United States Patent [19]

Kakizawa

[11] **3,750,383**

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[54] **QUARTZ-OSCILLATOR CONTROLLED TIMEPIECE USING LIQUID CRYSTAL DISPLAY DEVICE**

[75] Inventor: **Kouji Kakizawa,** Suwa, Japan

[73] Assignee: **Kabushiki Kaisha Suwa Seikosha,** Tokyo, Japan

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Dec. 29, 1970 Japan 45/128117

[52] **U.S. Cl.** ..... **58/50 R,** 58/23 BA

[51] **Int. Cl.** **G04b 19/30,** G04c 3/00

[58] **Field of Search** ..... 58/23 R, 23 A, 23 BA, 58/50 R

[56] **References Cited**

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Primary Examiner—Richard B. Wilkinson

Assistant Examiner—Edith C. Simmons Jackmon

Attorney—Alex Friedman, Harold I. Kaplan et al.

[57] **ABSTRACT**

A timepiece which is quartz-oscillator controlled and which displays the time by means of a liquid crystal digital device, contains a low voltage battery for operating the quartz-oscillator circuit and attendant divider, decoder, and driving circuits. The high voltage necessary for operating the liquid crystal display device is provided by a DC voltage boosting circuit energized by the same low voltage battery.

10 Claims, 4 Drawing Figures

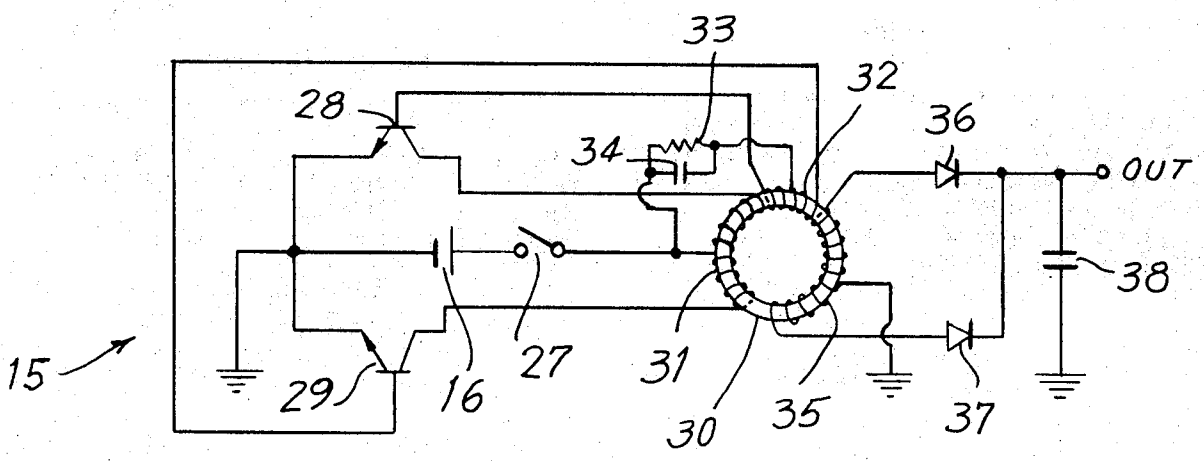


FIG. 1

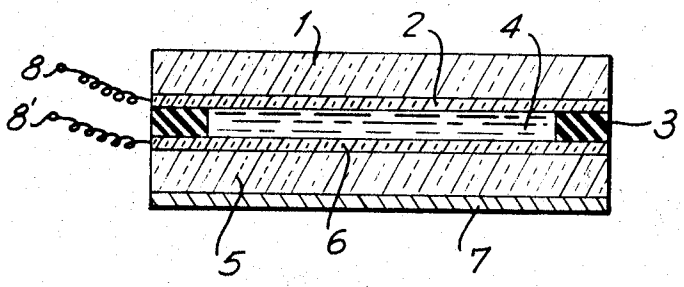

1
2
4
8
8'
3
5
6
7

FIG. 2

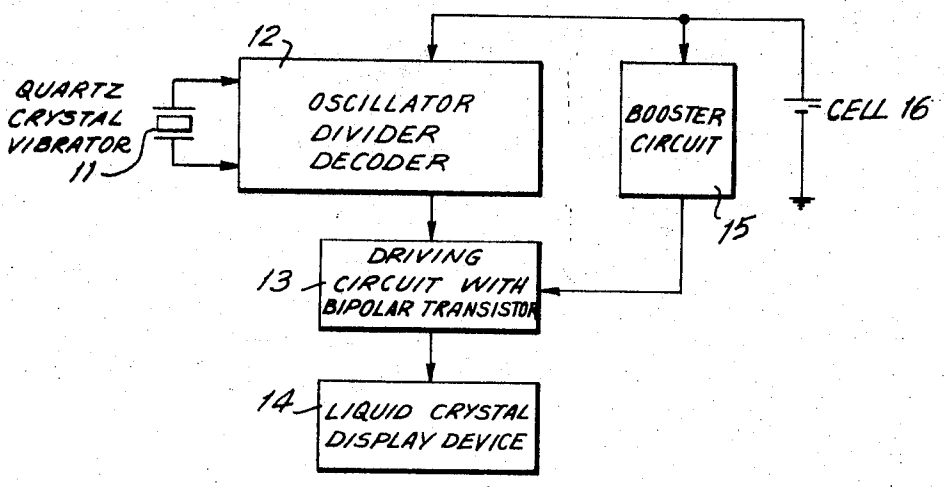

12
QUARTZ CRYSTAL VIBRATOR 11
OSCILLATOR DIVIDER DECODER
BOOSTER CIRCUIT
CELL 16
15
13
DRIVING CIRCUIT WITH BIPOLAR TRANSISTOR
14
LIQUID CRYSTAL DISPLAY DEVICE

FIG. 3

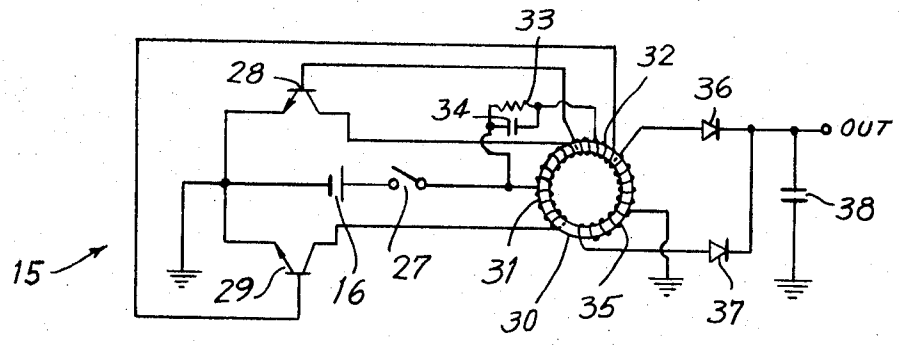
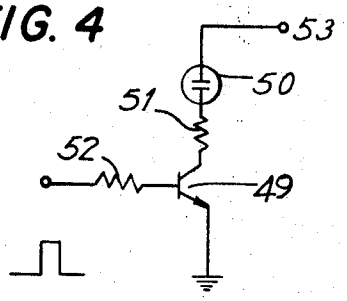


FIG. 4



QUARTZ-OSCILLATOR CONTROLLED TIMEPIECE USING LIQUID CRYSTAL DISPLAY DEVICE

BACKGROUND OF THE INVENTION

A variety of digital display elements consisting of luminous diodes, Nixey tubes, Braun tubes and digitrons have been used for displaying time. Liquid crystal display elements, however, have the following advantages:

1. The brighter the surroundings, the clearer the display.
2. Power consumption is less than 1mw/cm² of display area. This value is much smaller than what is required for the other types of display elements.
3. Liquid crystal display units for use in a watch can be made as thin as about 20 microns. This is highly desirable where the size of the timepiece is as restricted as is the case in many watches. 4. The cost per unit of display area is low.

A reason why liquid crystal display elements have not as yet been used in electrically driven watches is that whereas the production of standard time signals requires only a low voltage,liquid crystal display devices require voltages in the range from about 10V up to about 30V. In the severely restricted amount of space available in a wrist watch, it has been inconvenient to provide batteries of two different voltages for keeping time and for actuating a liquid crystal display device.

SUMMARY OF THE INVENTION

A low voltage battery provides the energy for an oscillator the frequency of which is controlled by a quartz crystal vibrator. The frequency of the oscillator is reduced by means of a divider. The low frequency signals pass through a decoder to a driving circuit using bipolar transistors to furnish the signals for actuating individual segments of a liquid crystal display device. The high voltage for actuating the selected liquid crystal segments is eupplied by a boosting circuit energized by the low voltage cell. The liquid crystal display device may be operated either by DC or AC voltage.

Accordingly, an object of the present invention is to provide a timepiece having improved circuitry wherein a low voltage battery can energize both a quartz crystal controlled oscillator circuit and a liquid crystal digital display device requiring a voltage substantially higher than that provided by the battery.

Another object of the present invention is to provide an improved circuit for boosting the voltage of the low voltage bat-tery.

A further object of the present invention is to provide improved circuitry for actuating the individual segments of a liquid crystal digital display device.

Still another object of the invention is to provide improved circuitry for a timepiece using a liquid crystal digital display device in which the energy consumed from the battery during reading of the timepiece is held to a minimum.

Still other objects and advantages of the invention will in part be obvious and will in part be apparent from the specification.

The invention accordingly comprises the features of construction, combination of elements and arrangement of parts which will be exemplified in the construction hereinafter set forth, and the scope of the invention will be indicated in the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

For a fuller understanding of the invention, reference is had to the following description taken in connection with the accompanying drawings, in which:

FIG. 1 is a vertical section of an element in a liquid crystal display device;

FIG. 2 is a block diagram indicating circuitry connections for operating a liquid crystal display device;

FIG. 3 is a circuit diagram of a booster for supplying a high voltage DC output from a low voltage battery; and

FIG. 4 is a circuit diagram of a portion of the drawing circuit coupled to a display element for actuating same.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

For the operation of a digital display device as is contemplated in the present invention, it is necessary that a sufficiently high voltage be impressed on selected segments comprising the various digits, where each digit may be made up of seven segments on one plate and a single area on the second plate where the area on the second plate faces all of the segments on the first plate. As a minimum, one of the plates having conductive segments thereon must be transparent together with such segments as are affixed thereto. Conductive leads must be joined to each of the segments on both plates so that selected segments can be actuated to form the desired digits.

In the embodiment shown in FIG. 1, transparent base plate 1 is of glass, and has coated on the inside thereof a transparent electrode film 2. Insulating spacer 3 between electrode base plates 1 and 5 forms a sealed chamber for containing liquid crystal material 4. The thickness of the insulating spacer and of the liquid crystal material in the chamber may range from 1 micron up to about 30 microns. Conductive film 6 on the inner face of glass base plate 5 may be either transparent or may be polished to a mirror surface. Where the conductive film 6 as well as base plate 5 are transparent, a film of aluminum or nickel or silver may be coated on the back side of glass base plate 5. If the back side of the glass plate 5 is sufficiently smooth, the deposit of metal will act as a mirror. Lead terminals 8 and 8' are connected to a source of voltage between 10V and 30V where the voltage is either AC or DC. Application of sufficient voltage to segments 2 and 6 renders the liquid crystal between display elements opaque and light-dispersing.

The presence of the metal layer 7 on the back side of glass base plate 5 which acts as a mirror, serves to increase the visibility of actuated segments. The contrast between the light reflected from the mirror 7 and dispersed light from opacified liquid crystal is essentially doubled.

The thickness of glass base plates 1 and 5 may range from 0.1mm to several mm. The conductive films 2 and 6 and the metal deposit 7 are thinner than 1 micron. Since the thickness of the liquid crystal material need be only a few microns, the entire liquid crystal display device can be as thin as 0.2 to 0.3 mm. Such thin liquid crystal display devices are most suitable for wrist watches where the thickness of the movement may lie between 2 and 7 mm, so that it is highly desirable that the display device be as thin as possible.

As aforenoted, voltages from 10 to 30 volts are required to cause light scattering by liquid crystal display elements. In contrast, a voltage of 1.5V is enough to drive the time-keeping portion of a wrist watch. Moreover, although the power consumption of a liquid crystal display device is low compared to other types of display power devices, it is nevertheless high relative to that needed to drive the wrist watch circuitry itself. Means for minimizing the energy consumed in actuating the liquid crystal digital display device will be described below.

The block diagram of FIG. 2 shows a quartz crystal vibrator 11 coupled with oscillator circuit 12. The high frequency oscillation generated by the quartz crystal vibrator 11 is reduced by a dividercircuit MOS transistors to low frequency timing signals. Said divider circuit transfers its output to a decoder circuit.

The decoder circuit produces an output to driving circuit 13 which uses bipolar transistors. When it is desired to read the time, booster circuit 15 is actuated by means of a manually-operated switch.

The liquid crystal elements which are to be actuated are selected by the decoder which actuates the corresponding driving circuits indicated in block 13. Booster circuit 15 supplies the high voltage necessary for actuating the selected elements of the liquid crystal display device.

Booster circuit 15 is shown in detail in FIG. 3. As with circuits 12, booster circuit 15 is actuated by battery (or cell) 16 but the booster circuit 15 can be shut off by means of switch 27. Switch 27 is closed only when it is desired to read the time, thus cutting off the power source needed for reading the time. This is particularly important in dark surroundings since the liquid crystal display device operates only in the presence of incident light. It should be noted that opening the switch 27 does not stop the operations of the contents of block 12.

Booster 15 contains a step-up transformer 30. Since the rate of oscillation during boosting may lie between 500Hz and 100kHz, a torodial ferrite core is preferred because of its high permeability and consequent high efficiency in stepping up voltage. Primary coil 31 is connected at its ends to the collectors of transistors 28 and 29,respectively. Coil 31 is center-tapped, the tap being connected to switch 27 and then to low voltage battery 16. Each end of detector coil 32 is connected to one of the bases of transistors 28 and 29. Detector coil 32 also has a center-tap which is connected to the center tap of coil 31 through resistor 33 and condensor 34 which are in parallel. Secondary coil 35 has severalfold more turns than primary coil 31 in order to provide the necessary increase in voltage. Secondary coil 35 is connected to ground at its center, and its ends are connected to the anodes of diodes 36 and 37, thereby providing full-wave rectification. The output is smoothed by capacitor 38.

As can be seen from the circuit diagram, primary coil 31 is connected to detecting coil 32 both by means of the core, a voltage being induced in said detector coil due to the flux produced by the current flowing in the primary coil, and the centertaps of the two coils. A self-oscillating circuit as defined, including said primary and detector coils, bipolar transistors 28 and 29, battery 16, resistor 33 and capacitor 34, said oscillating circuit being self-starting, the two transistors being alternately placed in a conductive state. The current flowing through the emitter-collector paths of bipolar transistors 28 and 29 can be adjusted by changing the value of resistor 33 and the value of capacitor 34. The purpose of using bipolar transistors is that oscillation can be started at a low electric voltage and a high current amplification rate (beta) can be obtained.

Tests have proved that the bipolar transistors arranged as shown in the circuit of FIG. 3 have a higher converting efficiency than MOS transistors. The push-pull circuit of FIG. 3 has been adopted in order to prevent direct current from overlapping on the core 30. The toroidal ferrite core serves to utilize fully the magnetic fluxes therein, thereby increasing the efficiency of voltage conversion and making possible the reduction in size of the circuit. By means of the circuit 15, voltages between 1.2 and 3.2V can be stepped up to 20V without difficulty.

As is evident from the above description, the booster system of FIG. 15 is particularly suitable for small timepieces such as wrist watches. It is also suitable for use in pocket-watches.

In the embodiment of FIG. 3 the transistors shown are of NPN type and the rectified output is shown as being positive. However, it is to be understood that transistors of the PNP type could also be used and that a rectified negative output would be just as useful.

A single driving circuit which actuates a single liquid crystal display segment is shown in FIG. 4 where a pulse is applied through resistor 52 to the base of transistor 49 making the emitter-collector path of transistor 49 conductive and connecting the lower segment of display element 50 to ground. With the closing of switch 27, circuit 15 is actuated, and the rectified output voltage of circuit 15 is applied to terminal 53 of FIG. 4, thus making the display element 50 visible.

Resistor 51 is connected in series with display element 50 in order to protect the device in the event of a short circuit. Resistor 52 is the base resistance of the transistor.

In the device as shown in FIG. 4, transistor 49 is of the NPN type. Here, too, a PNP transistor may be used.

As aforenoted, the energy content of battery 16 is conserved by closing switch 27 only when it is desired to read the time. In addition, energy is conserved by reason of the high efficiency of the oscillator circuit 15 and the toroidal transformer 30.

It will thus be seen that the objects set forth above, among those made apparent from the preceding description, are efficiently attained and, since certain changes may be made in the above construction without departing from the spirit and scope of the invention, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

It is also to be understood that the following claims are intended to cover all of the generic and specific features of the invention herein described, and all statements of the scope of the invention which, as a matter of language, might be said to fall therebetween.

What is claimed is:

1. A timepiece comprising oscillator means including a quartz vibrator for producing a high frequency time standard signal; divider means for dividing said high frequency time standard signal into low frequency timing signals; low voltage battery means; liquid crystal display means adapted for the digital display of time;

driving circuit means coupling said divider means and said liquid crystal display means for driving said liquid crystal display means in response to said timing signals; means directly coupling said battery means to said oscillator and divider means; and booster circuit means connected between said battery means and said driving circuit means for boosting the voltage of said battery means applied to said driving circuit means.

2. A timepiece as recited in claim **1,** wherein said divider means is formed from MOS transistors and said driver circuit means includes bipolar transistors.

3. The timepiece as defined in claim **2,** wherein said booster includes step-up transformer means having a primary winding, a detector winding and a secondary winding, second oscillator means connected to said detector and primary windings and to said battery means for self-oscillation to apply an alternating low voltage to said primary winding; and rectifier means connected to said secondary winding for producing a substantially D.C. high voltage from the alternating high voltage induced in said secondary winding for application to said driving circuit means.

4. A timepiece as recited in claim **3,** wherein said second oscillator means includes a pair of complementary transistor means connected with their respective emitter-collector paths each in series with said battery means and at least a portion of said primary winding, and with their respective bases each connected to at least a portion of said detector winding.

5. A timepiece as recited in claim **3,** wherein said detector winding has end terminals each connected with the base of one of said transistor means.

6. A timepiece as recited in claim **3,** wherein said primary winding has end terminals each connected to the respective emitter-collector path of one of said transistor means and a center-tap connected to said battery means, said battery means being in turn connected to both of said transistor means emitter-collector paths.

7. A timepiece as recited in claim **5,** wherein said detector winding has a center tap, said primary winding has a center tap, and said detector winding center tap and said primary winding center tap are connected through a resistor and a capacitor in parallel.

8. A timepiece as recited in claim **3,** said transformer means includes a toroidal ferrite core having said windings wound around it.

9. A timepiece as recited in claim **1,** wherein said booster cicruit means includes switch means for de-energizing said booster circuit means without uncoupling said battery means from said oscillator means, and said divider means.

10. A timepiece as recited in claim **1,** where said liquid crystal display means includes a plurality of liquid crystal display elements, said driving circuit means including a plurality of transistor means each having its respective emitter-collector path connected intermediate said booster circuit means and one of said liquid crystal display elements, and means interconnecting said divider means and the base of each of said transistor means for selectively applying a driving signal to the bases of the transistor means associated with the liquid crystal display elements to be energized for display of present time to place said transistor means in a conductive state to apply the high voltage of said booster curcuit means to said selected liquid crystal display elements.

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