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Eckenrode

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[54] **LIGHT CONTROL FOR TIMING DISPLAYS**

[75] Inventor: **James H. Eckenrode**, Millersville, Pa.

[73] Assignee: **HMW Industries, Inc.**, Lancaster, Pa.

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[52] **U.S. Cl.** ..... **58/50 R**, 250/215 X

[51] **Int. Cl.** **G04b 19/30**

[58] **Field of Search** ..... 58/23 R, 23 A, 50 R; 250/206, 215 X; 350/160 R, 160 LC

[56] **References Cited**

UNITED STATES PATENTS

3,575,491	4/1971	Heilmeier	350/160
3,505,804	4/1970	Hofstein	58/50
3,646,751	3/1972	Purland et al.	58/152
3,485,033	12/1969	Langley	58/50 X

Primary Examiner—Richard B. Wilkinson
Assistant Examiner—Edith C. Simmons Jackmon
Attorney—Le Blanc & Shur

[57] **ABSTRACT**

Disclosed is an electronic wristwatch having no moving parts and incorporating a light responsive solid state control circuit for the time display. An electro-optic digital display, either of active or passive elements, is switched off when the ambient light falls below a predetermined level. The active display is also turned off when the light is too bright and both the active and passive displays are provided with a manual override switch for actuating the display under dark conditions at the option of the wearer.

10 Claims, 6 Drawing Figures

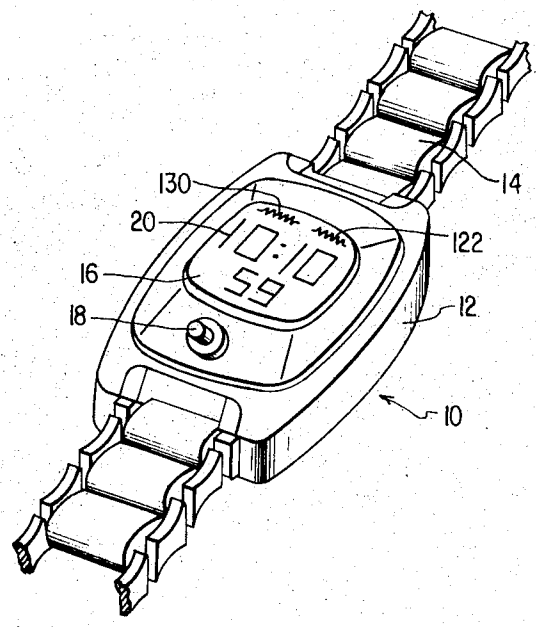


FIG. 1

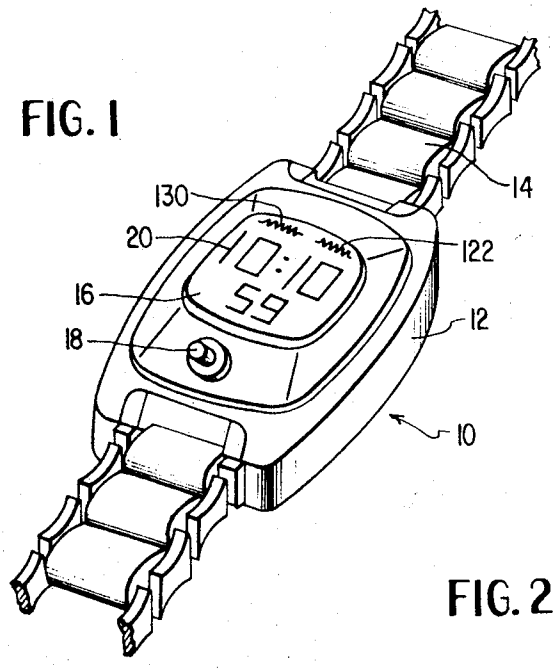


FIG. 3

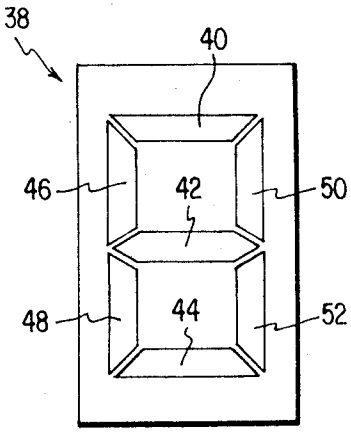


FIG. 2

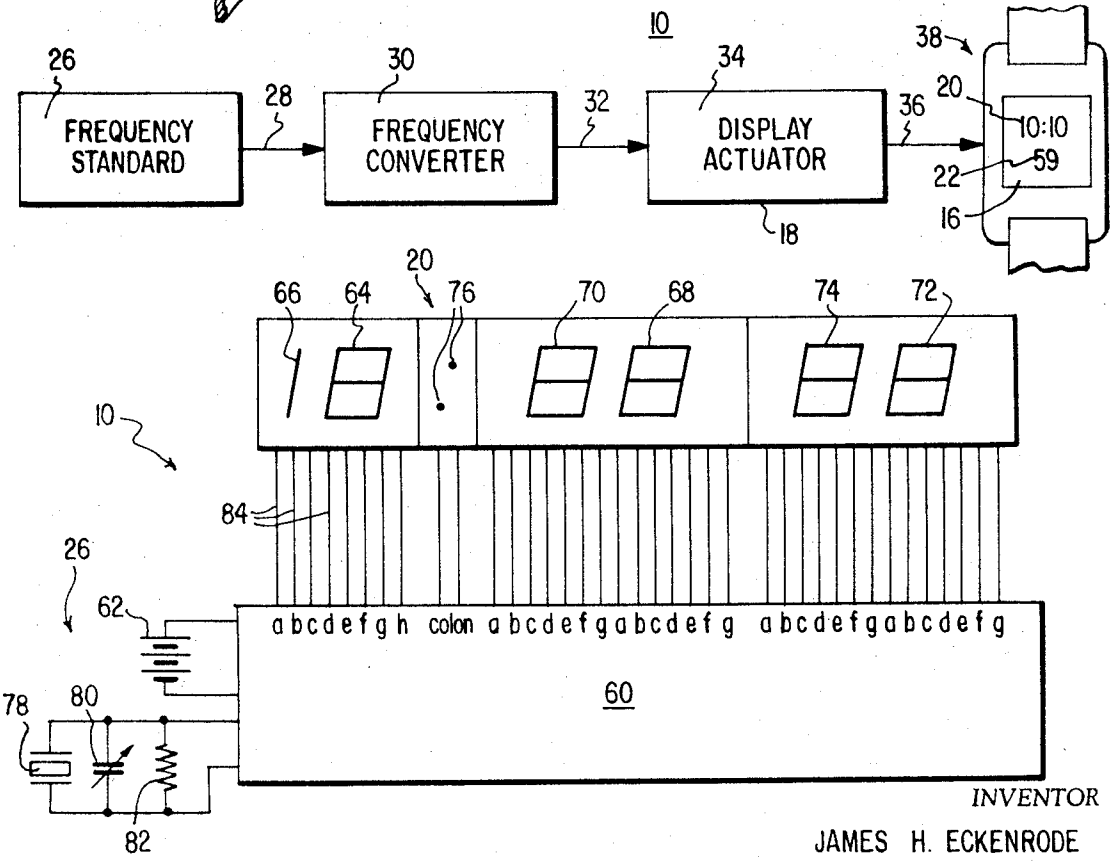


FIG. 4

INVENTOR
JAMES H. ECKENRODE

BY LeBlanc and Shur

ATTORNEYS.

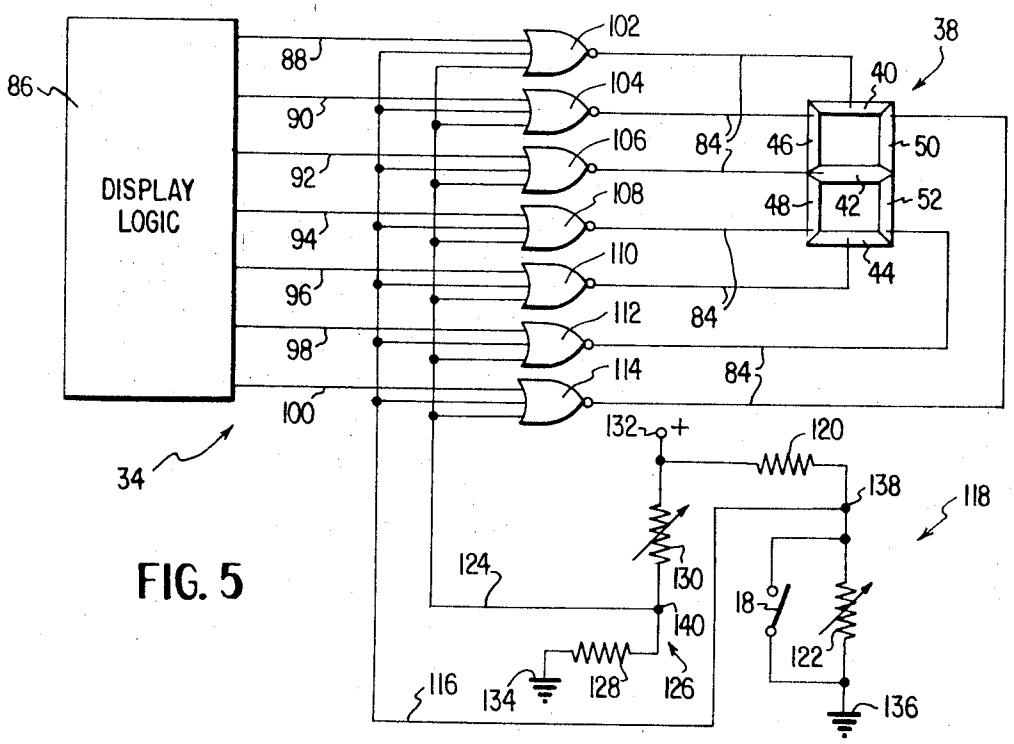


FIG. 5

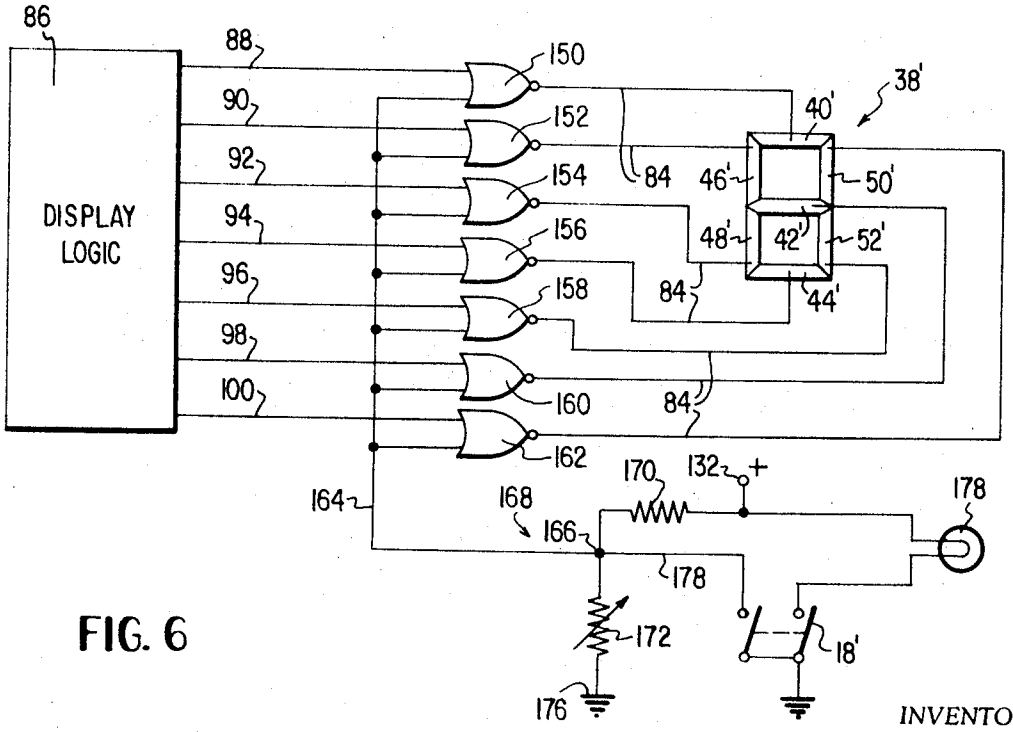


FIG. 6

INVENTOR
JAMES H. ECKENRODE

BY LeBlanc & Shur

ATTORNEYS.

LIGHT CONTROL FOR TIMING DISPLAYS

This invention relates to an ambient light responsive control circuit for timing displays and more particularly for use with a solid state timepiece in the form of an electric wristwatch which employs no moving parts. In order to conserve power, the control circuit turns off the display at times when the watch is not likely to be used or when the display cannot be read.

In the present invention, a frequency standard in the form of a crystal oscillator acts through solid state electronic circuit dividers and drivers to power in timed sequence the light-emitting diodes or liquid crystals of an electro-optic display. Low power consumption and small size and weight are achieved through the use of complementary MOS circuits to produce what is in essence a miniaturized fixed program computer and in the preferred embodiment the wristwatch is constructed so that substantially all the electrical circuitry is made using large-scale integrated circuit techniques.

Battery-powered wristwatches and other small portable timekeeping devices of various types are well known and are commercially available. The first commercially successful battery-powered wristwatch was of the type shown and described in assignee's U.S. Pat. No. 26,187, reissued Apr. 4, 1967, to John A. Van Horn et al. for ELECTRIC WATCH. Electric watches of this type employ a balance wheel and a hairspring driven by the interaction of a current-carrying coil and a magnetic field produced by small permanent magnets.

In recent years, considerable effort has been directed toward the development of a wristwatch which does not employ an electromechanical oscillator as the master time reference. For example, there is disclosed in assignee's U.S. Pat. No. 3,560,998, issued Feb. 2, 1971, an electronic watch utilizing an oscillator and frequency converter with low power complementary MOS circuits. The oscillator/frequency converter combination of that patent is described as suitable for driving conventional watch hands over a watch dial or, alternatively, for selectively actuating the display elements of an optical display in response to the drive signal output of the converter. In assignee's U.S. Pat. No. 3,576,099, issued Apr. 27, 1971, there is disclosed an improved watch construction in which the optical display is described as a plurality of light-emitting diodes which are intermittently energized to assure a minimum power consumption and an increasingly long life for the watch battery.

The present invention is directed to an improved watch construction of the same general type as disclosed in the above-mentioned patents and one which utilizes no moving parts to perform the timekeeping function. The wristwatch comprises a frequency standard, preferably operating at a frequency of 32,768 Hz and formed as a crystal-controlled complmentary MOS inverter used as an oscillator. Output signals from the frequency standard pass through a frequency converter, preferably in the form of a multi-stage binary frequency divider constructed of complementary MOS transistors. The signal is divided down in the frequency converter to produce an output at 1 Hz. This signal is supplied to a display actuator, preferably formed by a plurality of registers, gates and decoders, which drive an electro-optical display, preferably in the form of a bar segment arrangement of light-emitting diodes. Alternatively, the display may be formed by a bar segment arrangement of passive rather than active electro-optical elements, such as the well known liquid crystals.

Mounted on the face of the watch are one or more photosensitive electrical elements which sense the amount of ambient light impinging upon the face of the watch. The photosensors may be either photoresistors or phototransistors or other well known photoelectric solid state circuit elements. The photosensors are connected to the display actuator driving the light-emitting diode or liquid crystal display so that the display is automatically switched off under certain conditions of ambient light. For a passive type display, such as one using liquid crystals, a single photosensor may be used to turn off the display when the ambient light falls below a certain predetermined level. For watches incorporating active-type timing displays, such as light-emitting diodes, two photosensors are preferred, one acting to turn off the display as in the passive case when the ambient light falls below a predetermined level and the other turning off the display when the ambient light becomes too bright. As a result, the display which may or may not be intermittently energized is automatically turned off during periods when the watch is not in use or cannot be read so as to conserve the energy of the relatively small battery which may be fit into a conventional man's wristwatch case.

It is therefore one object of the present invention to provide an improved light control circuit for timing displays.

Another object of the present invention is to provide an arrangement for automatically turning off an electro-optical display in accordance with ambient light conditions.

Another object of the present invention is to provide a timing display control circuit particularly suited for use with passive type timing displays, such as those utilizing liquid crystals.

Another object of the present invention is to provide a timing display control circuit particularly for use with active displays, such as those utilizing light-emitting diodes.

Another object of the present invention is to provide a control circuit for timing displays which turns off the display when the incident light on the display falls below a predetermined level.

Another object of the present invention is to provide a control circuit for a timing display which automatically turns off the display when the ambient light becomes too bright.

Another object of the present invention is to provide an improved solid state wristwatch having a timing display control circuit.

Another object of the present invention is to provide an electronic wristwatch having no moving parts and incorporating an ambient light responsive solid state switch for turning off the display when the light incident on the display becomes either too bright or too dark.

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

FIG. 1 is a perspective view of a conventional sized man's wristwatch constructed in accordance with the present invention;

FIG. 2 is a simplified block diagram showing the principal components of the wristwatch of FIG. 1;

FIG. 3 shows a seven bar segment light-emitting diode array forming a part of the display of the wristwatch of FIGS. 1 and 2;

FIG. 4 is a circuit diagram showing the details of the electrical connections from the display actuator to the display diodes;

FIG. 5 shows the light control circuit for an active type timing display; and

FIG. 6 shows a light control circuit for a passive type timing display.

Referring to the drawings, the novel watch of the present invention is generally indicated at **10** in FIG. **1.** The watch is constructed to fit into a watch case **12** of approximately the size of a conventional man's wristwatch. The case **12** is shown connected to a wristwatch strap or bracelet **14** and includes a display window **16** through which time is displayed in digital form as indicated at **20.** Mounted on the case **12** is a pushbutton switch **18** by means of which the display **20** may be actuated when the wearer of the wristwatch **10** desires to ascertain the time, as more fully discussed below.

FIG. **2** is a simplified block diagram of the principal components of the watch **10** of FIG. **1.** The watch comprises a time base or frequency standard **26,** preferably chosen to produce an electrical output signal on lead **28** at a frequency of 32,768 Hz. This relatively high frequency is supplied to a frequency converter **30** in the form of a divider which divides down the frequency from the standard **26** so that the output from the converter **30** appearing on lead **32** is at a frequency of 1 Hz. This signal is applied to the display actuator **34,** which in turn drives the display **20** of the watch by way of electrical lead **36.** In the preferred embodiment, the display takes the form of a seven bar segment array of light-emitting diodes, preferably formed of gallium arsenide phosphide, which emit light when energized in the visible red region of the spectrum. FIG. **3** shows a single display station or numeral **38** consisting of seven light-emitting diodes **40, 42, 44, 46, 48, 50,** and **52** of elongated shape and arranged so that by lighting the appropriate combination of the bars any one of the numbers **0** through **9** may be displayed. The seven bar segment display of FIG. **3** is of the active type in that the light-emitting diodes act as a light source or radiator of visible light.

Alternatively, the seven bar segments illustrated in FIG. **3** may be formed from a seven bar segment array of liquid crystal material. The term liquid crystal is employed to mean those substances whose rheological behavior is similar to that of fluids but whose optical behavior is similar to the crystalline state over a given temperature range. Such substances exhibit mesomorphic behavior and of the three states of mesomorphic behavior, the nematic state exhibits the electro-magnetic-optic effect utilized in the present digital time display. A preferred nematic liquid crystal having the required electro-magnetic-optic properties is p-azoxyanisole. This material exhibits the desired mesomorphic behavior within a particular temperature range useful in watches. Characteristic of this liquid crystal under these conditions and with no electric or magnetic field applied is its substantial transparency. 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 this 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.

FIG. **4** is a simplified block diagram of the watch **10** of the present invention showing the electrical connection to the watch display. Principal portions of the electrical circuitry, including the active components of the oscillator or frequency standard **26** of FIG. **2,** all of the frequency converter **30,** and substantially all of the display actuator **34** in FIG. **2,** are contained in the integrated circuit block **60** of FIG. **4.** This block may be formed of one or several integrated circuit chips but in the preferred embodiment all the components within the block **60** are formed by large-scale integrated circuit techniques. In addition to the integrated circuit **60,** the watch comprises a battery **62** which, by way of example only, may comprise a conventional **3** volt wristwatch battery. This battery energizes the display **20** which is shown in FIG. **4** as consisting of a pair of hours stations comprising the digits station **64** and tens station **66,** a pair of minutes stations comprising the digits station **68** and tens station **70,** and a pair of seconds stations comprising the digits station **72** and the tens station **74.** In addition, the display **20** includes a pair of colon dots **76,** each formed by a single light-emitting diode or single liquid crystal. The components of the frequency standard or oscillator **26** external to the large-scale integrated circuit **60** are the oscillator crystal **78,** the oscillator variable trimming capacitor **80,** and an oscillator bias resistor **82.** Large-scale integrated circuit **60** is connected to the various stations of the display as illustrated in FIG. **4** by the electrical leads **84.**

In previous constructions, digital passive displays, such as liquid crystal displays and the like as used in portable solid state timing devices, have usually been set for continuous operation such that the liquid crystal elements are continuously energized from the power supply or battery. This means that they are continuously using current from the power source. However, a passive display depends upon ambient light for visual detection or reading and therefore cannot be seen in the dark or even in semi-dark environments. As a result, for long periods of time, the display may be drawing power from the limited supply of the battery which serves no useful purpose since with little or no ambient light, the display cannot be read.

The present invention is directed to a novel circuit construction for wristwatches and similar portable timing devices which extends both the life of the liquid crystal and the life of the power source by controlling a switch in response to ambient light levels which turns off the display for that period of time when there is only a low ambient light or no ambient light at all. Some examples of when the display is turned off include occasions when the watch is in a darkened room, such as a theater, in a bedroom at night when the owner is sleeping, and when the watch is on the owner's wrist but covered by a jacket, coat or shirt sleeves.

The control circuits of this invention are also applicable to active type displays, such as those utilizing light-emitting diodes for digitally displaying watch time. Displays of this type when incorporated in portable solid state timing devices have in the past usually been off except when they are switched on by means of a display control switch. This is done to conserve power because of their relatively high current drain. In the present in-

vention, the active display, such as one incorporating light-emitting diodes, is permitted to run continuously, i.e., is normally on, except when switched off by the control circuit here disclosed. In addition to turning off the active display during periods of darkness, the active light display control circuit preferably includes an arrangement to also turn off the display when ambient light is so bright as to cause "washout". The circuits of both the active and passive display controls include a manual switch so that the display may be turned on and read at the option of the wearer when the display has been turned off by the automatic control. That is, a manual switch is provided to override the automatic turn-off portion of the circuit should the wearer decide for some reason to activate the display when it would be otherwise turned off.

FIG. 5 shows a light control circuit for the wristwatch of FIG. 1 incorporating an active type timing display such as one utilizing light-emitting diodes. The station **38** in FIG. 5 is representative of any one of the stations **64, 70, 68, 72,** and **74** in FIG. 4. Display station **66** in FIG. 4 is formed by a pair of commonly connected bar segments which are either on or off to display a "1" in accordance with the hours tens condition of the time display. The bar segments of the light-emitting diodes in FIG. 5 are connected to the display actuator which includes a display logic circuit **86** connected by leads **88, 90, 92, 94, 96,98,** and **100** to respective NOR gates **102, 104, 106, 108, 110, 112,** and **114.** The outputs of the NOR gates are connected to the seven bar segments by the leads **84.** Each of the NOR gates is provided with three inputs and in addition to the inputs connected to the display logic circuit **86,** a second input of each of the gates is connected by a lead **116** to the junction of a first potentiometer or resistance divider **118** comprising a fixed resistor **120** and a variable photosensitive resistor **122.** A third input of each of the NOR gates is similarly connected by a lead **124** to a second potentiometer or resistance divider **126** comprising fixed resistor **128** and photosensitive resistor **130.** The two potentiometers are connected between the positive terminal **132** of the watch battery **62** and the grounded or negative side of the battery as indicated at **134** and **136** in FIG. **5.**

In operation of the circuit of FIG. **5,** a signal is transmitted from the display logic **86** to the various NOR gates which control the seven segment active display for each digit. With positive logic employed and photoresistors as the light sensors, the NOR gates are on or off as follows.

a. When the ambient light is low, the photoresistor resistance of resistor **122** is high and the junction **138** is at a more positive potential. At the same time, the resistance of photoresistor **130** is also high and junction **140** is negative and no signal is received by the display so that the display is off.

b. When ambient light is bright enough to cause "washout", the resistance of resistor **130** is low and junction **140** is more positive. At the same time, the resistance of resistor **122** is low and junction **138** is close to ground potential so again no signal is passed through the NOR gates.

c. When the ambient light is normal (not too light or too dark), the resistance of resistor **130** is high and resistor **122** is low so that junctions **138** and **140** are both close to ground and a signal passes through the gate and the display is on.

While the circuit of FIG. **5** has been described utilizing photoresistors **122** and **130,** it is apparent that one or both of these may be replaced by phototransistors.

As can be seen from the above description, when the ambient light level is such as that occurring in darkness or semi-darkness, i.e., below a predetermined level, both photoresistors **122** and **130** are in the high resistance state. In this condition, the positive potential on lead **116** prevents signals from the logic display **86** actuating the display station **38.** Conversely, when the ambient light is so high as to cause "washout", both photoresistors **122** and **130** are energized to their low resistance state and in this condition the high potential on lead **124** prevents the display from being energized. However, when the ambient light is in a predetermined range between the maximum and minimum values just described, photoresistor **122** is in the low resistance state and photoresistor **130** is in the high resistance state. In this case, both leads **116** and **124** are at a low potential so that signals from the display logic circuit **86** are transmitted to the display station **38** and the diodes are illuminated. The override switch **18** is connected across photoresistor **122** so that closure of this switch when the ambient light is in the dark or semi-dark condition shorts the high resistance of photoresistor **122** and the display is illuminated at the option of the wearer as long as the pushbutton switch **18** remains depressed and closed.

FIG. **6** shows a modified light control circuit for passive type timing displays in which like parts bear like reference numerals. In this case, the display station **38'** is comprised of seven segments **40', 42', 44', 46', 48', 50',** and **52'** of passive elements such as liquid crystals. These liquid crystal segments are energized over leads **84** from the logic display **86** as in the previous embodiment through NOR gates **150, 152, 154, 156, 158, 160,** and **162.** Each of the gates has one input connected to the display logic through respective leads **88, 90, 92, 94, 96, 98,** and **100** and the other input of each NOR gate is connected to common lead **164** in turn connected to the junction **166** of a voltage divider **168** comprising fixed resistor **170** and photoresistor **172.** As before, the photoresistor may be replaced by an equivalent phototransistor. Resistance divider **168** is connected between the positive terminal **132** of the power supply and the negative or grounded side of the power supply as indicated at **176.** A double pole, single throw switch **18'** when closed shorts photoresistor **172** to ground by way of lead **178.** Closure of the pushbutton switch **18'** through its other pole connects a suitable light source **178** across the power supply. This light source is positioned on the watch so as to transmit light to the display stations such as **38'** so that the display is illuminated and readable when the switch **18'** is closed. This switch again acts as an override switch to short out the high resistance of photoresistor **172** under dark or semi-dark ambient light conditions at the wearer's option. Light source **178,** by way of example only, may be a beta light as shown and described more fully in assignee's copending application Ser. No. 119,806, filed Mar. 1, 1971, a continuation of Ser. No. 794,551, now abandoned filed Jan. 28, 1969, the disclosure of which is incorporated herein by reference.

In operation, a signal is transmitted from the display logic **86** to the seven bar segment liquid crystal display **38'** through the NOR gates. As before, a logic "1" or positive signal at any input of the gate produces a "0"

at the gate output and blocks the signal from the display logic **86** to the segments. With such an arrangement, the NOR gates are on or off as follows.

When the ambient light is low, the resistance of photoresistor **172** is high and junction **166** is more positive. This results in a positive input to the NOR gates so that their outputs are negative and no signal is received by the display and the display is off. When the ambient light is above a predetermined minimum level, i.e., above the dark or semi-dark state, the resistance of photoresistor **172** is low, junction **166** is more negative or zero and the display is on. When the display is off, as at night or when ambient light is dim, the switch **18'** may be closed to short the photoresistor **172** and turn the display on. At the same time, the beta light **178** is energized to illuminate the liquid crystals so that they may be read. In some instances, switch **18'** may be a single pole switch and the separate pole for shorting out photoresistor **172** eliminated. In this case, closure of switch **18'** energizes the beta light **178** which radiates enough light onto the face of the watch so that the photoresistor **172** assumes a low resistance and the display is automatically turned on in response to the light from light source **178.**

It is apparent from the above that the present invention provides an improved solid state watch construction and particularly an improved light control system for turning the watch display off when the watch is not being read. The control circuit draws a minimum of power and may be actuated directly from the 3 volt power supply of a conventional electronic watch source. Important features of the present invention include the provision of a display, either active or passive, in which the display is normally on at all times but is turned off to conserve power and to prolong the life of the display during those times when the display is not likely to be read. For passive displays incorporating a liquid crystal display, a single photoresistor may be utilized (or phototransistor) on the face of the watch to turn off the display when the light falls below a predetermined level. The circuit preferably incorporates an override switch in both instances and with the passive display the switch may be combined with a separate light source such as a beta light so that the display may be read at the option of the wearer even when the ambient light is below the predetermined turn-off value. A second embodiment disclosed is directed to an active display such as one incorporating light-emitting diodes. Here again, the display is preferably provided with an override switch such that the display may be illuminated and read even when the light is below the predetermined turn-off level. The active display circuit preferably incorporates a second photoresistor or phototransistor for turning off the display not only when ambient light is too low, but also when the ambient light is too high so as to cause "washout" during which times the display is difficult to read anyway.

The display control system of the present invention may be combined with intermittent energization of the display both automatically or at the option of the wearer and further may be used in combination with automatic brightness control circuitry which varies the brightness of the display in accordance with ambient light conditions. However, the control circuit of the present invention is particularly adapted for use with a watch which is normally in the on condition and which is turned off only during periods of non-use by the automatic control circuitry of this invention. In addition to conserving battery power in that the display is not energized during periods of non-use, the automatic turn-off circuit of the present invention also helps to lengthen the life of the display itself which is of particular importance with respect to liquid crystal displays which at the present time have a somewhat limited useful life. It is understood that the switching control circuit disclosed turns off only the display and that the timekeeping components of the watch, including the frequency standard or frequency source **26** of FIG. **2,** the frequency converter **30** and the display actuator, are constantly energized so that time is always being kept and is ready for display at any time.

The invention may be embodied in other specific forms without departing from the spirit or essential characteristics thereof. The present embodiments are therefore to be considered in all respects as illustrative and not restrictive, the scope of the invention being indicated by the appended claims rather than by the foregoing description, and all changes which come within the meaning and range of equivalency of the claims are therefore intended to be embraced therein.

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

1. In a timepiece having an electro-optical time display, a photosensor, switch means coupling said photosensor to said display whereby said display is switched off when the light incident on said photosensor falls below a predetermined level, and a second photosensor, said switch means including means for switching off said display when the light incident of said second photosensor rises above a predetermined level.

2. A timepiece of sufficiently small size and power consumption for use as a wristwatch comprising a source of constant frequency electrical signals, a frequency divider coupled to the output of said source for producing a low frequency timing signal, an electro-optical time display, a display actuator coupling said frequency divider to said time display, said display actuator comprising a switch for switching off said display, and light responsive means coupled to said switch for actuating said switch when the light incident on said display falls below a predetermined level, said actuator comprising a display logic circuit, said switch comprising a plurality of logic gates coupling said logic circuit to said display.

3. Apparatus according to claim **2** wherein said display is of the passive type.

4. Apparatus according to claim **3** wherein said display comprises a plurality of liquid crystals.

5. Apparatus according to claim **2** wherein said display actuator includes a manual override switch for turning on said display when said light is below said predetermined level.

6. A timepiece according to claim **2** wherein said logic gates are NOR gates.

7. A timepiece according to claim **6** wherein said light responsive means comprises a resistance divider including a photosensor, and means coupling an intermediate point on said resistance divider to said NOR gates.

8. A timepiece according to claim **7** including a manual override switch coupled to said resistance divider for momentarily shorting out at least a portion of said resistance divider.

9. A timepiece according to claim 7 wherein said display comprises a plurality of passive elements, an auxiliary light source adjacent said display for directing light on said display, and a manual override switch for energizing said auxiliary light source when said light is below said predetermined level at the option of the timepiece wearer.

10. A timepiece according to claim 9 wherein said auxiliary light source comprises a beta light.

* * * * *