United States Patent [19]

Bergey

[11] **3,871,170**

[45] **Mar. 18, 1975**

[54] **SOLID STATE WATCH DISPLAY SWITCH**

[76] Inventor: **John M. Bergey,** 1807 Mayflower Cir., Lancaster, Pa. 17603

[22] Filed: **Feb. 20, 1974**

[21] Appl. No.: **444,146**

Related U.S. Application Data

[60] Division of Ser. No. 354,192, April 25, 1973, Pat. No. 3,823,550, which is a continuation-in-part of Ser. No. 217,765, Jan. 14, 1972, Pat. No. 3,742,699, which is a continuation-in-part of Ser. No. 138,557, April 29, 1971, Pat. No. 3,782,102.

[52] **U.S. Cl.** ..... **58/50 R,** 240/6.43

[51] **Int. Cl.** **G04b 19/30,** G04c 17/02

[58] **Field of Search** ..... 58/50 R; 240/6.43

[56] **References Cited**

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Primary Examiner—Edith Simmons Jackmon

Attorney, Agent, or Firm—LeBlanc & Shur

[57] **ABSTRACT**

Disclosed is a solid state wristwatch with an electro-optical digital display of light-emitting diodes. Incorporated in the watch is a switch for actuating the display in response to a predetermined movement of the wearer's arm so that movement of the other hand or arm is not required and the other hand is left free for carrying packages or other uses.

6 Claims, 18 Drawing Figures

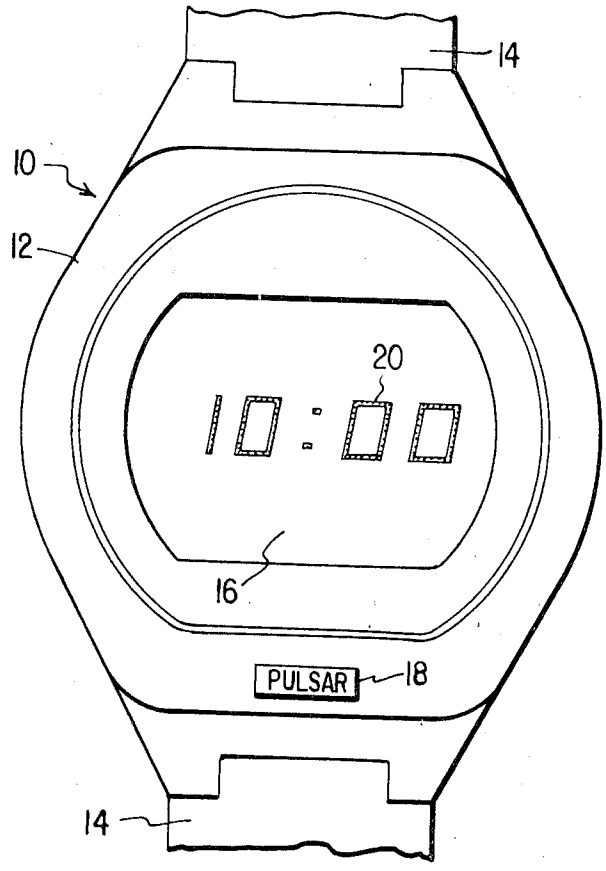


FIG. 1

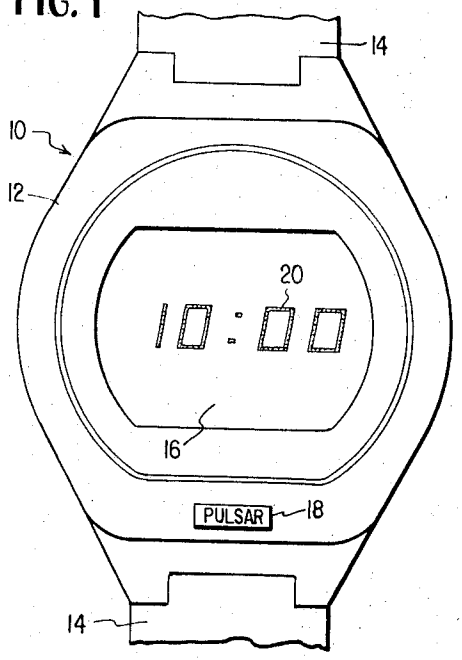
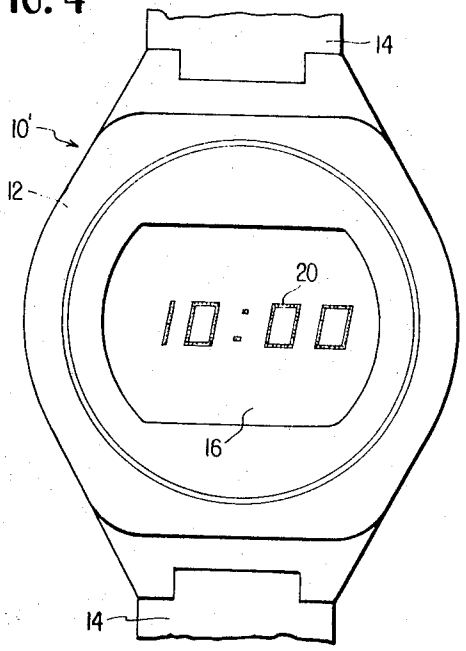


FIG. 4



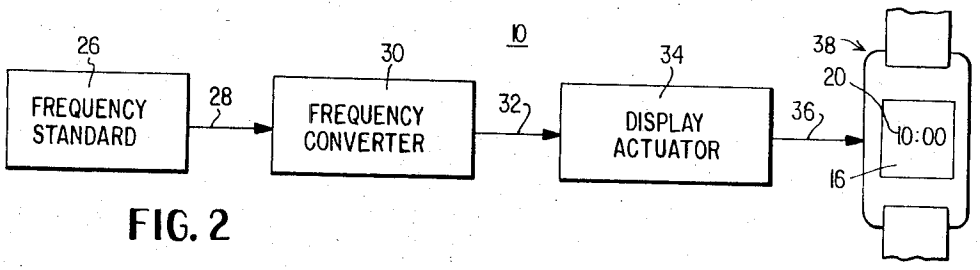


FIG. 2

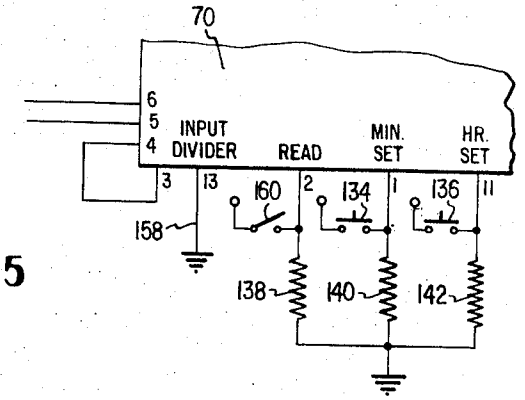


FIG. 5

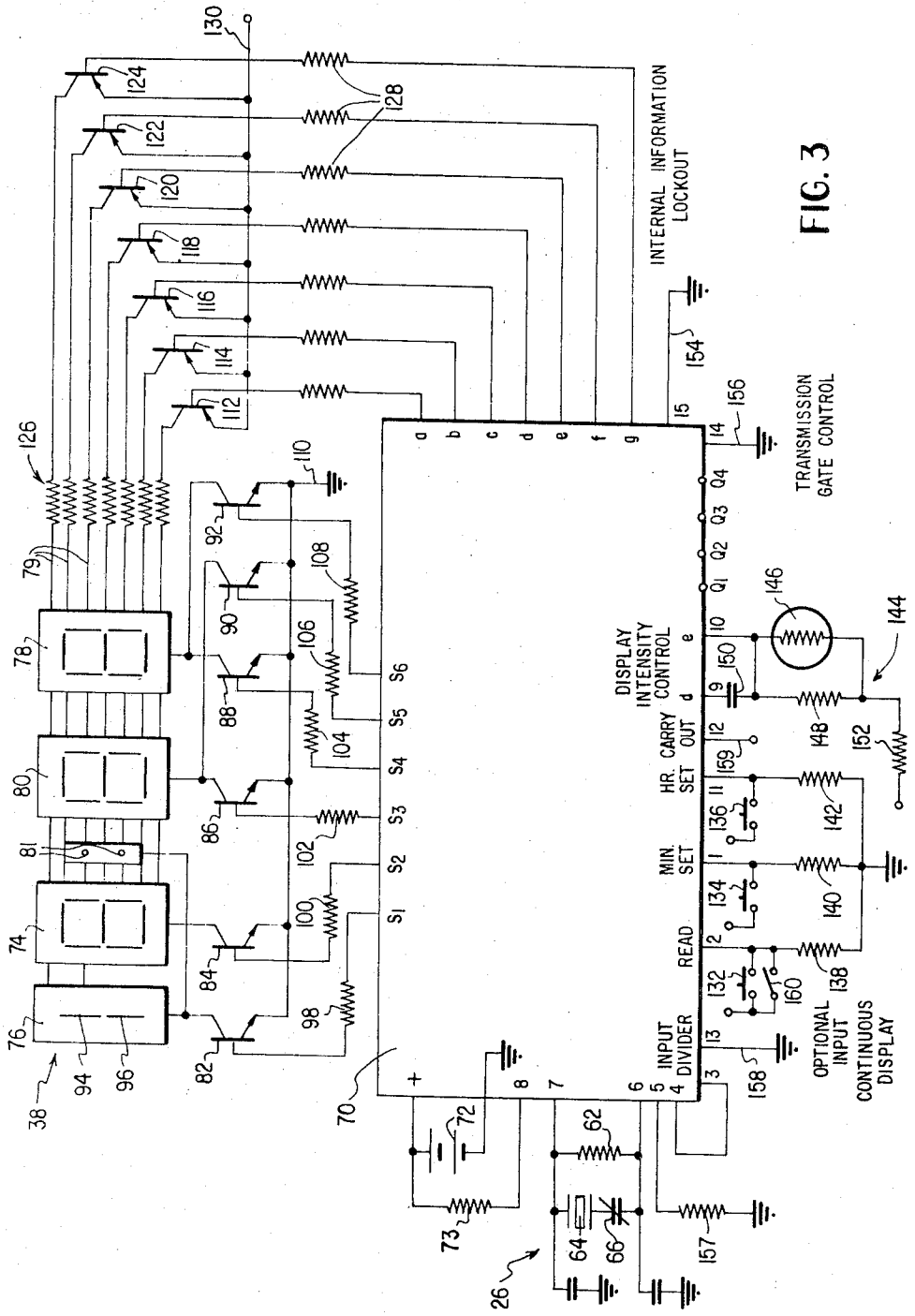

INTERNAL INFORMATION LOCKOUT
TRANSMISSION GATE CONTROL
DISPLAY INTENSITY CONTROL
HR. CARRY OUT
HR. SET
MIN. SET
READ
INPUT DIVIDER
OPTIONAL INPUT
CONTINUOUS DISPLAY

FIG. 3

FIG. 6

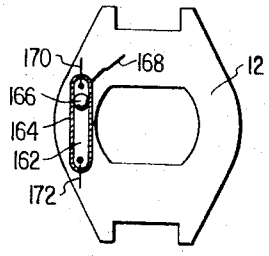


FIG. 8

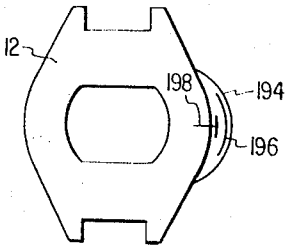


FIG. 7

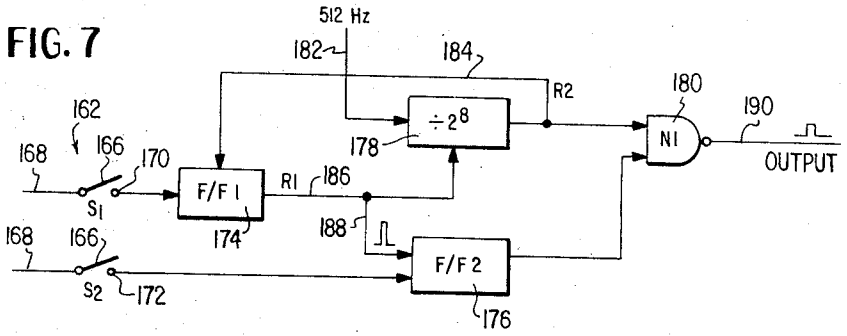


FIG. 9

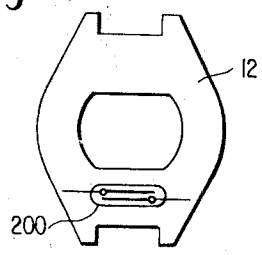


FIG. 10

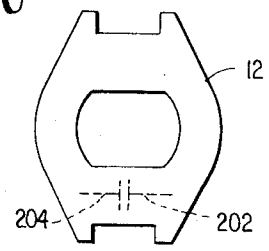
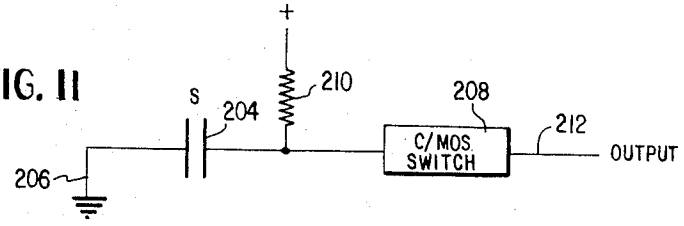


FIG. 11



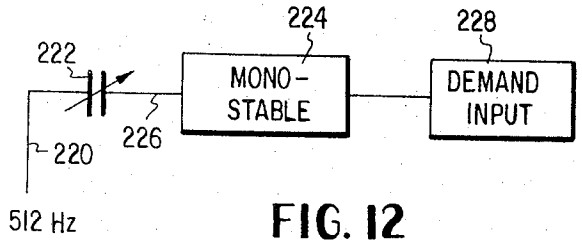


FIG. 12

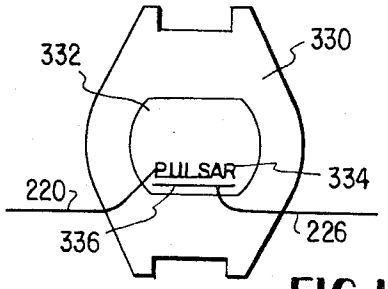


FIG. 13

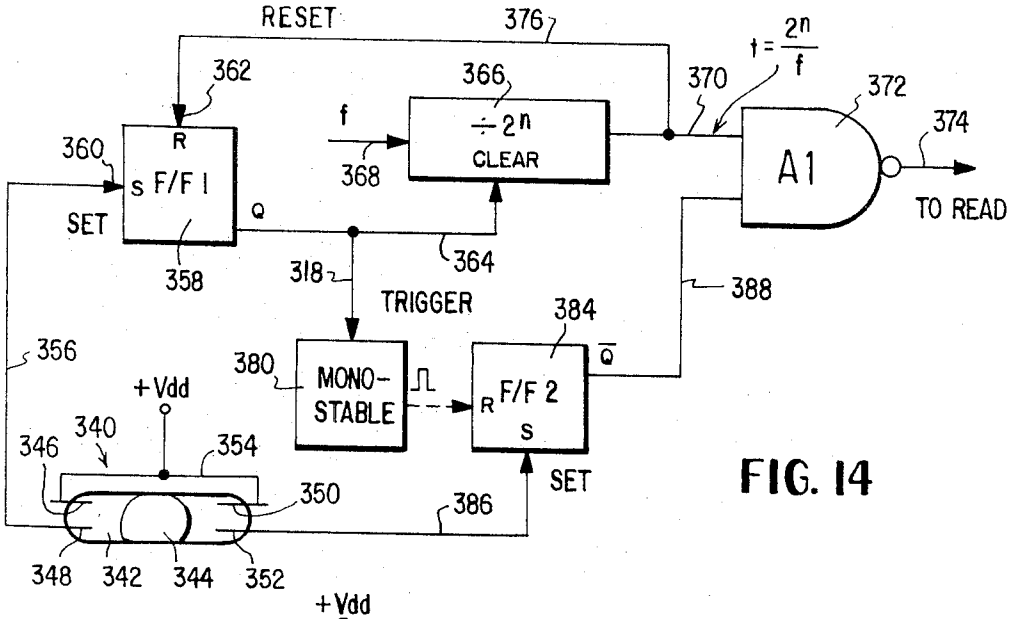


FIG. 14

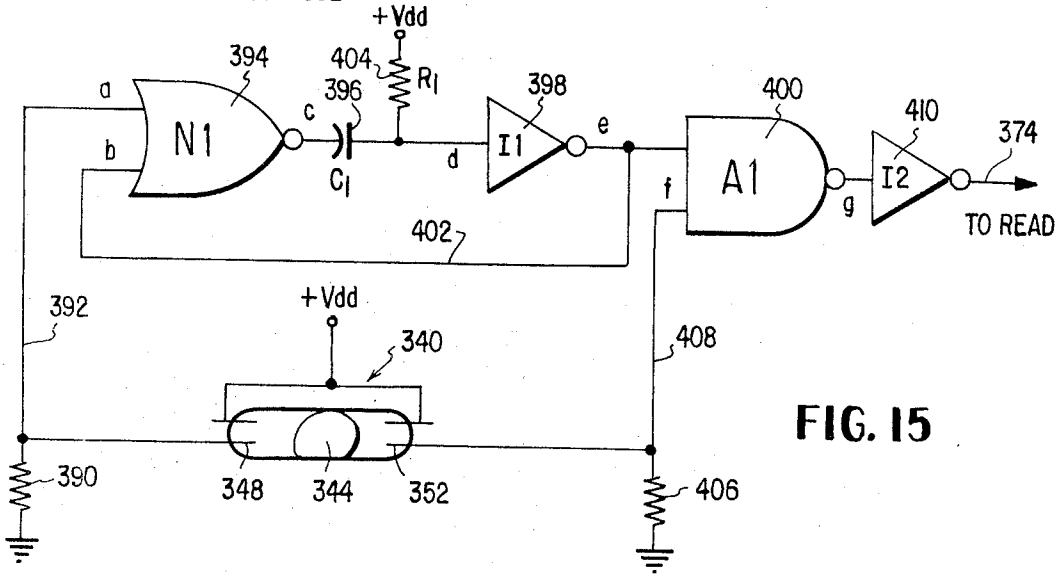


FIG. 15

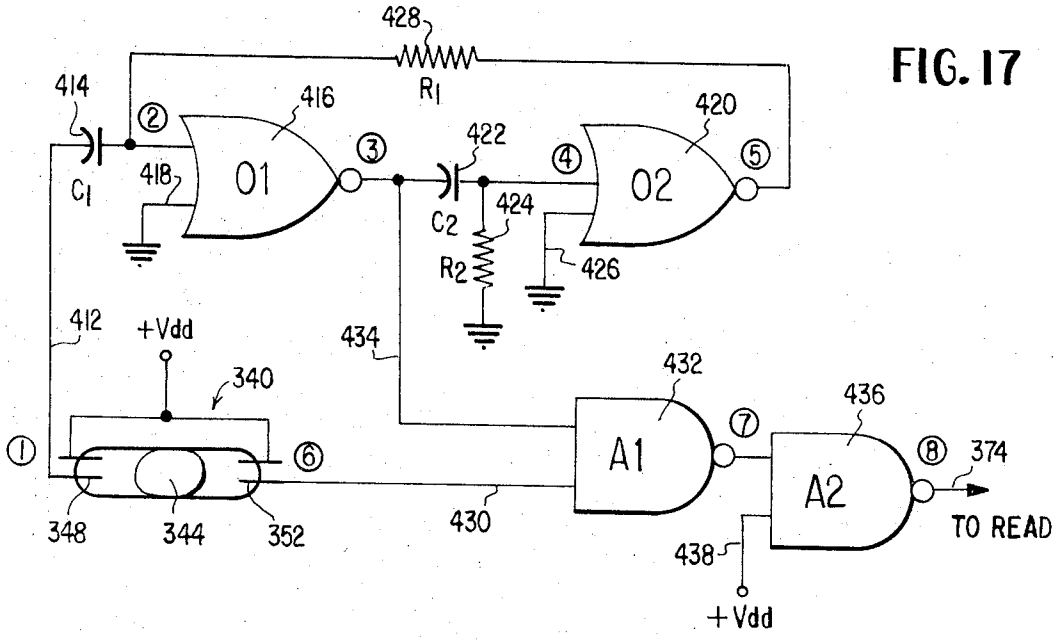


FIG. 17

FIG. 16

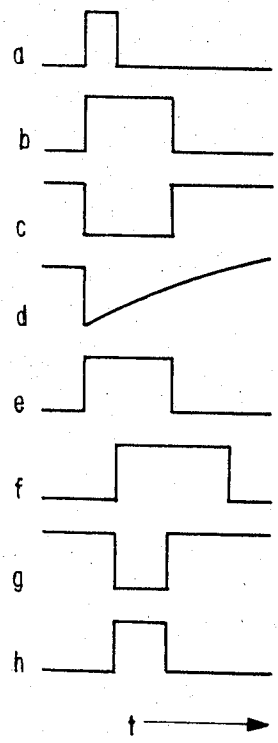
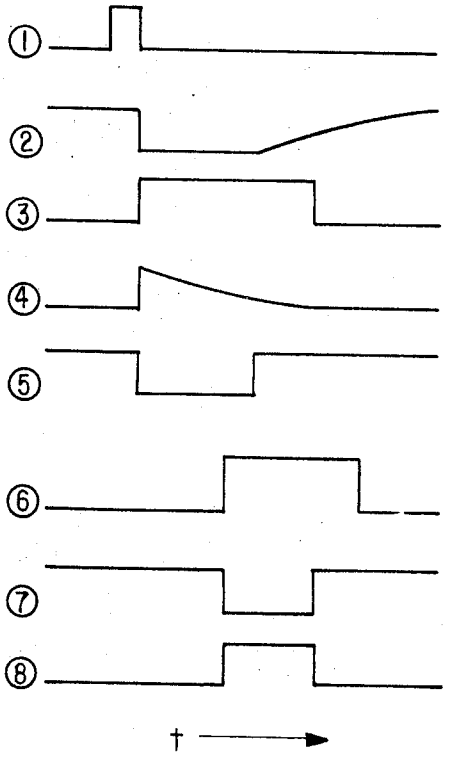


FIG. 18



SOLID STATE WATCH DISPLAY SWITCH

This is a division, of application Ser. No. 354,192 filed Apr. 25, 1973 which is now U.S. Pat. No. 3,823,550 and which is a continuation-in-part of co-pending U.S. Pat. application Ser. No. 217,765, filed Jan. 14, 1972, which is now U.S. Pat. No. 3,742,699 and which is in turn a continuation-in-part of U.S. co-pending Pat. application Ser. No. 138,557, filed Apr. 29, 1971, which is now U.S. Pat. No. 3,782,102.

This invention is directed to a solid state watch having an electro-optical display and, more particularly, to an improved switching arrangement for the display. In the present invention, the watch incorporates an arm-actuated switch which is operated when the wristwatch is moved with the arm of the wearer into a predetermined position or in a predetermined manner.

This invention relates to a solid state timepiece and, more particularly, to an electronic wristwatch which employs no moving parts. 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 of an electro-optical 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. The active components of the watch are completely sealed for longer life and the watch incorporates a read switch/magnetic setting arrangement.

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 is of the type shown and described in assignee's U.S. Reissue Pat. No. RE 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. In many instances, these constructions have utilized a crystal controlled high frequency oscillator as a frequency standard in conjunction with frequency conversion circuitry to produce a drive signal at a suitable timekeeping rate. However, difficulties have been encountered in arriving at an oscillator/frequency converter combination having not only the required frequency stability but also sufficiently low power dissipation and small size to be practical for use in a battery-powered wristwatch.

In order to overcome these and other problems, there is disclosed in assignee's U.S. Pat. No. 3,560,998, issued Feb. 2, 1971, a high frequency oscillator type watch construction using 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 takes the from of a plu-

rality of light-emitting diodes which are intermittently energized on demand at the option of the wearer of the watch. This assures a minimum power consumption and an increasingly long life for the watch battery. An improved watch construction of this general type incorporating solid state circuits and integrated circuit techniques is disclosed in assignee's U.S. Pat. No. 3,672,155 issued June 27, 1972.

The present invention is directed to an improved watch construction of the same general type as disclosed in the aforementioned patents and one which utilizes no moving parts to perform the timekeeping function. The watch of the present invention consists of three major components, namely, a quartz crystal time base, a miniature time computer module, and a power supply or battery. These microminiature components are packaged in a conventional sized wristwatch chassis or case. The tiny quartz slab is precisely cut to predetermined dimensions so that it vibrates at 32768 Hz when properly stimulated by pulses from an electronic oscillator. The high frequency from the crystal time base is divided down to 1 pulse per second by utilizing a multistage integrated circuit binary counter. The time computer module counts the pulse train, encodes it into binary form, and then decodes and processes the result so as to provide the appropriate signals at display stations.

Situated on the front of the watch adjacent the display is a pushbutton demand switch which, when depressed, instantly activates the appropriate visual display stations. Minutes and hours are programmed to display for one and one-quarter seconds, with just a touch of the demand switch. Continued depression of this switch causes the minute and hour data to fade and the seconds to immediately appear. The seconds continue to count as long as the wearer interrogates the computer module. Computation of the precise time is continuous and completely independent of whether or not it is displayed.

The watch display consists of a television screenlike colored filter which passes the cold red light from gallium arsenide phosphide (GaAsP) or gallium phosphide (GaP) light-emitting diodes. Preferably, a seven segment array forms each individual number (except for the hours tens station) at the appropriate moment at a brightness determined by a specially constructed dimmer or display intensity control circuit. This dimmer circuit utilizes a photodetector to measure ambient lighting conditions so the display intensity provides viewing comfort under all day or nighttime lighting conditions.

An important feature of the present invention is the incorporation in a watch of this type of a switch for energizing the display diodes in response to a predetermined movement of the wearer's arm on which the wristwatch is mounted during normal operation. In one embodiment, the arm-actuated switch is used as the sole demand switch for actuating the display, whereas in the preferred embodiment the arm-actuated switch is provided as an alternative to the conventional demand switch, also incorporated in the watch.

As is well known, light-emitting display diodes at the present time typically consume relatively large amounts of current when they are activated. Because of this, it has been found desirable to readout from the watch the displayed time only upon interrogation by the wearer. For this purpose, the watch has incorpo-

rated a demand switch actuated by a demand button on the face of the watch so that the time is displayed and the diodes energized only when the demand button is depressed. The demand button is most conveniently operated by the thumb or finger of the wearer's other hand, requiring freedom of the wearer's hand in order to depress the button. In some instances, such as when the wearer is carrying packages or objects in his other hand, depressing of the demand button in order to ascertain the time may be inconvenient.

In order to overcome this difficulty, the present invention incorporates in the wristwatch, preferably in addition to the conventional demand switch, an arm-actuated switch which causes the display to be illuminated and the time to become visible in response to a predetermined movement of the wearer's arm on which the wristwatch is mounted. In one embodiment of the present invention, the arm-actuated switch takes the form of an inertial switch operated by a short quick motion of the arm in opposing directions in a plane essentially horizontal to the watch face. In a second embodiment, a force-actuated switch is provided which operates in response to an upward movement of the hand or arm in a direction perpendicular to the plane of the watch face. In another embodiment, the display is provided with a magnetic switch and a permanent magnet is attached to or made a part of the wearer's clothing, such as for example a permanent magnet is embedded in a belt buckle. When the wearer wishes to observe the time, he simply draws his arm containing the watch into contact or close proximity to the permanent magnet. In still another embodiment of the present invention, the watch is provided with a capacitive switch actuated by a change in ambient capacitance brought about by moving the switch contained on the exterior surface of the watch away from the wearer's skin into proximity of the wearer's body. In all instances, the arm-responsive or arm-actuated switch is constructed and positioned to insure that a deliberate action will cause the switch closure, but at the same time to minimize inadvertent actuation of the switch by activity which one would experience during normal routine functions.

It is therefore one object of the present invention to provide an improved electronic wristwatch.

Another object of the present invention is to provide a wristwatch which utilizes no moving parts for performing the timekeeping function.

Another object of the present invention is to provide a solid state wristwatch incorporating an armactuated switch for the watch display.

Another object of the present invention is to provide a solid state watch having both a demand switch and an arm-actuated switch.

Another object of the present invention is to provide a solid state wristwatch in which the display is actuated by an inertial switch.

Another object of the present invention is to provide a solid state wristwatch in which the display is actuated by a force-responsive switch through operation of the wearer's wrist.

Another object of the present invention is to provide a solid state wristwatch in which the watch display is actuated by a magnetic switch in response to movement of the wearer's wrist.

Another object of the present invention is to provide a solid state wristwatch in which the watch display is actuated by a capacitive or resistance switch.

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 front or plan view of a wristwatch constructed in accordance with the present invention;

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

FIG. **3** is a detailed circuit diagram of portions of the electrical circuit of the wristwatch of FIG. **1**;

FIG. **4** is a plan view, similar to FIG. **1**, of a modified embodiment of the wristwatch constructed in accordance with the present invention;

FIG. **5** is a partial circuit diagram corresponding to FIG. **3** for the embodiment of the wristwatch illustrated in FIG. **4**;

FIG. **6** illustrates an arm-actuated inertial switch incorporated in the wristwatch of either FIG. **1** or FIG. **4**;

FIG. **7** is a circuit diagram showing the manner of operation of the inertial switch of FIG. **6**;

FIG. **8** shows a wrist-operated force-responsive switch for the wristwatch of either FIG. **1** or FIG. **4**;

FIG. **9** shows a magnetic read switch for the wristwatch of either FIG. **1** or FIG. **4**;

FIG. **10** illustrates diagrammatically a capacitive switch incorporated in the wristwatch of either FIG. **1** or FIG. **4**;

FIG. **11** is a circuit diagram illustrating the manner of operation of the capacitive switch of FIG. **10**;

FIG. **12** shows a modified capacitive switch circuit;

FIG. **13** shows a capacitive switch construction usable in the circuit of FIG. **12**;

FIG. **14** shows a circuit for a digital timer inertial switch similar to the one shown in FIG. **7**;

FIG. **15** shows a leading edge triggered circuit for an inertial switch constructed in accordance with this invention;

FIG. **16** shows voltage waveforms at various locations in the circuit of FIG. **15**;

FIG. **17** illustrates a trailing edge monostable inertial switch circuit; and

FIG. **18** shows voltage waveforms for the circuit of FIG. **17**.

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 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 demand switch pushbutton **18** by means of which the display **20** may be actuated when the wearer of the wristwatch **10** desires to ascertain the time.

In normal operation, time is continuously being kept but is not displayed through the window **16**. That is, no time indication is visible through the window and this is the normal condition which prevails in order to conserve battery energy in the watch. However, even though the time is not displayed through the window **16**, it is understood that the watch **10** continuously keeps accurate time and is capable of accurately displaying this time at any instant. When the wearer desires to ascertain the correct time, he depresses the pushbutton **18** with his finger and the correct time is immediately displayed at **20** through the window **16**.

The hours and minutes are displayed through the window **16** for a predetermined length of time, preferably one and one-quarter seconds, irrespective of whether or not the pushbutton **18** remains depressed. The exact time of the display is chosen to give the wearer adequate time to consult the display to determine the hour and minute of time. Should the minutes change during the time of display, this change is immediately indicated by advancement of the minute reading to the next number as the watch is being read. If the pushbutton **18** remains depressed, at the end of one and one-quarter seconds, the hours and minutes of the display are extinguished, i.e., they disappear, and, simultaneously, the seconds reading is displayed through the window **16**. The advancing seconds cycling from **0** to **59** continue to be displayed through window **16** until pushbutton switch **18** is released.

FIG. **2** is a simplified block diagram of the principal components of the watch **10** of FIG. **1**. The circuit comprises a time base or frequency standard **26** including a piezoelectric crystal to provide a very accurate frequency such that the frequency standard or oscillator oscillates at 32,768 Hz. This relatively high frequency is supplied by a lead **28** to a frequency converter **30** in the form of a divider which divides down the frequency from the standard so that the output from the converter **30** appearing on lead **32** is at a frequency of 1 Hz. The frequency converter **30** preferably comprises a binary counting chain of complementary MOS transistors of the type shown and described in assignee's U.S. Pat. No. 3,560,998, the disclosure of which is incorporated herein by reference. The 1 Hz signal is applied by lead **32** to a display actuator **34** which, in turn, drives the display **20** of the watch **10** by way of electrical lead **36**.

FIG. **3** is a circuit diagram of the watch **10** of the present invention with like parts bearing like reference numerals. Integrated circuit portions of the watch are illustrated by the large block **70**. This block may be formed of several integrated circuit chips, but in the preferred constructions, the large block **70** is formed of a single chip. In any event, it is understood that all the components within block **70** are formed by large-scale integrated circuit techniques.

In addition to the integrated circuit **70** in FIG. **3**, the watch comprises a battery **72** which, by way of example only, may comprise a 3 volt wristwatch battery or two conventional 1½ volt wristwatch cells connected in series. Connected to the positive side of the battery is a resistor **73** and the battery energizes the time display, generally indicated at **38**, which is shown in FIG. **3** as consisting of a pair of hours stations comprising the digits station **74** and the tens stations **76** and a pair of combination minutes and seconds stations comprising digits station **78** and tens station **80**. Stations **74**, **78**, and **80** in the preferred embodiment of the display each take 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. While a seven bar segment display is preferred, it is apparent that other type displays, such as a 27 dot matrix display, may be used.

In addition, the display **38** includes a pair of colon dots **81**, each formed by a single light-emitting diode. The display stations are energized from integrated circuit **70** connected to battery **72** by way of a plurality of leads **79**. The circuit is completed from the leads **79** to the anodes of the ligth-emitting diodes and the cathodes of the light-emitting diodes are individually connected to the other side of the power supply through strobing or switching N-P-N junction transistors **82**, **84**, 86, 88, 90, and **92**. There is a separate lead **79** for the total number of bar segments in a display station. That is, with a seven bar segment display, there are seven leads **79**, each one connected to a separate bar segment of each station as more fully described below. However, all the cathodes of each station are connected in common through the N-P-N junction transistor for that display. There are two bar segments **94** and **96** for the hours tens display station **76** and they have their cathodes connected to transistor **82** as do the colon dots **81**. All cathodes of the hours units station **74** are connected to transistor **84**. Display stations **78** and **80** are used to display both minutes and seconds so that station **80** has the cathodes of all diodes connected to transistor **86**, referred to as the minutes transistor, and to transistor **90**, which acts as the seconds transistor. Similarly, all the diode cathodes of display station **78** are connected to a minutes transistor **88** and a seconds transistor **92**. These transistors have their bases returned to the integrated circuit **70** through current limiting resistors **98**, **100**, **102**, **104**, **106**, and **108**, the emitters of the transistors being connected in common to ground, i.e., the negative side of the power supply battery **72**, as indicated at **110**.

The anodes of the bar segment diodes are energized from bipolar driver transistors illustrated in FIG. **3** as the P-N-P junction transistors **112**, **114**, **116**, **118**, **120**, 122, and **124**. Since the greatest number of bar segments at any display station is seven, there are seven driver transistors and seven leads **79**. The transistor collectors are connected to the display diodes through individual ones of current limiting resistors **126** and the driver transistor bases are connected to the integrated circuit **70** through protective resistors **128**. The emitters of the driver transistors are connected in common as at **130** to the positive side of power supply battery **72**.

Components of the oscillator **26** in FIG. **3** external to the integrated circuit **70** are the crystal **64**, the variable capacitor **66**, bias resistor **62**, and π network capacitors C_1 and C_2. The remaining portions of the oscillator are incorporated in the integrated circuit **70** of FIG. **3**. For a detailed description of the preferred embodiment of the oscillator, reference may be had to assignee's copending U.S. Pat. application Ser. No. 143,492, filed May 14, 1971, the disclosure of which application is incorporated herein by reference.

Also external to the integrated circuit is a demand or read switch **132** which is closed when the button **18** of FIG. **1** is depressed. Further manually operated switches external to the integrated circuit **70** are minute-set switch **134** and hours-set switch **136**. These switches are connected across battery **72** from the positive side of the battery to ground through respective series resistors **138**, **140**, and **142**. The resistors associated with these switches are used in order to ground the corresponding inputs, otherwise the corresponding inputs would be floating and could be anything. When closed, the switches are used to switch the input voltages from ground to plus.

In the watch of the present invention, the intensity of the light emitted from the display diodes is varied in accordance with ambient light. That is, the diode light in-

tensity is increased for greater contrast when the ambient light is bright, such as during daytime display, whereas the intensity of the light from the diodes is decreased when ambient light decreases. The automatic display intensity control circuitry if generally indicated at **144** in FIG. **3** and comprises a photosensitive resistor **146** suitably mounted on the face of the watch connected to the positive side of battery **72** and to a resistor **148** and capacitor **150.** These components are connected to the positive side of the power supply through series resistor **152.** Other external components connected to integrated circuit **70** include an internal information lockout lead **154,** a transmission gate control lead **156,** and an optional input or continuous display lead **158,** all normally grounded. A further connection to ground is through resistor **157** and the integrated circuit **70** is also provided with a carryout lead and terminal **159.**

For a detailed disclosure of the elements making up integrated circuit **70** and the operation of the watch circuitry illustrated in FIG. **3,** reference may be had to the previously mentioned copending U.S. Pat. application Ser. No. 143,492, filed May 14, 1971, incorporated by reference. Briefly, the oscillator **26** under the control of piezoelectric quartz crystal **64** produces an output signal having a frequency of 32,768 Hz. This is divided down by the frequency converter **30** incorporated in integrated circuit **70** in the form of a binary divider chain to a frequency of 1 Hz. The display actuator **34,** also partially incorporated in the integrated circuit **70,** decodes and converts these signals into a form suitable for driving a display which timing signals are applied through resistors **128** and bipolar driver transistors **112, 114, 116, 118, 120, 122,** and **124** as time-indicating signals to the anodes of the display diodes of the display stations. The intensity of the light from the display diodes is controlled by the photosensor **146** mounted on the face of the watch in response to the intensity of ambient light. In order to converse energy from the watch battery, not all stations are energized at the same time. To this end, strobing signals are developed at the integrated circuit terminals S_1, S_2, S_3, S_4, S_5, and S_6 and these are applied to the strobe transistors **82, 84, 86, 88, 90** and **92.** When the demand button is first depressed, the hours are displayed on stations **74** and **76** and the minutes of time are displayed on stations **78** and **80.** After one and one-quarter seconds, these stations are extinguished and if the demand button remains depressed, stations **78** and **80** then display the seconds of time as long as the demand button remains depressed. It is thus seen that stations **78** and **80** serve to display both minutes and seconds. The strobing outputs are such that the sequence of the display is as follows:

(a) tens of hours and colon, (b) units of hours, (c) tens of minutes, (d) units of mintues when the demand button is first depressed or, if it remains depressed after one and one-quarter seconds, (a) nothing, (b) nothing, (c) tens of seconds, (d) units of seconds, and in either event the cycle then repeats.

An important feature of the present invention resides in the fact that the watch **10** is provided with an arm-responsive switch **160** connected in parallel with the demand switch **132** as illustrated in FIG. **3.** Switch **160** is normally open but closes in response to a predetermined movement of the wearer's arm on which the wristwatch is mounted. In this way, it is not necessary for the demand button **18** of FIG. **1** to be depressed for time to be displayed by the diodes. This makes it possible for the wristwatch wearer to ascertain the time even in those instances where it may not be convenient to press the demand button, such as when he is carrying something or in any other instance when the other hand is otherwise occupied.

In the preferred embodiment of the present invention, the arm-actuated switch **160** is used in combination with or in additon to the demand switch **132** actuated by pushbutton **18.** FIG. **4** is a front or plan view of a modified watch **10** consturcted in accordance with the present invention. The wristwatch of FIG. **4** is in all respects identical to the watch of FIG. **1** with the exception that the pushbutton **18** is eliminated. In this embodiment, the display is only actuated by a predetermined movement of the wearer's arm and the watch is provided with a single display switch, such as the arm-actuated switch **160** as illustrated in FIG. **5.** As can be seen, the only difference between the two emobidments is that the arm-actuated switch in the embodiment of FIGS. **4** and **5** is the sole switch for actuating the display, whereas in the embodiment of FIGS. **1–3,** the arm-actuated switch **160** is connected in parallel with the demand switch and the display may be operated by actuation of either one of the switches.

FIG. **6** illustrates one form which the armactuated switch **160** may take. FIG. **6** is a view of the watch case **12** with the back removed and the other parts of the watch omitted for the sake of clarity. Mounted within the watch case by suitable adhesive, such as epoxy or the like, is a miniature inertial switch; generally indicated in FIG. **6** at **162.** The switch comprises an electrically conductive metal sleeve **164** in which is mounted a free-floating electrically conductive metal ball **166.** Sleeve **164** is connected to an electrical lead **168.** Passing through one end of sleeve **164** is a first electrical contact **170** and passing through the other end of the sleeve is a second electrical contact **172.** Contacts **170** and **172** are electrically insulated from sleeve **164** by any suitable means, such as for example by surrounding the portion of the contact passing through the sleeve with a suitable electrical insulator (not shown). FIG. **7** shows the equivalent electrical circuit for the switch **162** and shows associated components, including a first flip-flop **174,** a second flip-flop **176,** a divider **178,** and an NAND gate **180.** Divider **178** is connected by a lead **182** to the binary divider chain forming the frequency converter **30** of FIG. **2** so that a **512** Hz signal available from one of the stages of the frequency converter **30** is applied to divider **178** of FIG. **7.** In operation, the inertial switch **162** is actuated by a short quick motion of the arm on which the watch is mounted in opposing directions in a plane essentially horizontal to the face of the watch. The round metal ball **166** in FIG. **6** first impacts against the round insulated contact **170** and the metal sleeve which contains the ball. With this impact, a closure signal is sent to the time circuit illustrated in FIG. **7.** Before a preselected time has elapsed, for example, 500 milliseconds, the ball must complete the second circuit through insulated contact **172.** In this way, both contacts have to be closed by a deliberate swing of the arm within a preselected time interval. A wearer would rarely duplicate this particular motion sequence during routine daily activities.

Referring to FIG. **7,** switch **S2** comprising ball **166** and insulated contact **172** can be in any state but switch

S2 and S1 (formed by the ball and contact 170) cannot both be closed at the same time because of the mechanical nature of the switch as illustrated in FIG. 6. Flip-flop 176 can be at any state but flip-flop 174 is reset to receive an input from switch S1 by a reset pulse (R2) from divider 178 over lead 184. Nothing happens until switch S1 closes. When switch S1 closes, flip-flop 174 produces an output reset pulse (R1) which is applied by a lead 186 and a further lead 188 to flip-flop 176. The pulse on lead 188 resets flip-flop 176 and the pulse on lead 186 applied to counter 178 resets the counter. Reset pulse R1 at the output of flip-flop 174 is conditioned prior to entry into flip-flop 176 to get a short pulse. The 512 Hz input to the counter on lead 182 causes an output to occur on an output lead 190 from NAND gate 180 after 2^8 pulses are counted which takes about 500 milliseconds. The 512 Hz signal is readily available from the frequency divider 30 of the watch and negative logic is used in FIG. 7 for consistency with the rest of the watch circuit. If switch S2 is closed before the 500 millisecond limit, the other necessary signal to cause an output pulse from NAND gate 180 is present. If switch S2 does not close within 500 milliseconds after the closure of switch S1, counter 178 will not cause a NAND gate output, but merely resets flip-flop 174. The output 190 from NAND gate 180 triggers the display circuit in the same manner as momentary closure of the demand switch 132 so that the hours and minutes of times are displayed for a predetermined period, such as one and one-quarter seconds. The construction shown in FIGS. 6 and 7 is fully compatible for use in addition to the demand switch as illustrated in FIG. 3 or may be used without a demand switch as illustrated in the circuit of FIG. 5. In both cases, the construction of FIGS. 6 and 7 constitutes the arm-responsive switch 160, generally illustrated in FIGS. 3 and 5.

FIG. 8 illustrates a modified construction for the arm-responsive switch 160 of FIG. 3 or FIG. 5. In FIG. 8, the arm-responsive switch, generally indicated at 192, takes the form of a simple force-actuated mechanical switch. Force switch 192 is mounted on the side of the watch case 12 and is a simple single-pole single-throw switch comprising a flexible diaphragm 194 carrying a movable switch contact 196 and a stationary or fixed contact 198 mounted in the sidewall of the watch case 12. Again, switch 192 is constructed so that it is actuated by a deliberate and somewhat unconventional movement of the watch wearer which is completely independent of the arm or hand of the wearer opposite that on which the watch is mounted. In the embodiment illustrated in FIG. 8, the switch is contained inside the sealed flexible diaphragm 194 and an upward movement of the hand in a direction perpendicular to the plane of the watch face causes the movable contact 196 to be forced along with the diaphragm into engagement with the fixed contact 198 by the lower back side of the hand upon which the wristwatch is mounted. That is, the watch is placed in the conventional manner on the wearer's wrist but is oriented so that the switch 192 faces forward, i.e., toward the wearer's hand. With the watch worn in the normal upward facing position, a backward flexure of the wrist causes the lower back side of the hand to engage the diaphragm 194 to close the contacts and operate the switch. With this construction, the switch may be held closed as long as the wearer desires, i.e., as long as his wrist remains flexed, and the switch 192 functions in the exact same manner as the pushbutton switch 132.

FIG. 9 shows a further embodiment of the switch 160 of FIGS. 3 and 5. In FIG. 9, the switch, indicated at 200, takes the form of a magnetic switch mounted by epoxy or other suitable adhesive on the inside of the case 12, which case is made of nonmagnetic material. By way of example only, switch 200 may be a magnetic reed switch of the type shown and described in copending U.S. Pat. application Ser. No. 138,557 filed Apr. 29, 1971. This switch is preferably mounted close to the inside surface of the watch case so that it may be actuated by bringing a permanent magnet close to the outside of the watch case adjacent the location of the reed switch 200 so that the switch is operated by the magnetic field from a permanent magnet passing through the watch case. Again, switch 200 acts in the same manner as the demand switch 132 and can be held closed as long as possible. In order to obtain arm-responsive operation, the permanent magnet is attached to or made part of the wearer's clothing. In the preferred embodiment, a permanent magnet is embedded in the buckle of the wearer's belt. When the wearer wishes to observe the time, he simply draws his arm on which the watch is mounted into contact with or close proximity to his belt buckle so that the permanent magnet in the buckle operates the switch 200 to display time. Again, the time display is independent of the wearer's other arm and requires a fairly unconventional movement or bringing of the watch into a fairly unconventional position, such as one which would not be experienced during normal routine functions.

FIG. 10 shows a further modified construction for the arm-responsive switch 160. In the embodiment of FIG. 10, the switch, indicated by the reference numeral 202, is responsive to capacitance and includes a capacitor 204. The capacitor is indicated in dashed lines in FIG. 10 to indicate that it is mounted on the outside surface of the watch case 12 where it is normally away from or remote from the wearer's wrist. The switch is actuated by a change in capacitance with the switch being sensitive enough to be actuated by a change in ambient capacitance brought about by moving the watch on which the switch is mounted away from the wearer's skin into proximity with the body of the wearer. As an alternative to change in capacitance, the circuit can be made responsive to change in resistance if desired and the electrical circuit for either a variable capacitance, variable resistance, or a switch combining both is illustrated in FIG. 11. In this circuit, the capacitor 204 is connected between ground 206 and a complementary MOS transistor switch 208. Connected in series between ground and the positive side of the power supply of the battery with capacitor 204 is a resistor 210. A change in either capacitance or resistance or both causes the complementary MOS switch 208 to change state producing an output on lead 212 to energize the display in the manner previously described. The change in resistance can, for example, be brought about by contact with the bare skin of the wearer. Other more complicated circuits can be used, including sensing the detuning of a tuned oscillator circuit by bringing body capacitance into the circuit and completing a circuit through the introduction of normally available body moisture. Other arrangements for varying either capacitance, resistance, or both, are readily apparent.

FIG. 12 shows a modified circuit construction forming a capacitive switch in accordance with the present invention and FIG. 13 illustrates the physical construction for the capacitor used in the switching circuit of FIG. 12. Referring to FIG. 12, lead 220 is connected to a suitable high frequency source in the watch such as to the frequency converter or divider 30 of FIG. 2 to supply a high frequency signal to the variable capacitor 222. By way of example only, lead 220 may be connected to one of the stages of the divider where a binary signal such as a 512 Hz square wave is available and supplied to the capacitor. The output of capacitor 222 feeds the input of a monostable multivibrator 224 by way of lead 226. The output of monostable 224 is connected to the demand circuit input illustrated at 228 in FIG. 12 which, by way of example, may comprise the resistor 138 of FIG. 3 so that when the monostable 224 changes state a demand signal is developed across resistor 138 and applied to the READ input 2 of the large scale integrated circuit 70 of FIG. 3.

FIG. 13 illustrates a watch case 330 having a viewing window in which is mounted a watch crystal or glass 332. A logo 334 is etched preferably into the underside of glass 332 and filled with an electrical conductor such as gold, silver or aluminum so that the logo 334 forms one plate of variable capacitor 222 of FIG. 12. This plate is connected by lead 220 underneath the crystal to the divider. Also etched in the underside or inside surface of the watch glass or crystal is a line 336 similarly filled with an electrical conductor material to form the other plate of variable capacitor 222 and this plate is similarly connected by lead 226 inside the watch to the monostable 224. With the construction illustrated in FIG. 13 capacitor 222 formed by the logo 334 and line 336 may typically have a capacitance value of 0.1 pf. When the watch case and crystal are brought near the skin of the wearer of the watch, the capacitance increases to a value which may be on the order of 5 pf. This change in capacitance is sufficient to pass the 512 Hz signal on the lead 220 from the divider to the monostable 224 causing the output of the monostable to change state and energize the display diodes in the manner previously described.

FIG. 14 shows a digital timer for an inertial switch constructed in accordance with the present invention. The circuit of FIG. 14 is similar to that shown in FIG. 7 but includes a pulse shaper and a modified inertial switch construction. The inertial switch generally indicated at 340 comprises a sealed glass tube 342 preferably evacuated and filled with an inert gas. In the tube is a movable electrical conductor in the form of a drop of mercury 344 which is held together in a single cohesive mass by surface tension. Projecting through the left end of the glass tube in FIG. 14 are a first pair of electrodes 346 and 348 and projecting through the right end of the glass tube are a pair of similar spaced electrodes 350 and 352. Electrodes 346 and 350 are connected to the positive side of the power supply battery by a lead 354 or to $+V_{dd}$ as indicated in the drawing. Switch 340 forms a single pole double throw inertial switch with electrode 348 connected by lead 356 to a flip-flop 358 having a set input 360 and a reset input 362. The output Q of flip-flop 358 is connected by lead 34 to the clear terminal of a binary counter or register 366 which divides by 2^n where n is the number of binary stages in the counter. The counter input is taken from lead 368 labelled f and while this may be at any relatively high frequency lead 368 is preferably connected to the 512 Hz stage of the frequency converter or divider 30 of FIG. 2. The output of counter 366 is supplied by lead 370 as one input to a NAND gate 372 whose output 374 forms the read or demand signal to the diodes in the manner previously described. The counter output is also applied over lead 376 as a reset signal to flip-flop 358.

The Q output of flip-flop 358 is also applied over a lead 378 to a pulse shaper in the form of a monostable multivibrator 380 whose output on lead 382 is a narrow trigger pulse applied to the reset input of a second flip-flop 384. The set input of flip-flop 384 is connected by a lead 386 to the electrode 352 of switch 340. The Q output of flip-flop 384 is applied over a lead 388 as a second input to NAND gate 372.

In the operation of the circuit of FIG. 14 when the mercury drop 344 contacts the left pair of electrodes 346 and 348 flip-flop 358 switches states, enabling the divider 366 and this divider or counter acts as a digital delay. A pulse appears on the counter output lead 370 after a time of $2n/f$ seconds. By way of example only, this time delay may be on the order of 35 ms. The change of state of flip-flop 358 also triggers the one shot monostable 380 and the output of the monostable resets the second flip-flop 384.

When the mercury drop 344 subsequently engages the right electrodes 350 and 352 the signal on lead 386 sets flip-flop 384 and the output of this flip-flop applies a high level on lead 388 to one input of NAND gate 372. If the signal on lead 370 applied to the other input of the NAND gate is still low and the left contact 348 has acted through flip-flop 358 and monostable 380 to produce a low Q on lead 388, an output appears on output lead 374 of NAND gate 372 to activate the display. However, if an output from the divider on lead 370 appears first, it resets flip-flop 358 over lead 376 and also clears itself so that no output appears on lead 374 and the display is not energized.

FIG. 15 shows a modified circuit construction in which like parts bear like reference numerals. In this embodiment, the delay is formed by a leading edge triggered monostable multi-vibrator. In FIG. 15 electrode or contact 348 of the inertial switch 340 is connected to a grounded tie-down resistor 390 and by a lead 392 to one input of an NOR gate 394. The output of NOR gate 394 is connected through a capacitor 396 and an inverter 398 to one input of a NAND gate 400. The output of inverter 398 is fed back by way of a lead 402 to the other input of NOR gate 394 and the junction of capacitor 396 and inverter is connected through a resistor 404 to the positive side of the wristwatch battery power supply.

Electrode or contact 352 of the inertial switch 340 is also connected to a grounded tie-down resistor 406 and by way of a lead 408 to the other input of NAND gate 400. The output of the NAND gate is connected through a second inverter 410 to output lead 374 which energizes the display.

FIG. 16 shows voltage waveforms at various locations in the circuit of FIG. 15 labelled a through h respectively. In the operation of the circuit of FIG. 15 when the mercury drop 344 completes the circuit to the left contact 348 the positive pulse triggers a monostable multi-vibrator comprised of NOR gate 394, inverter 398 resistor 404 and capacitor 396. As a result, a positive pulse of a duration determined primarily by resis-

tor 404 and capacitor 396 is presented on lead e at the upper input to NAND gate 400. If the mercury switch 340 now makes contact to the right electrode 352 within that duration of time, a negative pulse is presented at the output of NAND gate 400 as indicated at g which is otherwise normally high and this pulse is inverted in inverter 410. If the switch does not make contact with electrode 352 within the R-C time constant period then no pulse is presented at the output g of NAND gate 400 and the display is not activated.

FIG. 17 shows a further modified inertial switch construction again with the parts bearing like reference numerals. In FIG. 17 the inertial switch 340 is utilized with a falling edge trigger monostable multivibrator. In this construction, the left electrode 348 of inertial switch 340 is connected by a lead 412 through a capacitor 414 to the upper input of a NOR gate 416 the lower input of which is grounded as indicated at 418. The output of NOR gate 416 is connected to the input of a second NOR gate 420 by way of a series capacitor 422 and a shunt resistor 424. The other input of NOR gate 420 is again grounded as indicated at 426. A feed back resistor 428 connects the output of NOR gate 420 to the upper input of NOR gate 416.

The right electrode 352 of inertial switch 340 is connected by a lead 430 to one input of a NAND gate 432. The other input of this NAND gate is connected by a lead 434 to the output of NOR gate 416. The output of NAND gate 432 feeds to one input of a second NAND gate 436 and the other input of this second NAND gate is connected to the positive side of the wristwatch power supply battery as indicated at 438. The output of NAND gate 436 on lead 374 again is the energizing signal or demand signal for the light-emitting diode display of the wristwatch.

FIG. 18 shows voltage waveforms at various points in the circuit of FIG. 17 labelled 1 through 8 respectively. The operation of the circuit of FIG. 17 is essentially the same as the operation of the circuit of FIG. 15. However, in FIG. 17 the monostable is falling edge triggered and engagement of the mercury drop 344 with the left-hand contact 348 actuates a monostable multivibrator formed by NOR gates 416 and 420. An impulse on lead 412 from the contact engagement produces a pulse of a duration determined primarily by resistors 424 and 428 and capacitors 414 and 422. This pulse is presented at the upper input of NAND gate 432 and if the mercury drop engages the right contact 352 within the duration of this pulse an output from NAND gate 432 is inverted in NAND gate 436 to produce a diode energizing output on output lead 374.

An important feature of the circuits of FIGS. 14, 15 and 17 as well as of the circuit of FIG. 7 is that all of these circuits may be constructed using complementary symmetry MOS transistors. This is also true of the capacitance circuit of FIG. 12. Since the circuits are useable with CMOS they are susceptible to large scale integration and may be incorporated into and form a part of the large scale integrated CMOS circuit 70 of FIG. 3. Using large scale integrated circuit techniques, the entire CMOS block 70 including the circuits just described may be formed on a single integrated circuit chip.

It is apparent from the above that the present invention provides an improved solid state wristwatch construction and, more particularly, one which incorporates a display actuating switch which is responsive to a predetemined movement of the wearer's arm. In all instances, the arm-responsive switch may be used by itself or in conjunction with a demand switch. It is provided to make it possible to display time without necessitating any operation by the wearer's other hand so that the other hand is free for carrying packages or other uses as may be desired. In all instances, the arm-responsive switch is constructed and/or positioned so that it is actuated only by a deliberate and relatively unconventional movement on the part of the wearer. This assures that the watch display will not be inadvertently actuated too many times so as to cause an undue drain on the watch battery.

In some embodiments, the arm-actuated switch produces only an impulse so that only the minutes and seconds of time are displayed for a preprogrammed duration, such as one and one-quarter seconds. In other embodiments, the arm-responsive switch may be actuated as long as the wearer desires so that the seconds of time are also displayed. It is apparent that different delays may be programmed into the watch if it is desired that time be automatically displayed for a longer period and it is further apparent that instead of displaying only hours and minutes in response to an electrical impulse, additional display stations may be provided so that hours, minutes and seconds may be automatically displayed for a predetermined length of time.

In the preferred embodiment, the electro-optical display elements take the form of light-emitting diodes. However, it is understood that the display can assume any one of several forms. For example, the electro-optical display may be formed using such well known devices as miniature incandescent bulbs, other types of light-emitting diodes, or the well known liquid crystals, as well as lesser known devices, such as ferro electric crystals or electroluminescent displays and others.

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.

I claim:

1. A wristwatch comprising a frequency standard for producing substantially constant frequency electrical signals, a frequency converter coupled to said frequency standard for producing corresponding electrical signals of lower frequency than said frequency standard, an electro-optical time display for displaying time in decimal numbers, a display acuator coupling said frequency converter to said electro-optical time display, an electrical power supply terminal for energizing said time display from a power supply, and an arm responsive switch coupling said power supply terminal to said display whereby said display is energized upon a predetermined movement of a wearer's arm upon which said wristwatch is mounted, said arm responsive switch being responsive to variations in resistance.

2. A wristwatch comprising a watch case, timekeeping means in said case including a solid state electronic circuit and an electro-optical time display for displaying time in decimal numbers, an electrical power supply terminal in said case for energizing said display from a power supply, and a switch carried by said case

coupling said power supply terminal to said display, said switch being operative in response to a predetermined movement of a wearer's arm upon which the wristwatch is mounted, said switch comprising a solid state switch, and an electrical impedance means coupled to said switch whereby said switch is operated in response to a change in impedance.

3. A wristwatch according to claim 2 wherein said impedance means comprises a capacitor and said switch is operated by a change in capacitance.

4. A wristwatch according to claim 3 including a viewing crystal, said capacitor being mounted on said crystal.

5. A wristwatch according to claim 4 wherein said capacitor is mounted on the inside surface of said crystal.

6. A wristwatch according to claim 2 wherein said impedance means comprises a resistor and said switch is operated by a change in resistance.

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