting diode or the like.

The art of chronometry has developed from a mechanical watch, using a spring as its power source, to a battery-powered watch comprising an electromagnetically driven tuning fork or hairspring balance, and to a time piece comprising a crystal oscillator which can generate a high-frequency signal as a time standard. There has also been developed a totally electronic watch which makes use of an electro-optical display element such as a liquid-crystal or light emitting diode or the like as a time indicator and does not have any moving parts at all.

In the prior art systems for determining the rate of a mechanical watch, the sounds produced by oscillations or impacts of an oscillating body incorporated in the watch, i.e. its ticks, are detected acoustically by means of a microphone positioned outside of the watch case. In a conventional system for determining the rate of a watch controlled by a tuning fork, having a relatively high oscillating frequency and low ticks, or an electromagnetic driven watch whose clockwork does not produce ticks, the generated magnetic leakage flux is electromagnetically detected by means of a monitoring coil positioned outside the watch case.

In the totally electronic watch which does not produce any tick nor is there any magnetic leakage flux, it is impossible to measure the rate of the watch acoustically or electromagnetically. In this case, it is known to provide a lead extending through the watch

case to deliver a rate signal to an external speed sensor. This conventional method, however, has the disadvantages that a circuit incorporated within the watch case is liable to be subjected to outside disturbances, that the monitoring lead occupies additional space, and that the watch must be connected by way of a conductor to the speed sensor every time the rate measurement is to be carried out. Thus, this prior art method is unsuitable for testing watches on a large scale.

An object of the present invention is to provide an improved method of and a system for, determining the operating speed of an electronic timepiece whose visual indicator is an electro-optic display element, excited by an applied alternating voltage of fixed frequency and is stepped at a rate harmonically related to that frequency.

According to a first aspect of the present invention a method of determining the operating speed of an electronic timepiece having an electro-optical time indicator, which is periodically stepped at a rate harmonically related to a fixed exciting frequency applied to an electrode of the indicator, comprises the steps of capacitively picking up said exciting frequency by a conductive plate juxtaposed with the electrode, converting the frequency so picked up into a pulse train and measuring the recurrence rate of the pulses of the train.

According to a second aspect of the invention a system for determining the operating speed of an electronic timepiece having an electro-optical time indicator which is periodically stepped at a rate harmonically related to a fixed exciting frequency applied to an electrode of the indicator, comprises a conductive plate arranged to be positioned in juxtaposed relation with the electrode of such a timepiece for defining therewith a coupling capacitance, a resistance connected to said capacitance for developing thereacross a voltage which is in step with the voltage applied to the electrode, amplifier means connected to receive the developed voltage and rate measuring means connected to said amplifier means.

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In order that the invention may be more readily understood it will now be described by way of example only, with reference to the accompanying drawing in which:—

5 Figure 1 shows schematically an embodiment of a speed sensing system for an electronic watch having a liquid-crystal display cell;

10 Figure 2 is a graphic representation of the phase relationship between a voltage wave driving the liquid-crystal cell shown in Figure 1 and a detected pulse train;

15 Figure 3 is a block diagram of the circuit arrangement of a crystal-oscillator type watch which employs the liquid-crystal display cell shown in Figure 1;

Figure 4 schematically illustrates details of the speed sensor shown in Figure 1; and

20 Figure 5 is a graphic representation of a train of voltage pulses detected by the system shown in Figure 4.

In Figure 1 is shown a speed-sensing system applied to a watch having a liquid-crystal display cell. A form of the liquid-crystal cell comprises two parallel glass substrates 1a and 1b provided on their inner surfaces with electrodes 2a and 2b respectively, forming a gap therebetween. Between the electrodes 2a and 2b is sandwiched a liquid-crystal substance 3. The upper electrode 2a is transparent. If an electric field is applied across the two electrodes 2a and 2b, the liquid-crystal substance 3 is electro-optically modulated to display letters or figures in response to the electrode pattern.

35 In general, the electric field applied across the electrodes 2a and 2b is an alternating voltage of the order of several volts to several tens of volts as determined by taking the life of the liquid-crystal into consideration and is a square wave 5 obtained from an electric power source 4 as shown in Fig. 2.

45 In accordance with the invention, we mount a metal plate 6 near the liquid-crystal cell parallel to exciting electrode 2a and spaced apart from its carrier plate 1a. The electrode 2b is directly connected to ground while the metal plate 6 is grounded through a terminal 8 and a resistor 7.

50 When the electric field is applied across the electrodes 2a and 2b, the potential of the electrode 2a changes from 0 to V as shown by the voltage wave 5 in Fig. 2, to electrostatically induce an electric charge on the metal plate 6. The resulting output voltage at the terminal 8 is a pulse train 9 having the waveform shown in Fig. 2.

60 Thus, the cell electrode 2a and the metal plate 6 constitute a capacitor having a very small capacitance through which the output of oscillator 4 is electrostatically transmitted to the resistor 7. As a result, the exciting voltage wave 5 is differentiated into the voltage wave 9. If the voltage wave 5 is a

square wave with steep flanks, the pulse amplitude of train 9 approaches the peak voltage V of wave 5.

The wave form 9 depends upon the time constant determined by the capacitance of the electrode and plate 6 and by the magnitude of resistor 7. If this time constant is very small compared with the period of the voltage wave 5, the voltage wave 9 becomes a series of sharp spike pulses.

70 The capacitance can be of the order of 0.01 to 1 pF and the value of the resistor 7 can be of the order of 1 to 100 MΩ, which can be easily realised.

Owing to the high impedance, electrostatic coupling between the resistor 7 and the oscillator 4 through a capacitance of not more than 1 pF ensures that only a small load current is drawn from the oscillator 4 whose stability, therefore, is not degraded. In addition, the liquid-crystal display cell is not adversely affected by the presence of a large shunt capacitance.

80 Experimental tests have shown that if the peak voltage delivered by the oscillator 4 is 5 V, the dimension of the metal plate 6 is 5 mm × 5 mm × 0.3 mm (thickness) and the gap between the electrode 2a and the metal plate 6 is at least 2mm, then the capacitance of members 2a and 6 is of the order of 0.1 pF, and that if the value of the load resistor 7 is 1 MΩ, the peak output voltage at the terminal 8 is 50 mV. In Fig. 1, reference numeral 10 designates an amplifier and wave shaper.

100 In a watch whose clockwork comprises an oscillator controlled by a crystal or a tuning fork, the natural frequency of the crystal or the tuning fork determines the rate of the watch. The signal delivered to each digit position of the time indicator changes every second, minute or hour with a precision depending upon the stability of the oscillator frequency. The bipolar pulse train 9 of the same fundamental frequency triggers the amplifier 10 to allow rapid measurement of the rate of the watch.

105 In Fig. 3 we have shown an embodiment of the invention wherein an oscillator 21 is controlled by a crystal 22 and connected to deliver a stable alternating voltage to a first frequency divider 23. Reference numeral 24 designates a battery connected to operate as an electric power supply with an output of 1.5 V. The first frequency divider 23 has two outputs 25 and 26. The output 25, at a frequency of 64 Hz, is delivered to a second frequency divider 27 which feeds one pulse 28 per minute to a 7-segment decoder 29 from which a 7-segment digital display signal is delivered through a driver 30 to a liquid-crystal display cell 31. Thus, decoder 29 is stepped at a rate of $\frac{1}{60}$ Hz to change the pattern of energisation of display 31.

The output 26 at a frequency of 256 Hz, is delivered to a bootstrap type AC/DC converter 32 feeding a high direct current voltage 33 of 7 V to the second frequency divider 27, decoder 29 and driver 30, in parallel.

The second frequency divider 27 delivers an output signal 34 of 32 Hz to the driver 30 which supplies an alternating voltage of 7 V to the display cell 31. The exciting frequency of voltage 34 is therefore harmonically related to the stepping rate determined by the signal 28.

In Fig. 4 is shown a circuit arrangement which can detect the rate of a watch 40 of the form shown in Fig. 3. A metal plate 42 is arranged above a display window 41 of watch 40. A gap 43 between the display window 41 and the metal plate 42 has a width of up to 1 mm. The watch 40 and the metal plate 42 are surrounded by a simple electrostatic shield 44. In the present embodiment, sufficient electrostatic shielding effect is obtained by using a thin aluminium sheet as the enclosure 44.

The metal plate 42 is connected to an amplifier 45 including a junction-type field-effect transistor. A load resistor 46 connected to the electrostatic pick-up plate 42 has a magnitude of 1 M Ω and the dimensions of that plate are 5 mm $\times$ 5 mm $\times$ 0.3 mm (thickness). If the gap 43 is about 1 mm, the wave form 51 of the monitoring voltage developed across the resistor 46 is again a bipolar pulse train as shown in Fig. 5. The respectively picked up voltage has a peak amplitude 52 of 40 mV and a period 53 of 31,250 μ sec (32 Hz).

The output from the amplifier 45 is delivered through a wave shaper 47 to a 1/2^s frequency divider 48 by which the frequency is stepped down to a nominal value of 1 Hz. The output from the frequency divider 48 is delivered to a counter 49 which forms part of a conventional rate meter.

In a specific instance the deviation from the nominal frequency was found to be not more than 1×10^{-7} per 10 periods on the average. This stability, calculated in terms of daily difference corresponds to a gain or loss of at most 0.01 sec/day which is considered a sufficiently high degree of precision.

In another instance, metal plate 42 used as a monitoring electrode is replaced by a glass plate of 10 mm $\times$ 10 mm $\times$ 0.5 mm (thickness) and covered on one surface with a transparent electrically conductive film of SnO₂ which gives the same satisfactory results as the aforescribed arrangement. Moreover, the use of a transparent electrode plate 42 renders it possible to detect the rate of the watch 40 while reading the time displayed by its indicator.

The electro-optical display element used

as the time indicator of the electronic watch need not be a liquid-crystal cell. The invention may be applied to any other display elements driven by an electric field such, for example, as light emitting diodes, plasma displays, electro-chromic displays, electroluminescent displays and the like.

Because of its low energy consumption, the speed monitoring system according to the invention is simple in construction and precise in operation.

WHAT WE CLAIM IS:—

1. A method of determining the operating speed of an electronic timepiece having an electro-optical time indicator, which is periodically stepped at a rate harmonically related to a fixed exciting frequency applied to an electrode of the indicator, comprising the steps of capacitively picking up said exciting frequency by a conductive plate juxtaposed with the electrode, converting the frequency so picked up into a pulse train and measuring the recurrence rate of the pulses of the train.

2. A method of determining the operating speed of an electronic timepiece having an electro-optical time indicator which is periodically stepped at a rate harmonically related to a fixed exciting frequency applied to an electrode of the indicator, substantially as hereinbefore described with reference to the accompanying drawing.

3. A system for determining the operating speed of an electronic timepiece having an electro-optical time indicator which is periodically stepped at a rate harmonically related to a fixed exciting frequency applied to an electrode of the indicator, said system comprising a conductive plate arranged to be positioned in juxtaposed relation with the electrode of such a timepiece for defining therewith a coupling capacitance, a resistance connected to said capacitance for developing thereacross a voltage which is in step with the voltage applied to the electrode, amplifier means connected to receive the developed voltage and rate measuring means connected to said amplifier means.

4. A system as claimed in claim 3 wherein the capacitance and said resistance define a differentiation circuit with a time constant which is small compared to the period of said voltage applied to the electrode.

5. A system as claimed in claim 3 wherein the resistance has a magnitude of at least one megohm and in use the capacitance is up to 1 pF.

6. The combination of an electronic timepiece having an electro-optical time indicator which is periodically stepped at a rate harmonically related to a fixed exciting frequency applied to an electrode of the indicator and the system claimed in claim 3, 4 or 5.

The output 26 at a frequency of 256 Hz, is delivered to a bootstrap type AC/DC converter 32 feeding a high direct current voltage 33 of 7 V to the second frequency divider 27, decoder 29 and driver 30, in parallel.

The second frequency divider 27 delivers an output signal 34 of 32 Hz to the driver 30 which supplies an alternating voltage of 7 V to the display cell 31. The exciting frequency of voltage 34 is therefore harmonically related to the stepping rate determined by the signal 28.

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The output from the amplifier 45 is delivered through a wave shaper 47 to a 1/2nd frequency divider 48 by which the frequency is stepped down to a nominal value of 1 Hz. The output from the frequency divider 48 is delivered to a counter 49 which forms part of a conventional rate meter.

In a specific instance the deviation from the nominal frequency was found to be not more than 1×10^{-7} per 10 periods on the average. This stability, calculated in terms of daily difference corresponds to a gain or loss of at most 0.01 sec/day which is considered a sufficiently high degree of precision.

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Because of its low energy consumption, the speed monitoring system according to the invention is simple in construction and precise in operation.

WHAT WE CLAIM IS:—

1. A method of determining the operating speed of an electronic timepiece having an electro-optical time indicator, which is periodically stepped at a rate harmonically related to a fixed exciting frequency applied to an electrode of the indicator, comprising the steps of capacitively picking up said exciting frequency by a conductive plate juxtaposed with the electrode, converting the frequency so picked up into a pulse train and measuring the recurrence rate of the pulses of the train.

2. A method of determining the operating speed of an electronic timepiece having an electro-optical time indicator which is periodically stepped at a rate harmonically related to a fixed exciting frequency applied to an electrode of the indicator, substantially as hereinbefore described with reference to the accompanying drawing.

3. A system for determining the operating speed of an electronic timepiece having an electro-optical time indicator which is periodically stepped at a rate harmonically related to a fixed exciting frequency applied to an electrode of the indicator, said system comprising a conductive plate arranged to be positioned in juxtaposed relation with the electrode of such a timepiece for defining therewith a coupling capacitance, a resistance connected to said capacitance for developing thereacross a voltage which is in step with the voltage applied to the electrode, amplifier means connected to receive the developed voltage and rate measuring means connected to said amplifier means.

4. A system as claimed in claim 3 wherein the capacitance and said resistance define a differentiation circuit with a time constant which is small compared to the period of said voltage applied to the electrode.

5. A system as claimed in claim 3 wherein the resistance has a magnitude of at least one megohm and in use the capacitance is up to 1 pF.

6. The combination of an electronic timepiece having an electro-optical time indicator which is periodically stepped at a rate harmonically related to a fixed exciting frequency applied to an electrode of the indicator and the system claimed in claim 3, 4 or 5.



7. The combination of claim 6 wherein the indicator comprises a liquid crystal cell.
8. The combination as claimed in claim 6 wherein the plate and the electrode are both transparent.
5 9. A system for determining the operating speed of an electronic timepiece sub-

stantially as hereinbefore described with reference to the accompanying drawing.

BATCHELLOR, KIRK & EYLES,
Chartered Patent Agents,
100 Great Russell Street,
London WC1B 3LA.
For the Applicants.

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