

PATENT SPECIFICATION

(11) 1 475 841 (9)

1 475 841

- (21) Application No. 16589/75 (22) Filed 22 April 1975
 (31) Convention Application No. 49/046248 (32) Filed 24 April 1974
 (31) Convention Application No. 49/080932 (32) Filed 15 July 1974 in
 (33) Japan (JA)
 (44) Complete Specification published 10 June 1977
 (51) INT CL³ G04C 3/00
 (52) Index at acceptance
 G3T A5X



(54) AN ELECTRONIC TIMEPIECE

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

At present electronic timepieces, for example quartz crystal timepieces, on the market are rarely provided with means for displaying when the useful life of a driving battery thereof is about to expire. Accordingly, the battery is changed when it is presumed to be about to expire and often the only time when the user realises that the battery requires replacement is when the timepiece actually stops.

There is, however, on the market a quartz crystal timepiece with a battery life display device but this is driven by a separate battery.

According to one aspect of the present invention, there is provided an electronic timepiece comprising a time standard means for producing a time standard signal, driving circuitry for producing from the time standard signal driving signals, display means arranged to be driven by the driving signals, and battery voltage detecting means, including a field effect transistor and at least one resistor, for detecting when the output voltage of a battery driving the timepiece falls below a predetermined voltage.

The battery voltage detecting means preferably includes selecting means for setting the said predetermined voltage.

Said selecting means may comprise a load resistor of the field effect transistor, said load resistor being selected to detect a fall of battery voltage below the desired predetermined voltage. Alternatively, said selecting means may comprise a potential divider for varying the voltage applied to the gate of the field effect transistor.

The field detector transistor may form part

of an integrated circuit chip which also includes the or a part of the driving circuit.

In one embodiment the electronic timepiece includes a memory circuit for memorising the output of the battery voltage detecting means.

Preferably, said battery voltage detecting means is arranged to detect the battery voltage at periodic intervals. Thus the arrangement may be such that the battery voltage is not detected when driving signals are or are about to be generated.

Means may be provided to modify the display produced by the display means when the voltage detecting circuit detects that the battery voltage has fallen below said predetermined voltage. The time standard means may be a quartz crystal oscillator.

According to a further aspect of the present invention there is provided an electronic timepiece including a time standard, electronic circuitry, display means, a power source battery and battery voltage detecting circuitry for detecting the voltage of said power source battery, said battery voltage detecting circuit consisting of a first stage having an enhancement type MOS.FET and a resistor, said enhancement type MOS.FET being arranged in such a way that the voltage of said power source battery or a voltage related thereto is applied between the gate and the source and the load resistor is connected as a drain load, and a second stage having at least an enhancement type MOS.FET inverter whose input is connected to the drain or load resistor of said first stage portion.

The display means, in the preferred embodiment, includes a seconds hand which is advanced stepwise, the battery voltage detecting circuit, in operation, modifying the advancement of the seconds hand when the battery voltage has fallen below said predetermined voltage, the battery voltage detecting circuit being arranged to detect the output voltage of the battery in between the steps of the modified advancement of the seconds hand.

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

50

55

60

65

70

75

80

85

90

95

Figure 1 is an explanatory circuit diagram illustrated in the use of a field effect transistor as a battery voltage detector;

Figure 2 illustrates graphically the relationship between the battery voltage E_1 of the battery and the voltage E_2 across a resistor of the circuit illustrated in Figure 1;

Figure 3 is a circuit diagram of one embodiment of a battery voltage detecting circuit for an electronic timepiece according to the present invention;

Figure 4 shows graphically load characteristic curves of the battery voltage detecting circuit of Figure 3;

Figure 5 shows graphically the relationship between battery voltage E and drain voltage V_D for various low resistances for the battery voltage detecting circuit of Figure 3;

Figure 6 is a circuit diagram of the second embodiment of a battery voltage detecting circuit for an electronic timepiece according to the present invention;

Figure 7 is a circuit diagram of a third embodiment of a battery voltage detecting circuit for an electronic timepiece according to the present invention;

Figure 8 is an explanatory circuit diagram illustrating a battery voltage detecting circuit;

Figure 9 illustrates graphically the relationship between battery voltage E_1 and the voltage E_2 across a resistor and a voltage E_3 between source and drain the field effect transistor of the circuit illustrated in Figure 8;

Figure 10 is a circuit diagram of an electronic timepiece, for example, a quartz crystal timepiece according to the present invention; and

Figure 11 is a timing chart illustrating operation of the electronic timepiece of Figure 10.

In the drawings like parts have been designated by the same reference numerals.

Figure 1 is an explanatory diagram illustrating the use of a field effect transistor as a battery voltage detector. The battery voltage detector as shown in Figure 1 comprises a battery 1 as a variable voltage power source, an enhancement type P. MOS transistor 2 and a load resistor 3.

Figure 2 illustrates graphically the relationship between the battery voltage E_1 of the battery 1 and the voltage E_2 across the resistor 3. When the battery voltage E_1 is greater than the threshold voltage V_{TH} of the transistor 2, the voltage E_2 is equal to the voltage E_1 because the transistor 2 is conductive. As the battery voltage approaches the threshold voltage V_{TH} , the voltage E_2 rapidly decreases because the transistor 2 is changing from being conductive to being non-conductive. When the battery voltage E_1 is less than or equal to the threshold voltage

V_{TH} the voltage E_2 is zero because the transistor 2 is non-conductive.

The change of the transistor 2 from being conductive to being non-conductive can be used to indicate the fall of the battery voltage below a predetermined voltage set by the threshold voltage V_{TH} of the field effect transistor. However, it is difficult to predetermine the threshold voltage V_{TH} of the transistor 2 and if the transistor 2 is formed as part of an integrated circuit which includes other circuitry, it is difficult to change the threshold voltage of the transistor 2. Accordingly, the transistor 2 must be independent and cannot form part of an integrated circuit which includes other circuitry. Thus a battery voltage detector such as illustrated in Figure 1 has poor operational efficiency because the threshold voltage of the transistor 2 cannot be accurately matched to battery voltage requirements and consequently it is limited in its practical applicability.

Figure 3 is a circuit diagram of one embodiment of a battery voltage detecting circuit for an electronic timepiece according to the present invention. The battery voltage detecting circuit comprises a battery 11, an enhancement type P. MOS transistor 12, a variable resistor 14 and an inverter 15, these components being connected as illustrated. The battery 11 is shown as a variable power supply for the convenience of illustration. The transistor 12 changes from being conductive to non-conductive when the battery voltage falls below a predetermined value.

Figure 4 shows graphically load characteristic curves of the battery voltage detecting circuit of Figure 3. In Figure 4 the abscissae represents the voltage V_{DS} between drain and source of the transistor 12 and also the battery voltage E of the battery 11, and the ordinate represents the drain current I_D of the transistor 12. Curves A_1 to A_6 show $V_{DS}-I_D$ characteristics for a plurality of gate voltages V_G from 1.0V to 1.5V. Lines B_1 to B_6 are load lines obtained by establishing a drain voltage V_D of 0.7V for each value of the battery voltage of 1.0V to 1.5V for the purpose of switching the inverter 15 by the respective value of the battery voltage when the threshold voltage of the inverter 15 is set at 0.7V. Curve A_1 and line B_1 correspond, curve A_2 and line B_2 correspond etc.

Figure 4 will be explained as reference to the following example. A load resistor R_{L2} , i.e. the resistance of the variable resistor 14, that is desired to make the drain voltage V_D 0.7V and to switch the inverter 15 when the battery voltage E falls to 1.4V is obtained from a straight line connecting the point 1.4V on the abscissa and the point α at which the voltage V_{DS} is 0.7V, namely the intersection of the curve A_2 ($V_G=1.4V$) and the line B_2 ; it will be appreciated that the gate voltage V_G is equal to the battery voltage.

The load resistance R_{L2} is:

$$\frac{V_{DS2}}{I_{D2}}$$

and the drain voltage V_D at which the battery voltage E is 1.5V is obtained from a point β which is the intersection of line B_2' , which is parallel with line B_2 , passing through the point 1.50V of the abscissa and the curve A_1 ($V_G=1.5V$). The drain voltage V_D is the value which is obtained by deducting the voltage V_{DS} from 1.50V and is 1.01V in this example.

In the case where the load resistance is R_{L2} , when the battery voltage is 1.5V, the drain voltage V_D is 1.01V and the output of the inverter 15 is "Low". When the battery voltage falls to 1.4V, the drain voltage V_D becomes 0.7V and the output of the inverter 15 becomes "High". Accordingly, the battery voltage detecting circuit determines when the battery voltage falls to 1.4V.

A load resistance R_{L3} may be obtained from line B_3 , and in this case the drain voltage V_D is 1.25V when the battery voltage E is 1.50V and the drain voltage V_D is 0.7V when the battery voltage E is 1.30V. A load resistance R_{L4} may be obtained from line B_4 and in this case the drain voltage V_D is 1.38V when the battery voltage E is 1.50V and the drain voltage V_D is 0.7V when the battery voltage E is 1.20V. A load resistance R_{L5} may be obtained from line B_5 and in this case the drain voltage V_D is 1.46V when the battery voltage E is 1.50V and the drain voltage V_D is 0.7V when the battery voltage E is 1.10V. A load resistance R_{L6} may be obtained from the line B_6 and in this case the drain voltage V_D is 1.49V when the battery voltage E is 1.50V and the drain voltage V_D is 0.7V when the battery voltage E is 1.00V. Thus the detecting level of the battery voltage detecting circuit of Figure 3 is determined by the load resistance, i.e. the resistance of the variable resistor 14.

Figure 5 shows graphically the relationship between the battery voltage E and the drain voltage V_D for load resistances R_{L2} to R_{L6} referred to above. It will be appreciated that the battery voltage E corresponding to a drain voltage 0.7V depends upon the load resistance.

Figure 6 is a circuit diagram of a second embodiment of a battery voltage detecting circuit for an electronic timepiece according to the present invention. In Figure 6, the variable resistor 14 of the battery voltage detecting circuit of Figure 3 is replaced by a potential divider 18 whose central tap is connected to the gate of the transistor 12, a resistor 17 being connected to the drain of the transistor. The detecting level of this

battery voltage detecting circuit is determined by the setting of the potential divider 18.

Figure 7 is a circuit diagram of a third embodiment of a battery voltage detecting circuit for an electronic timepiece according to the present invention. In this embodiment there is provided a voltage divider which includes a resistor 20 and a diode 19, the output of the voltage divider being connected to the gate of the transistor 12. The detecting level of this battery voltage detecting circuit is determined by the resistor 20.

As will have been appreciated it is possible to change the apparent threshold voltage of the transistor 12 in the battery voltage detecting circuit of Figures 3, 6 and 7, so that the transistor 12 can be formed on an integrated circuit chip with other circuitry. The output of the battery voltage detecting circuit can be displayed easily, for example, part of the time display of the electronic timepiece may be caused to flash when the battery voltage falls below the detecting level of the battery voltage detecting circuit. Moreover, the battery voltage detecting circuit may be used to indicate the remaining useful life of the battery and the current consumption of the timepiece, and to set the detecting level of the battery voltage detecting circuit to the battery voltage corresponding to its battery capacity by the resistance value.

As the means for the resistance value, it is conceivable to use, for example, an automatic trimming of a thick film resistance or the solid resistance element selectively in addition or as an alternative to the variable resistor. When the resistance value becomes small and the current consumption of the battery voltage detecting circuit becomes consequently relatively large because of controlling the detecting level, the current consumption can readily be reduced by detecting the battery voltage at intervals and/or for short periods, rather than continuously.

Figure 8 is an explanatory circuit diagram illustrating a battery voltage detecting circuit and Figure 9 illustrates the relationship between the voltage E_1' of a power source battery 101 and the voltage E_2' across a variable resistor 104 and the voltage E_3' between source and drain of a field effect transistor 108. Curve E_{2A} in Figure 9 represents the voltage E_2' at the time when the resistance of the variable resistor 104 is relatively large and curves E_{2B} and E_{2C} represent the voltages E_2' , E_3' at the time when the resistance of the variable resistor 104 is relatively small. Thus, the switching voltage—that is to say the predetermined voltage of the battery 101 detected by the detecting circuit—can be easily controlled by changing the resistance of the variable resistor 104. However, this battery voltage detecting circuit has the disadvantage that there is an increase of current consumption when the resistance of

12

the variable resistor 104 is relatively small. In some instances the resistance of the variable resistor 104 may be several tens of kilohms (k Ω) and this may maximise the drain current of the field-effect transistor; thus the current consumption of the battery voltage detecting circuit will considerably exceed 10 micro-amperes and a battery voltage detecting circuit with such a current consumption is impractical.

Generally, in a quartz crystal wristwatch, the standard battery voltage is 1.59V and the average current consumption is 10 micro-amperes. In such a case when the battery nears the end of its useful life it takes about a week for the battery voltage to fall from 1.45V to 1.35V. The minimum voltage required to drive a quartz crystal wristwatch is about 1.35V. Therefore, if a battery voltage detecting circuit detects when the battery voltage has fallen to between 1.45 and 1.50V, the battery will continue to drive the quartz crystal wristwatch for a week or so after the fall in battery voltage has been detected and displayed. Since the battery voltage falls relatively slowly, it is unnecessary to measure the battery voltage continuously. The battery voltage may, for example, be detected once a day and the result memorised and when there is a predetermined voltage drop from one day to the next, an indication may be given that the battery is nearing the end of its useful life. A battery voltage detecting circuit which only detects the battery voltage periodically will, it will be appreciated, have a relatively low power consumption. Thus if the battery voltage is detected once a second and it takes 1 millisecond to perform the detection the average current consumption of the battery voltage detecting circuit is one thousandth the current consumption of a battery voltage detecting circuit which detects the battery voltage continuously, namely, in the example given above, the power consumption will be 0.1 micro-amperes or less which is negligible compared with the total current consumption of the quartz crystal wristwatch.

Figure 10 is a circuit diagram for an electronic timepiece, for example, a quartz crystal timepiece, according to the present invention. The electric timepiece is a plurality of negative trigger master-slave flip-flop circuits 209 to 223 (herein referred to as FF circuits 209 to 223). The D terminal of each FF circuit

is connected to the $\bar{Q}_n$ terminal of the subsequent FF circuit unless otherwise stated. The FF circuits 209 to 219 constitute a divider circuit for dividing the time standard signal from a quartz crystal oscillator consisting of a quartz crystal 238 and an inverter 230 to produce driving signals. The FF circuit 220 and a NAND gate 224 constitute a control circuit of a battery-voltage detecting circuit. A P-MOS transistor 202, a N-MOS

transistor 205, load resistors 204, 206 and an inverter 232 constitute the battery voltage detecting circuit. The FF circuit 221 constitutes a memorising circuit for memorising the output of the battery voltage detecting circuit. The FF circuit 222, NAND gates 225, 226 and an EX-OR gate 229 constitute a battery life display control circuit. The FF circuit 223, inverters 234, 235, and NOR gates 227, 228 constitute a forming circuit for forming driving signals. Inverters 236, 237 constitute a driving circuit which supplies a motor driving coil 239 with relatively large current driving signals. The divider circuit may be reset by means of a switch 240.

The output of the NAND gate 224 is "Low" once every two seconds for a period of 7.8 milliseconds, and "High" at all other times. Accordingly, when the NAND gate 224 is "Low" the transistor 202 is operative. When the battery voltage is higher than a predetermined level the P-MOS transistor 202 is conductive. In this case, therefore, the transistor 202 is only conductive for 7.8 milliseconds every 2 seconds and the output of the inverter 232 is "High". When the battery voltage is lower than the predetermined level, the transistor 202, when operative, is non-conductive and accordingly the output of the inverter 232 remains "Low".

Since the battery voltage is detected every 2 seconds and for a period of 7.8 milliseconds, the transistor 202 and the transistor 205 are non-conductive for most of the time so that the current consumption of the battery voltage detecting circuit is greatly reduced. The FF circuit 221 memorises the output signal from the battery voltage detecting circuit. Depending upon the state of the FF circuit 221 the driving circuit is controlled by the battery life display control circuit in such a way that a seconds hand driven by a motor of which the coil 239 forms part, is indexed every second by one step when the battery voltage is higher than the predetermined level, namely when the output of the FF circuit 221 is "Low", and is indexed every 2 seconds by two steps when the battery voltage is lower than the predetermined level, namely, when the output of the FF circuit 222 is "High". Thus the fact that the battery driving the electronic timepiece is about to expire will be apparent from the fact that the seconds hand is indexed once every two seconds by two steps whereas it is normally indexed one step every second.

Figure 11 is a timing chart illustrating the operation of the timepiece of Figure 10.

In this embodiment, the battery voltage is detected by the battery voltage detecting circuit at a different time from when the driving signals are or are about to be produced. However, the timing between battery voltage detection and production of driving signals

can be matched to battery characteristics maximum peak current etc.

Thus the output voltage of the battery is detected in between steps of the modified advancement of the seconds hand.

WHAT WE CLAIM IS:—

1. An electronic timepiece comprising a time standard means for producing a time standard signal, driving circuitry for producing from the time standard signal driving signals, display means arranged to be driven by the driving signals, and battery voltage detecting means, including a field effect transistor and at least one resistor, for detecting when the output voltage of a battery driving the timepiece falls below a predetermined voltage.

2. An electronic timepiece as claimed in Claim 1 in which the battery voltage detecting means includes selecting means for setting the said predetermined voltage.

3. An electronic timepiece as claimed in Claim 2 in which said selecting means comprises a load resistor of the field effect transistor, said load resistor being selected to detect a fall of battery voltage below the desired predetermined voltage.

4. An electronic timepiece as claimed in Claim 2 in which said selecting means comprises a potential divider for varying the voltage applied to the gate of the field effect transistor.

5. An electronic timepiece as claimed in any preceding Claim in which the field effect transistor forms part of an integrated circuit chip which also includes the or a part of the driving circuit.

6. An electronic timepiece as claimed in any preceding Claim including a memory circuit for memorising the output of the battery voltage detecting means.

7. An electronic timepiece as claimed in any preceding Claim in which said battery voltage detecting means is arranged to detect the battery voltage at periodic intervals.

8. An electronic timepiece as claimed in Claim 7 in which the arrangement is such that the battery voltage is not detected when driving signals are or are about to be generated.

9. An electronic timepiece as claimed in any preceding Claim in which means are provided to modify the display produced by the display means when the battery voltage detecting circuit detects that the battery voltage has fallen below said predetermined voltage.

10. An electronic timepiece as claimed in any preceding Claim in which the time standard means is a quartz crystal oscillator.

11. An electronic timepiece including a time standard, electronic circuitry display means, a power source battery and a battery voltage detecting circuitry for detecting the voltage of said power source battery said battery voltage detecting circuit consisting of a first stage having an enhancement type MOS.FET and a resistor, said enhancement type MOS.FET being arranged in such a way that the voltage of said power source battery or a voltage related thereto is applied between the gate and the source and the load resistor is connected as a drain load, and a second stage having at least an enhancement type MOS.FET inverter whose input is connected to the drain or load resistor of the first stage portion.

12. An electronic timepiece as claimed in any preceding Claim in which the display means includes a seconds hand which is advanced stepwise, the battery voltage detecting circuit, in operation, modifying the advancement of the seconds hand when the battery voltage has fallen below said predetermined voltage, the battery voltage detecting circuit being arranged to detect the output voltage of the battery in between the steps of the modified advancement of the seconds hand.

13. An electronic timepiece substantially as herein described with reference to and as shown in Figures 3, 4, 5, 6, 7, 10 or 11 of the accompanying drawings.

Agents for the Applicants:
J. MILLER & CO.,
Chartered Patent Agents,
Lincoln House,
296/302 High Holborn,
London, WC1V 7JH.



* C L M S *

1,475,841

can be matched to battery characteristics maximum peak current etc.

Thus the output voltage of the battery is detected in between steps of the modified advancement of the seconds hand.

WHAT WE CLAIM IS:—

1. An electronic timepiece comprising a time standard means for producing a time standard signal, driving circuitry for producing from the time standard signal driving signals, display means arranged to be driven by the driving signals, and battery voltage detecting means, including a field effect transistor and at least one resistor, for detecting when the output voltage of a battery driving the timepiece falls below a predetermined voltage.

2. An electronic timepiece as claimed in Claim 1 in which the battery voltage detecting means includes selecting means for setting the said predetermined voltage.

3. An electronic timepiece as claimed in Claim 2 in which said selecting means comprises a load resistor of the field effect transistor, said load resistor being selected to detect a fall of battery voltage below the desired predetermined voltage.

4. An electronic timepiece as claimed in Claim 2 in which said selecting means comprises a potential divider for varying the voltage applied to the gate of the field effect transistor.

5. An electronic timepiece as claimed in any preceding Claim in which the field effect transistor forms part of an integrated circuit chip which also includes the or a part of the driving circuit.

6. An electronic timepiece as claimed in any preceding Claim including a memory circuit for memorising the output of the battery voltage detecting means.

7. An electronic timepiece as claimed in any preceding Claim in which said battery voltage detecting means is arranged to detect the battery voltage at periodic intervals.

8. An electronic timepiece as claimed in Claim 7 in which the arrangement is such that the battery voltage is not detected when driving signals are or are about to be generated.

9. An electronic timepiece as claimed in any preceding Claim in which means are provided to modify the display produced by the display means when the battery voltage detecting circuit detects that the battery voltage has fallen below said predetermined voltage.

10. An electronic timepiece as claimed in any preceding Claim in which the time standard means is a quartz crystal oscillator.

11. An electronic timepiece including a time standard, electronic circuitry display means, a power source battery and a battery voltage detecting circuitry for detecting the voltage of said power source battery said battery voltage detecting circuit consisting of a first stage having an enhancement type MOS .FET and a resistor, said enhancement type MOS .FET being arranged in such a way that the voltage of said power source battery or a voltage related thereto is applied between the gate and the source and the load resistor is connected as a drain load, and a second stage having at least an enhancement type MOS .FET inverter whose input is connected to the drain or load resistor of the first stage portion.

12. An electronic timepiece as claimed in any preceding Claim in which the display means includes a seconds hand which is advanced stepwise, the battery voltage detecting circuit, in operation, modifying the advancement of the seconds hand when the battery voltage has fallen below said predetermined voltage, the battery voltage detecting circuit being arranged to detect the output voltage of the battery in between the steps of the modified advancement of the seconds hand.

13. An electronic timepiece substantially as herein described with reference to and as shown in Figures 3, 4, 5, 6, 7, 10 or 11 of the accompanying drawings.

Agents for the Applicants:
J. MILLER & CO.,
Chartered Patent Agents,
Lincoln House,
296/302 High Holborn,
London, WC1V 7JH.