

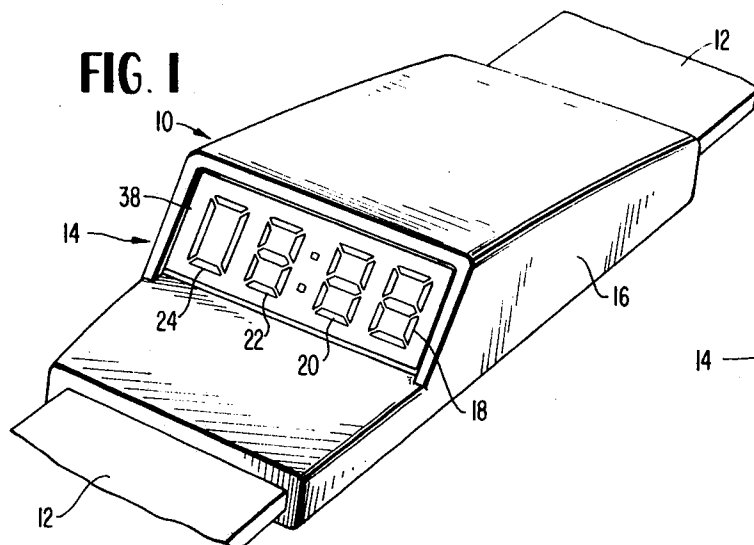
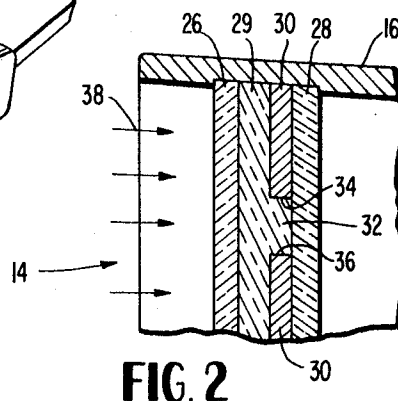
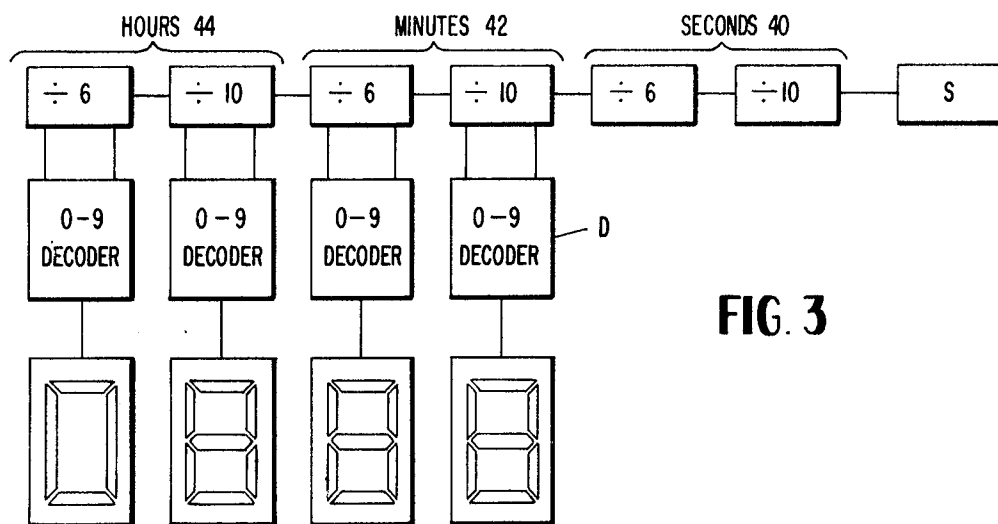
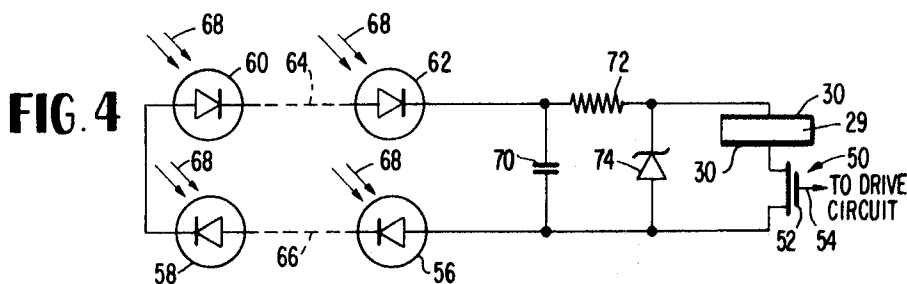
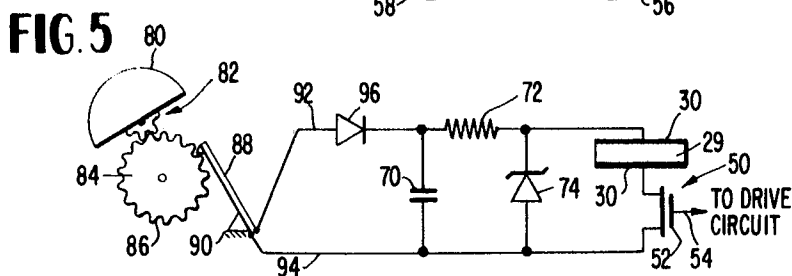
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WRISTWATCH WITH LIQUID CRYSTAL DISPLAY

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WRISTWATCH WITH LIQUID CRYSTAL DISPLAY
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9 Claims

ABSTRACT OF THE DISCLOSURE

Disclosed is a liquid crystal display and power supply system particularly suited for a wristwatch. A bar segment digital display is subjected to an electric field to energize selected portions of the display in accordance with the output of a timekeeping source within the watch. The display is separately powered either from solar cells or from a piezoelectric transducer actuated by watch movement.

This invention relates to a time piece incorporating a liquid crystal display or readout and more particularly to a small time piece such as a wristwatch incorporating a novel liquid crystal display and power supply assembly.

Various methods have been employed to render watch or clock dials readable under variable lighting conditions. For example, it is common knowledge to provide watch or clock dials formed either with luminous numerals against a non-luminous background or a luminous background and non-luminous numerals to provide readability under low light conditions. Additionally, watch and clock dial faces have been provided with auxiliary light sources to light the dial under dark conditions. It has also previously been known to provide clocks utilizing fluorescent materials which can be irradiated by ultraviolet rays for reading in the dark.

While time pieces having fixed dials and numeral displays and provided with various devices to provide readability during various lighting conditions are abundant, the advent of digital displays for watches, clocks and the like has raised significantly different problems in providing digital readability under all lighting conditions as compared with the problems previously encountered with the display of fixed numerals on a watch or clock dial. A serious problem involves providing digital readability for wristwatch displays because of the compactness of the wristwatch which affords little space and adequate power for the elaborate known lighting techniques.

In assignee's compending application, Ser. No. 794,551 filed Jan. 28, 1969, there is disclosed a digital time display watch which significantly overcomes these problems. This is accomplished by making use in the digital time display of the electro-magnetic optical properties of liquid crystals in combination with a suitable light source. A liquid crystal is a substance whose rheological behavior is similar to the crystalline state over a given temperature range, an example of which is the nematic substance p-azoxyanisole. One of the characteristics of liquid crystals in the nematic class is their optical effect in two different states. In a quiescent state with no energy applied, the liquid crystal is essentially transparent. However, when an energy field is applied, either electric or magnetic, the liquid crystal exhibits a light scattering characteristic.

The present invention is directed to a liquid crystal display system of the same general type as that disclosed in compending application, Ser. No. 794,551, filed Jan. 28, 1969, but one that is particularly adapted for use in an electrical or electronic wristwatch where the space and available power are necessarily limited by the small size of the watch. The liquid crystal is capable of reflective contrast ratios better than 15 to 1 with efficiencies of 45% of the standard white. The system of the present inven-

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tion has the capability of being packaged in very small displays and the crystal produces dynamic scattering caused by the application of an electric field. Through the use of a novel power supply arrangement, it is possible to produce an electric field in the neighborhood of from 10 to 40 volts for the liquid crystal with a power consumption of about 100 microwatts per square inch. This power level is quite acceptable for a numerical display of time in a conventional sized wristwatch.

According to one embodiment of the present invention the liquid crystal display is combined with a power source in the form of a plurality of photovoltaic cells connected to provide a relatively high voltage at a low current. Combined with the photo cells is an accumulator for storing energy during periods when ambient light is too low to provide sufficient power to drive the liquid crystal. Since only about 30% of the watch face is used for display, it is possible to mount the photovoltaic cells on the remaining surface in order to generate the voltage necessary to drive the liquid crystals. The photovoltaic cells are used only for energizing the liquid crystals and the decoding and drive circuits of the watch are powered in the usual manner by a conventional 3-volt battery incorporated within the watch.

In a second embodiment an eccentric or oscillating weight similar to the weight conventionally used in an automatic or self-winding watch movement is used to drive a rotatively mounted gear. The gear is used to flex a piezoelectric bar or rod to generate electrical energy. This energy is rectified and stored in an accumulator, again to power liquid crystals to produce a digital liquid crystal display of time at the watch face. As before, the actual drive and decoding circuits for the watch do not operate from the energy stored in the accumulator, but are powered in the usual manner by a conventional 3-volt battery used to drive the watch circuitry.

It is, therefore, one object of the present invention to provide an improved time display for time pieces such as watches, clocks and the like.

Another object of the present invention is to provide an improved display system particularly suited for incorporation in a wristwatch where the space and available power are necessarily limited by the small size of the watch.

Another object of the present invention is to provide an improved digital display for electronic wristwatches and other time pieces.

Another object of the present invention is to provide a display system for time pieces incorporating liquid crystals in a combination with a separate power supply used to energize the crystals.

Another object of the present invention is to provide a liquid crystal display for wristwatches powered by a plurality of photovoltaic cells.

Another object of the present invention is to provide a liquid crystal display for wristwatches in which the crystal is powered by a piezoelectric transducer.

These and further objects and advantages of the invention will be more apparent upon reference to the following specifications, claims and appended drawings wherein:

FIG. 1 is a perspective view of a liquid crystal watch having a digital time display constructed in accordance with the present invention;

FIG. 2 is an enlarged fragmentary cross-sectional view of one of the bar segments forming a portion of the display in the watch of FIG. 1;

FIG. 3 is a block diagram illustrating the drive mechanism for the watch of FIG. 1;

FIG. 4 is an electrical circuit showing the power supply arrangement for energizing the liquid crystal display; and

FIG. 5 is a circuit diagram of a modified power supply and display system showing the liquid crystals powered by a piezoelectric transducer.

Referring to the drawings, FIG. 1 shows at 10 a wrist-watch having a watchband 12 and a time display face generally indicated at 14. Watch 10 includes a casing 16 housing a timekeeping source and circuitry for translating the timekeeping function of the source into digital form for display through watch face 14. Details of the timekeeping source and associated circuitry are illustrated in block form in FIG. 3 and described below, it being sufficient to state that four digital display stations—18, 20, 22 and 24—are exposed for display of selected time indicating digitals through face 14. Two additional stations similar to station 18 can be employed if it is also desired to display seconds through the watch face. Face 14 is inclined upwardly at an angle from housing 16, so as to be readily viewable by the wearer of the watch when the wearer's arm is naturally raised to bring the watch casing into full view.

In the preferred embodiment, the digital display stations are arranged across face 14 to display hours and minutes. For example, as seen in FIG. 1 the right-hand display station 18 comprises a seven-bar segment arranged to display minutes in selected units from 0 to 9, while the next adjacent station 20 includes a seven-bar segment arranged to display selected tenths of minutes from 0 to 5, whereby the full range of minutes from 0 to 59 can be displayed through the pair of seven-bar segment stations 18 and 20. Display station 22 includes a seven-bar segment arranged to display the hours in selected units from 0 to 9, while the next adjacent station 24 comprises a four-bar segment arranged to display selected tenths of hours in units from 0 to 1, whereby the hours from 1 to 12 can be displayed through the pair of bar segments 22 and 24. It will be noted that the last segment 24 comprises a four-bar segment since it is not necessary to provide a full seven-bar segment where only the digits 0 and 1 are to be displayed. A full seven-bar segment could, however, be employed in lieu of a four-bar segment if desired.

FIG. 2 is a partial cross-section showing one of the bar segments such as the uppermost segment station 18. It is understood that the remaining bar segments of that station and the bar segments of each of the other digital display stations are similarly constructed. Display face 14 comprises a front, substantially transparent plate 26, preferably formed of glass, and a rear plate formed of a dark material, for example, dark gray reflective glass.

Plates 26 and 28 are spaced one from the other by suitable spacers not shown and a liquid crystal substance 29 described below is disposed between and preferably coextensive with plates 26 and 28. The front surface of the rear glass 28 is coated with a transparent electrode material indicated at 30 with portions of the surface uncoated and defining a pair of electrodes across each of the bar segments at each station, 18, 20, 22, and 24. For example, coating 30 may be applied over the entire front surface of rear plate 28 with the electrode material subsequently etched away to define a pair of electrodes for each segment of the seven-bar segments, 18, 20, and 22, and the four-bar segment 24, as well as to electrically insulate the electrode pairs from one another. As illustrated in FIG. 2, the top bar segment of the seven-bar station 18 is shown at 32 with the edges of the electrode material as at 34 and 36 forming a pair of electrodes. Each of the bar segments of each display station 18, 20 and 22 and 24 is similarly formed to provide electrode pairs across the etched portions of the electrode material. The electrode pairs may be suitably electrically insulated (as by etching) one from the other or the potential of the selected individual electrodes of various bar segments may be the same; for example, they may be connected to ground. Light passes through the front plate 26 as indicated by the arrows at 38 in FIG. 2 to make the display visible, which light may be either ambient light or light

from a suitable source mounted on the watch.

FIG. 3 shows a block diagram of the overall drive system for the watch 10 of FIG. 1. In that figure, a suitable power source such as an electronic oscillator is labeled S and this may take the form of any suitable pulse generator the output of which is fed to a series of dividers 40, 42 and 44. The dividers convert the timed output from source S (which by way of example only may be a highly accurate crystal controlled solid state oscillator) into binary decimal signals which in turn are converted by decoders D into the energizing code for the bar segment displays. The logic circuitry for converting the binary decimal signal into a bar segment output for each digital display is well-known and further description is deemed unwarranted. Any suitable logic circuit may be employed such that the pairs of electrodes defining the bar segments can be selectively energized in a time sequence to provide a digital time display.

As noted above, a liquid crystal substance 29 is disposed between plates 26 and 28. The term liquid crystal is used to mean a substance whose rheological behavior is similar to that of fluids, but whose optical behavior is similar to the crystalline state over a given temperature range. These substances exhibit mesomorphic behavior and of the three states of mesomorphic behavior the nematic state exhibits the electromagneto-optic effect utilized in the present digital time display. A preferred nematic liquid crystal having the required properties is p-azoxyanisole. This material exhibits the desired mesomorphic behavior with the desired temperature range for watches and it is characteristic of this liquid crystal under these temperature conditions that with no electric or magnetic field applied it is substantially transparent. However, when a field, either electric or magnetic, is applied the liquid crystal becomes turbulent and scatters light, the effect of which is to reflect light which appears white. An additional characteristic of the liquid crystal is the fact that the greater the incident light on the energized liquid crystal the greater the reflectivity, brightness, and hence contrast with the surrounding environment.

It is understood that when the portions of the liquid crystal 29 disposed between the electrodes of the bar segments remain in an unenergized state, the dark background of the rear plate 28 is seen through the front transparent plate 26 and the transparent liquid crystal. Accordingly, in viewing the display's face 14, the dark background afforded by rear plate 28 is seen through the transparent electrode material 30 (essentially the entire display face 14) and through the portions of the liquid crystal lying between the electrodes of the unenergized bar segments. However, the electrodes which are energized through the logic circuitry of FIG. 3 energize the liquid crystals between them such that incident light is scattered. This incident light which is reflected appears white against the dark surrounding background. In this way, the energized liquid crystal bar segments provide a readily readable and clearly distinguishable time display in digital form, the digits being formed by the selectively energized liquid crystal bar segments which appear white by scattering incident light and which contrast with the dark background of the rear plate 28. Moreover, the greater the incident light, the greater the contrast.

FIG. 4 shows the manner in which the liquid crystal forming one of the bar segments is energized. In FIG. 4, the liquid crystal 29 is illustrated as connected to the spaced electrodes 30 through a transistor switch 50, preferably in the form of an insulated gate field effect transistor. Gate electrode 52 of the switch is connected by lead 54 to the output of one of the decoders D of FIG. 3. When switch 50 is closed, the circuit is completed to electrodes 30 and liquid crystal 29 is energized to become reflective.

It is characteristic of liquid crystals that they require for energization an electrical field of from 10 to 40 volts, but with a power consumption that is only 100 microwatts per square inch. This relatively high voltage/low cur-

rent for energization is provided in the watch 10 by incorporating in the watch a plurality of photovoltaic cells or solar cells such as those indicated at 56, 58, 60 and 62. The photovoltaic cells are connected in a series to provide the relatively high voltage and low current necessary to energize liquid crystal 29. The connection is illustrated by dash lines at 64 and 66 to indicate that more photovoltaic cells can be used if desired. Since only about 30% of the watch face illustrated in FIG. 1 is used by the display, the solar cells 56, 58, 60 and 62 may be mounted on face 14 about the display to collect ambient light as indicated by the arrows 68. Alternatively, the solar cells may be mounted on the top of the watch case if so desired, where more room is available for the incorporation of a greater number of cells.

Connected to the output of the solar cells is an accumulator in the form of a capacitor 70. The accumulator is provided for energizing the liquid crystal 29 during those times when the ambient light 68 is too low to provide sufficient power to drive the crystal. The energy from the ambient light produced by the solar cells is generated during light periods and stored in the accumulator 70 for later use.

The accumulator 70 which can take the form of a rechargeable battery rather than a capacitor is connected to electrodes 30 through a current limiting resistor 72. A Zener diode 74 can be provided if desired to control the voltage level, but diode 74 is optional.

FIG. 5 shows a modified embodiment wherein the liquid crystal 29 is energized from a piezoelectric transducer instead of the solar cells of FIG. 4. In FIG. 5 like parts bear like reference numerals and the power source is again connected to the liquid crystal through the accumulator 70 and transistor switch 50 controlled from one of the decoders D in FIG. 3. In the embodiment of FIG. 5 the watch is provided with an eccentric or oscillating weight 80 of the type conventionally used in automatic or self-winding watch movements which weight drives a gear 84 through a gear train generally indicated at 82. The teeth 86 of gear 84 successively engage and oscillate or flex the end of a piezoelectric rod or bar 88 rigidly held at its other end as at 90. Bar 88 is preferably formed of a suitable piezoelectric ceramic such as barium titanate or the like. The electrical signal developed by piezoelectric bar 88 is conducted by leads 92 and 94 through a rectifier diode 96 to the accumulator 70 in the form of a capacitor. The output from the accumulator passes to current limiting resistor 72 and the optional Zener diode 74 in FIG. 5 to the electrodes 30 energizing crystal 29. Again the accumulator can be a rechargeable battery rather than a capacitor.

It is apparent from the above that the present invention provides a novel display device and one particularly suited for incorporation in a wristwatch where the watch size limits the space and energy available to operate the watch and its display. Important features of the invention include the incorporation of liquid crystals to produce an optical display, which crystals are energized from power sources sufficiently small for incorporation either inside the watch case or on the surface of either the case or the watch dial or face. The liquid crystal is capable of reflective contrast ratios of better than 15 to 1 with efficiencies of 45% of the standard white when subjected to electrical fields of from about 10 to 40 volts with a power consumption of only about 100 microwatts per square inch. These power levels are quite capable of being supplied by the sources illustrated in FIGS. 4 and 5.

In accordance with the invention, it is possible to construct a digital wristwatch display which will display minutes, hours and even seconds, using numerals made from various combinations of seven segments. Alternatively the digital display may be formed from a thirteen dot matrix. The display can be driven from counting and

logic circuits using complementary MOS circuits so that the decoding network necessary to drive the liquid crystals can be made using conventional integrated circuit techniques. The power necessary for operating the drive and decoder circuits is about the same as now required for watches incorporating mechanical transducers. These circuits including the timing source S of FIG. 3, the dividers, and the decoders can all be energized from a conventional 3-volt battery as currently used in present electrical watches. The physical size and cost of the construction as shown is less than that for a corresponding watch gear train so that ample room is available for the incorporation of the additional power sources of FIGS. 4 and 5 to activate the liquid crystal display. While the invention has been described in conjunction with a particular bar display, it is apparent that other types of displays, both digital and otherwise, may be incorporated using the liquid crystals herein disclosed energized by small power sources of sufficiently small size that they may be mounted on or in a conventional sized wristwatch.

What is claimed and desired to be secured by United States Letters Patent is:

1. An optical display system for timepieces comprising a timepiece housing including a power source, timekeeping means within said housing, display means including a liquid crystal mounted on said housing and coupled to said timekeeping means, a separate power source carried by said housing, and means in said housing coupling said separate power source to said liquid crystal.
2. A system according to claim 1 wherein said separate power source comprises at least one photovoltaic cell.
3. A system according to claim 1 wherein said separate power source comprises a plurality of photovoltaic cells connected in series with said liquid crystal.
4. A system according to claim 1 wherein said separate power source comprises a piezoelectric transducer.
5. A system according to claim 1 wherein said separate power source comprises a piezoelectric crystal, and an eccentric weight coupled to said crystal for vibrating said crystal to produce an electrical output.
6. A wristwatch comprising a wristwatch case, display means on said case including a liquid crystal, a timekeeper in said case, an electrical power source carried by said case, and a solid state switch coupling said power source to said crystal, an accumulator said switch being operative in response to the output of said timekeeper to selectively energize said liquid crystal from said power source through said accumulator.
7. A wristwatch according to claim 6 wherein said display means includes means for digitally displaying time.
8. A wristwatch according to claim 6 including a Zener diode coupling said accumulator to said liquid crystal.
9. A wristwatch according to claim 6 wherein said power source comprises a piezoelectric crystal, and a rectifier diode coupling said crystal to said accumulator.

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