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(54) ELECTRONIC TIMEPIECE

(71) We, KABUSHIKI KAISHA SUWA SEIKOSHA, a Japanese company of 3-4, 4-chome, Ginza, Chuo-ku, 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 electronic timepieces.

The major drawback of conventional electronic timepieces is that there is no clear indication when a driving battery thereof nears the end of its useful life. The life of the battery of some conventional electronic timepieces is between one and two years and the user tends to forget when he bought the electronic timepiece or when he last replaced the battery.

In other types of battery powered devices there may conventionally be provided a battery testing device for indicating the state of the battery at any given time. These known battery testing devices may comprise voltage sensors together with display devices. However, up till now it has not been suggested to provide a battery testing device in an electronic timepiece because of the difficulty in housing it in the limited space available especially if the battery testing device incorporates a moving coil meter or a light emitting diode.

According to the present invention there is provided an electronic timepiece comprising an oscillator for producing a time standard signal, a divider circuit for producing from the time standard signal a driving signal, a time display arrangement arranged to be driven by the driving signal to display a time indication, battery voltage sensing means for determining the output voltage of a battery arranged to power the timepiece, and control means responsive to the battery voltage sensing means for causing the or a part of the time display arrangement to indicate when the output voltage of the battery falls below a predetermined value.

Preferably said time display arrangement comprises an electro-mechanical converter, a gear train and at least one time indicating hand.

The control means may be arranged so that when the output voltage of the battery is above said predetermined value a seconds indicating hand is indexed one step after each one-second interval of time and when the output voltage of the battery falls below said predetermined value the seconds indicating hand is indexed two steps after each two-second interval of time.

In the preferred embodiment the electro-mechanical converter is a stepper-motor.

The invention is illustrated, merely by way of example, in the accompanying drawings, in which:—

Figure 1 is a circuit diagram of an electronic timepiece according to the present invention;

Figure 2 illustrates graphically the waveforms at various points in the circuit of Figure 1; and

Figure 3 shows graphically the voltage discharge characteristics of a battery of the timepiece of Figure 1.

Referring first to Figure 1 there is shown, in circuit diagram form, an electronic timepiece, for example a wristwatch, according to the present invention. An inverter I_1 , a quartz crystal vibrator X , a resistor R_1 , and capacitors C_1 , C_2 constitute a quartz crystal oscillator circuit which produces a standard time signal. The standard time signal is amplified by an inverter I_2 and fed to a clock terminal CL_1 of a D-type flip-flop circuit $F.F_1$ which forms part of a divider circuit consisting of a plurality (n) of D-type flip-flop circuits $F.F_1$, $F.F_2$, ..., $F.F_K$, ..., $F.F_n$, each of which acts as a binary counter, connected in cascade. If the time standard signal has a frequency of 32,768 Hz and if the divider circuit consists of 16 flip-flop circuits connected in cascade, the output signal from the divider circuit will have a frequency of $\frac{1}{2}$ Hz. The output signal from the divider circuit is fed to a pair of delay-type flip-flop circuits $F.F_{n+1}$, $F.F_{n+2}$ which produce a delayed output signal.

The output signals from the flip-flop circuit $F.F_K$, the flip-flop circuit $F.F_n$, the flip-flop circuit $F.F_{n+1}$ and the flip-flop circuit $F.F_{n+2}$ are illustrated in Figure 2 by wave-

forms Q_k , Q_n , Q_{n+1} and Q_{n+2} , respectively, in Figure 2.

A battery voltage sensing circuit is provided to detect change in the output voltage of a battery B which drives the electronic timepiece, the battery voltage sensing circuit comprising a Zener diode D, a transistor T and a resistor R.

The voltage discharge characteristics of the battery B are shown in Figure 3. When the threshold voltage V_{th} , determined by the Zener diode D and the base voltage of the transistor T, is lower than the output voltage of the battery B, a base current of the transistor T flows, and the collector potential P thereof becomes relatively low. When the battery nears the end of its useful life, the output voltage of the battery B falls below the threshold voltage V_{th} , the base current to the transistor T ceases to flow and the collector potential P becomes relatively high (see waveform P in Figure 2).

Inverters I_3 , I_4 , I_5 , and gate circuits O_1 , O_2 , A_1 , A_2 , A_3 , connected as shown in Figure 1, produce from the delayed output signal from the flip-flop circuits $F.F_n$, $F.F_{n+1}$, $F.F_{n+2}$, under the control of the collector potential P of the transistor T, driving signals. A waveform of these driving signals, when the collector potential P is relatively low, is different from the waveform of the driving signals when the collector potential P is relatively high. The driving signals from the inverter I_5 and the gate circuit A_3 are shown by waveforms q and r respectively in Figure 2.

Inverters I_7 and I_8 act as a buffer amplifier circuit for obtaining a relatively large value motor driving current from the driving signals from the inverter I_5 and the gate circuit A_3 , the motor driving current flowing through a driving coil L of a stepper motor having a stator S and a permanently magnetised rotor R. The motor driving current is illustrated by a waveform i in Figure 2. Rotation of the rotor R by the motor driving current causes a wheel W engaged with the rotor to rotate. A seconds hand H secured to a shaft (not shown) of the wheel W, is rotated in consequence.

Since the output signal from the divider circuit has a frequency of $\frac{1}{2}$ Hz, when the collector potential P is relatively low, i.e. the battery B produces an output voltage above the threshold voltage V_{th} , the motor driving current flowing through the coil L consists of alternate positive and negative pulses, one pulse appearing each second as shown in the left hand portion of the waveform i in Figure 2. Accordingly, the rotor R which in this example has six magnetic poles, is rotated by each pulse to 60° . Assuming a gear ratio between the rotor R and the wheel W of 1:10, the seconds hand H is indexed one

step each one-second interval of time. When the output voltage of the battery B falls below the threshold voltage V_{th} , the collector potential P of the transistor T becomes relatively high. As a result, the motor driving current consists of a positive pulse and an immediately succeeding negative pulse occurring every two seconds as shown by the right hand portion of the waveform i in Figure 2. Accordingly, the rotor R is rotated through 120° every two seconds and the seconds hand H is indexed two steps after each two-second interval of time. Whilst the correct time is always indicated, when the battery begins to reach the end of its useful life, this becomes apparent to the user of the timepiece by virtue of the movement of the seconds hand. The electronic timepiece can be made so that the seconds hand is indexed two steps after each two-second interval of time for the last several days to last several dozen days of the useful life of the battery thus giving the user plenty of time to replace the battery. It will be appreciated that the above described electronic timepiece has the advantage that a very distinct display of when the battery is reaching the end of its useful life is given and the necessary circuitry takes up a relatively small space.

It will be appreciated that the present invention may be applied to other types of electronic timepiece and, in particular, resides basically in the use of an existing display device which displays the or a part of the time indication also to give an indication when the battery nears the end of its useful life.

WHAT WE CLAIM IS:—

1. An electronic timepiece comprising an oscillator for producing a time standard signal, a divider circuit for producing from the time standard signal a driving signal, a time display arrangement arranged to be driven by the driving signal to display a time indication, battery voltage sensing means for determining the output voltage of a battery arranged to power the timepiece, and control means responsive to the battery voltage sensing means for causing the or a part of the time display arrangement to indicate when the output voltage of the battery falls below a predetermined value.

2. An electronic timepiece as claimed in claim 1 in which said time display arrangement comprises an electro-mechanical converter, a gear train and at least one time indicating hand.

3. An electronic timepiece as claimed in claim 2 in which the control means is arranged so that when the output voltage of the battery is above said predetermined value a seconds indicating hand is indexed one step after each one-second interval of time

forms Q_k , Q_n , Q_{n+1} and Q_{n+2} , respectively, in Figure 2.

A battery voltage sensing circuit is provided to detect change in the output voltage of a battery B which drives the electronic timepiece, the battery voltage sensing circuit comprising a Zener diode D, a transistor T and a resistor R.

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Inverters I_3 , I_4 , I_5 , and gate circuits O_1 , O_2 , A_1 , A_2 , A_3 , connected as shown in Figure 1, produce from the delayed output signal from the flip-flop circuits FF_n , FF_{n+1} , FF_{n+2} , under the control of the collector potential P of the transistor T, driving signals. A waveform of these driving signals, when the collector potential P is relatively low, is different from the waveform of the driving signals when the collector potential P is relatively high. The driving signals from the inverter I_5 and the gate circuit A_3 are shown by waveforms q and r respectively in Figure 2.

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2. An electronic timepiece as claimed in claim 1 in which said time display arrangement comprises an electro-mechanical converter, a gear train and at least one time indicating hand.
3. An electronic timepiece as claimed in claim 2 in which the control means is arranged so that when the output voltage of the battery is above said predetermined value a seconds indicating hand is indexed one step after each one-second interval of time



(D)

and when the output voltage of the battery falls below said predetermined value the seconds indicating hand is indexed two steps after each two-second interval of time.

5 4. An electronic timepiece as claimed in claim 2 or 3 in which the electro-mechanical converter is a stepper-motor.

5. An electronic timepiece substantially

as herein described with reference to and as shown in the accompanying drawings.

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