

[54] **MODULAR SOLID STATE WRISTWATCH**

[75] Inventors: **Robert E. McCullough**, Lancaster;
Cleon W. Hougendobler, East
Petersburg, both of Pa.

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

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58/85.5, 58/90 B

[51] Int. Cl. **G04b 19/30, G04b 37/04, G04b 27/00**

[58] Field of Search **58/23 R, 23 A, 23 AC,**
58/50 R, 85.5, 88, 90 R

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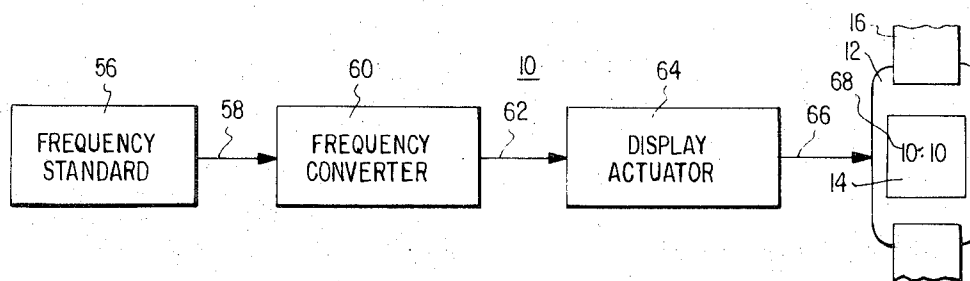
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Primary Examiner—Richard B. Wilkinson
Assistant Examiner—Edith C. Simmons Jackson
Attorney—Robert E. LeBlanc

[57] **ABSTRACT**

Disclosed is a solid state wristwatch having no moving parts and utilizing a digital time display of light-emitting diodes. The watch features a modular construction for ease of assembly and reliability. Also disclosed is a setting magnet for the watch stored in the watch bracelet.

20 Claims, 28 Drawing Figures



13 Sheets-Sheet 1

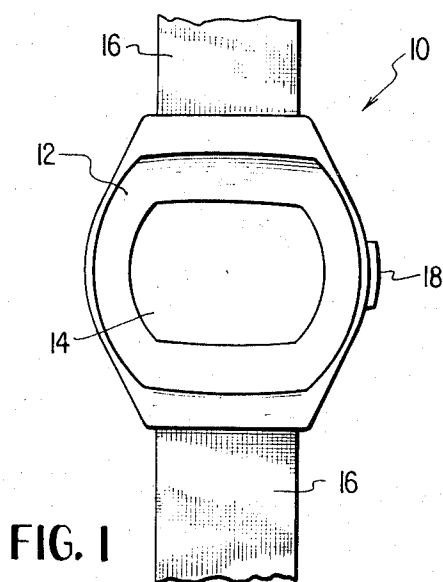


FIG. 2

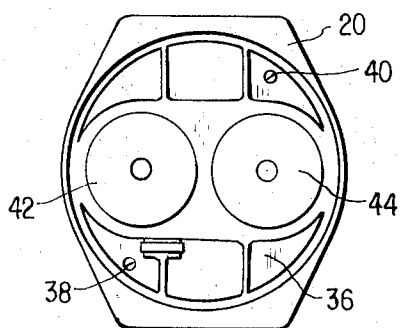
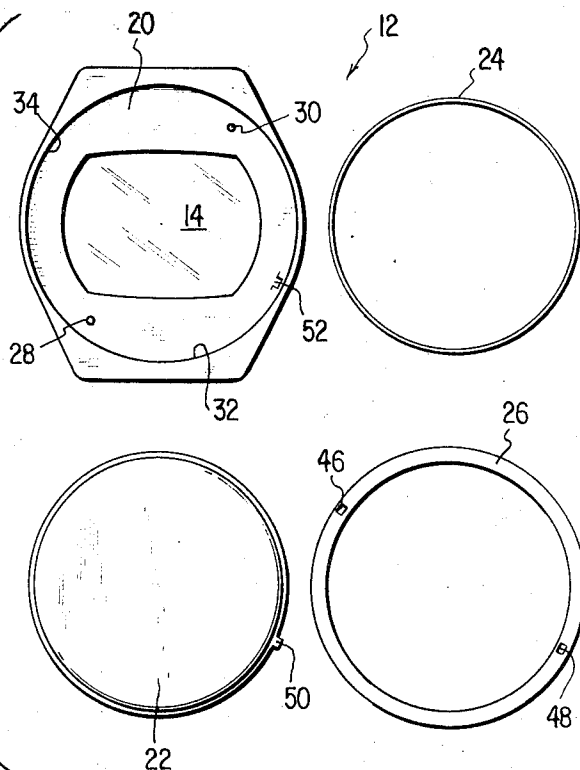


FIG. 3

FIG. 4

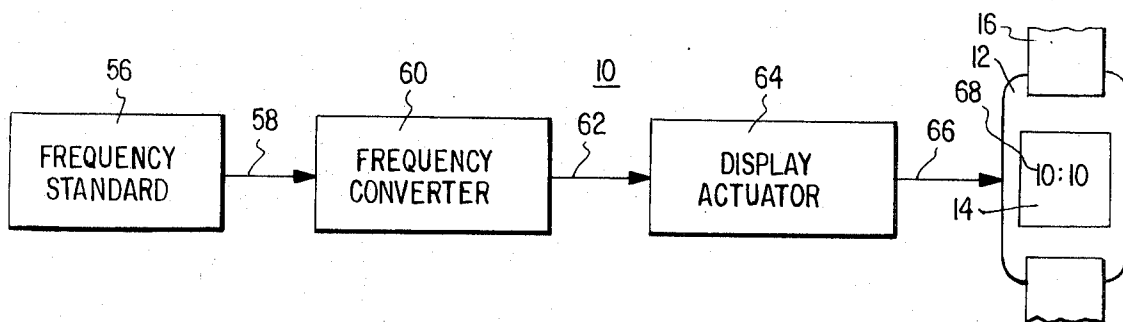
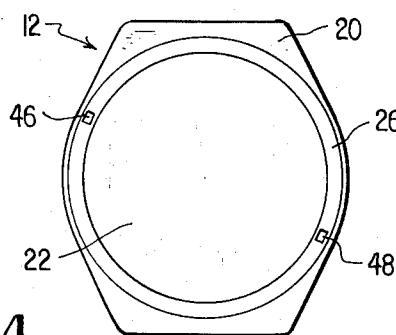


FIG. 5

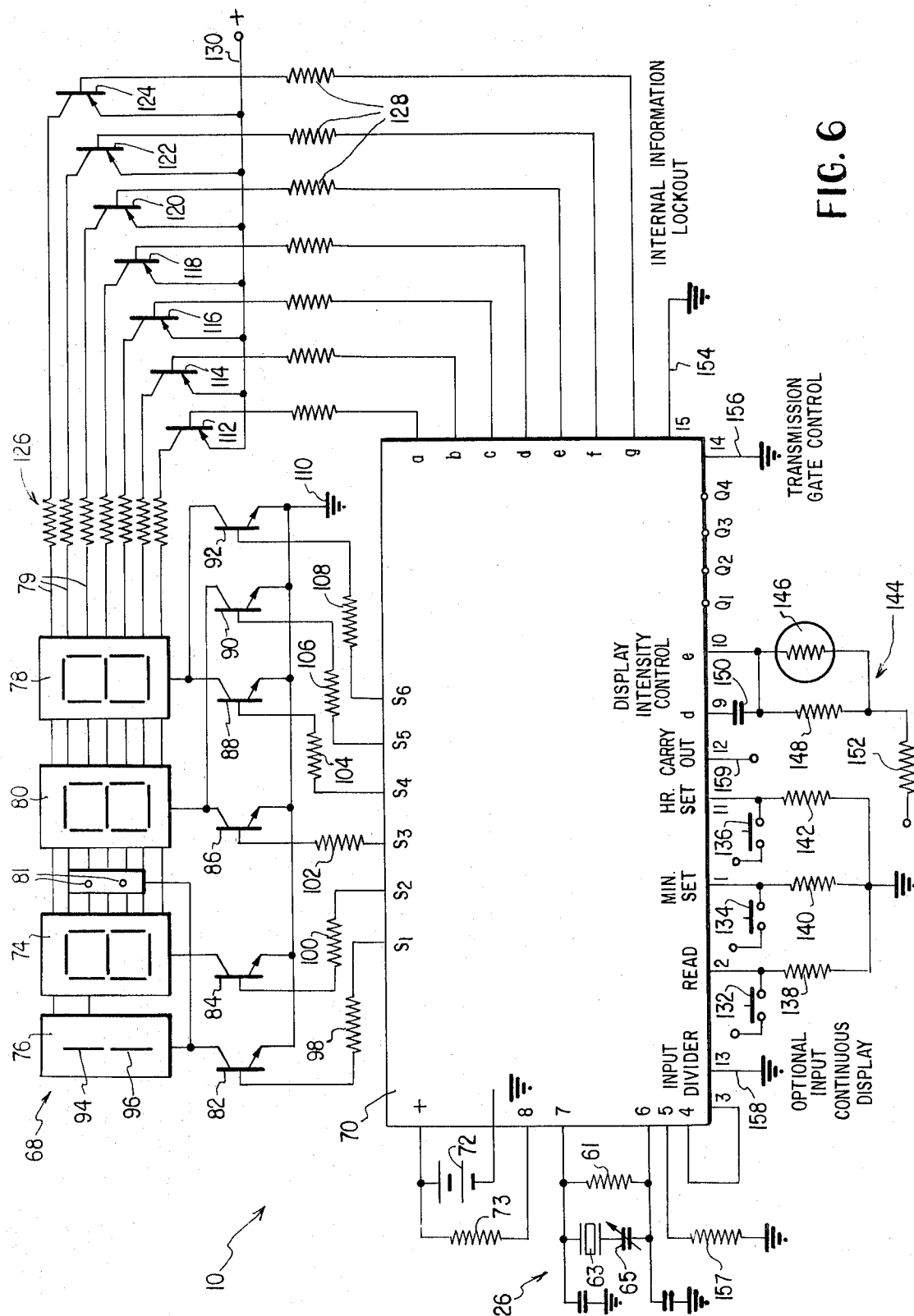
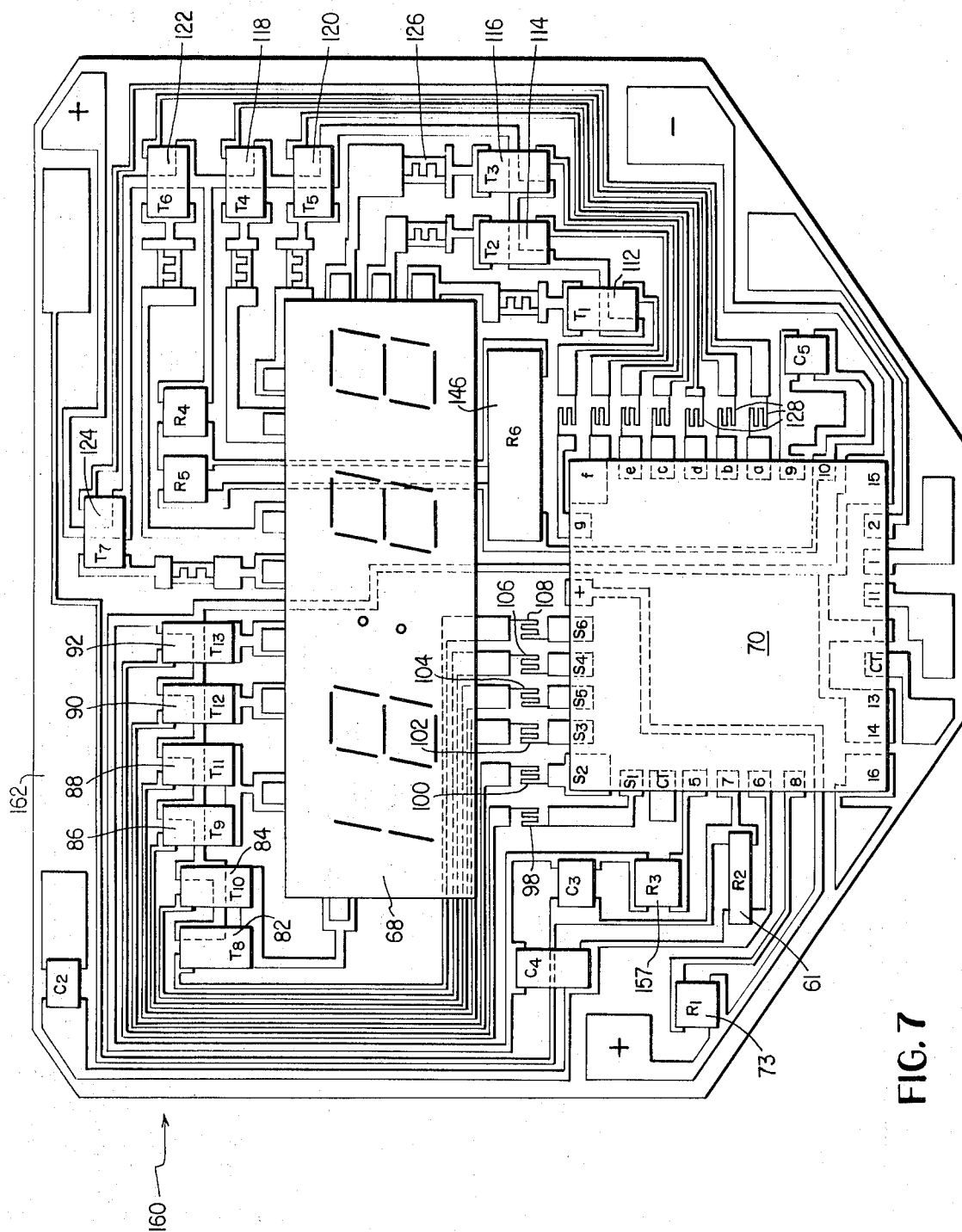


FIG. 6



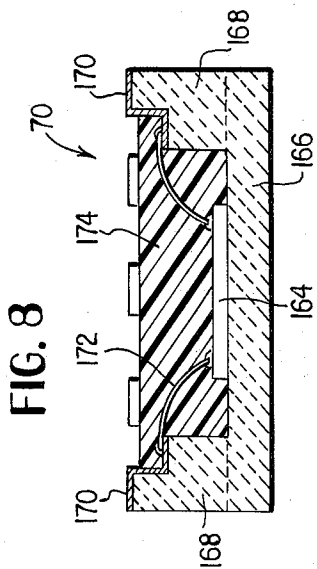
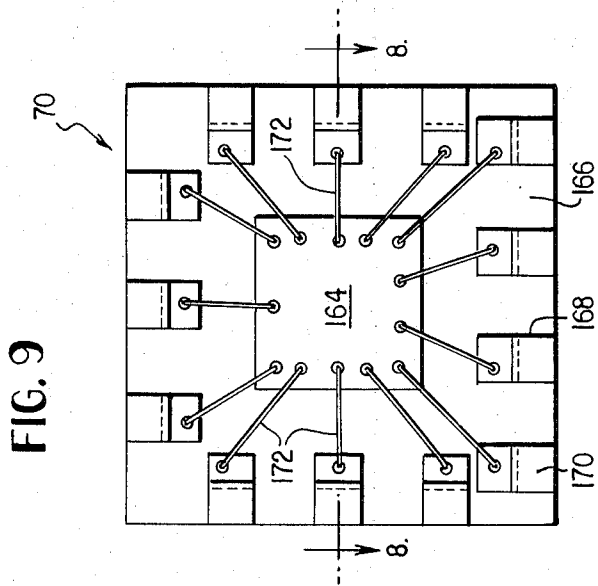
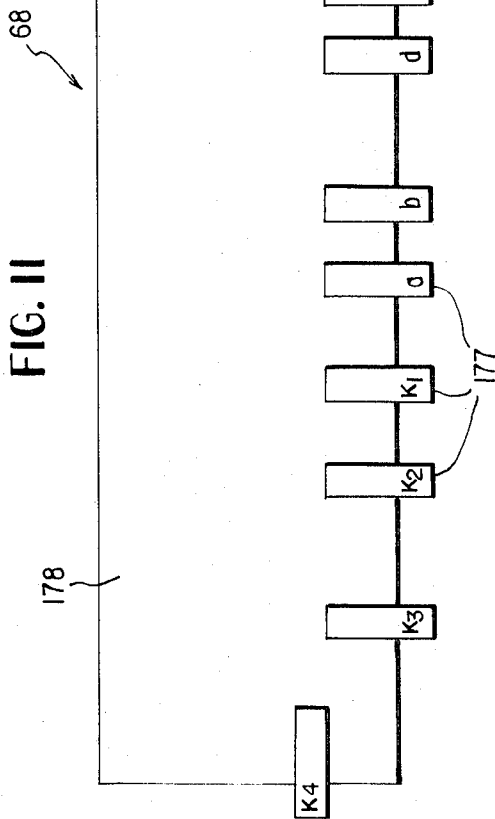
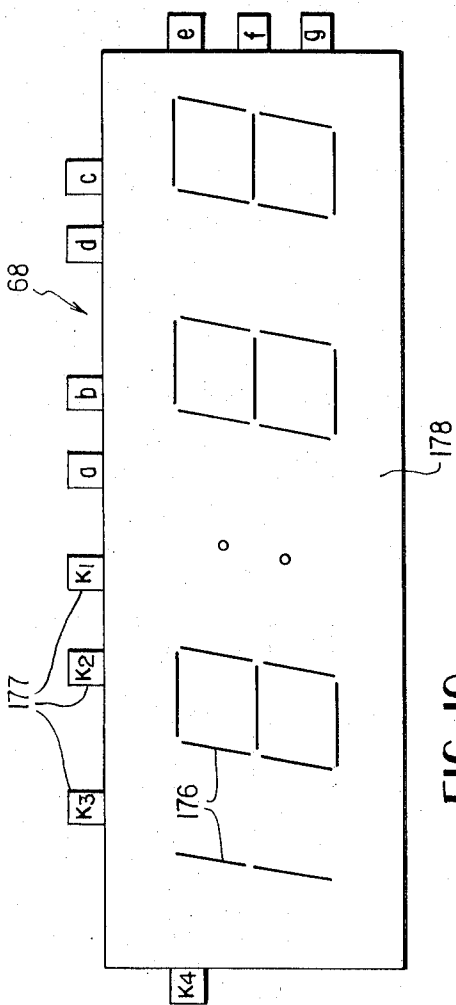


FIG. 12

68

178

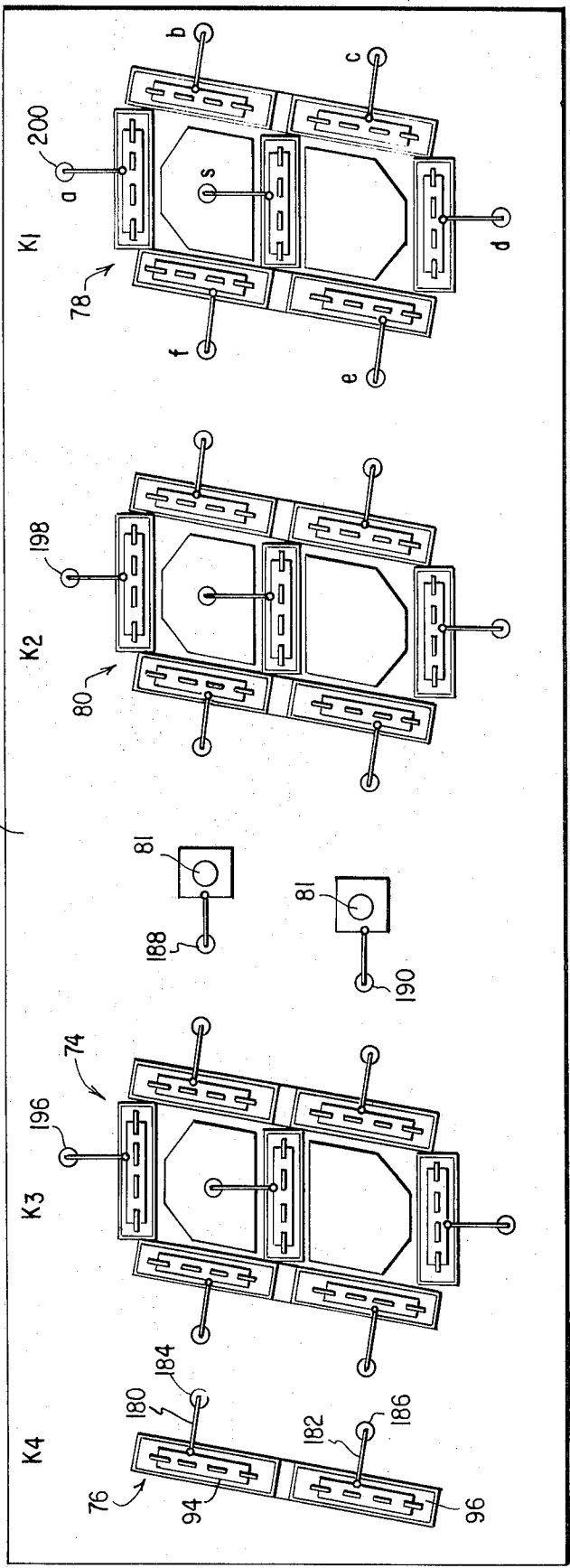


FIG. 13

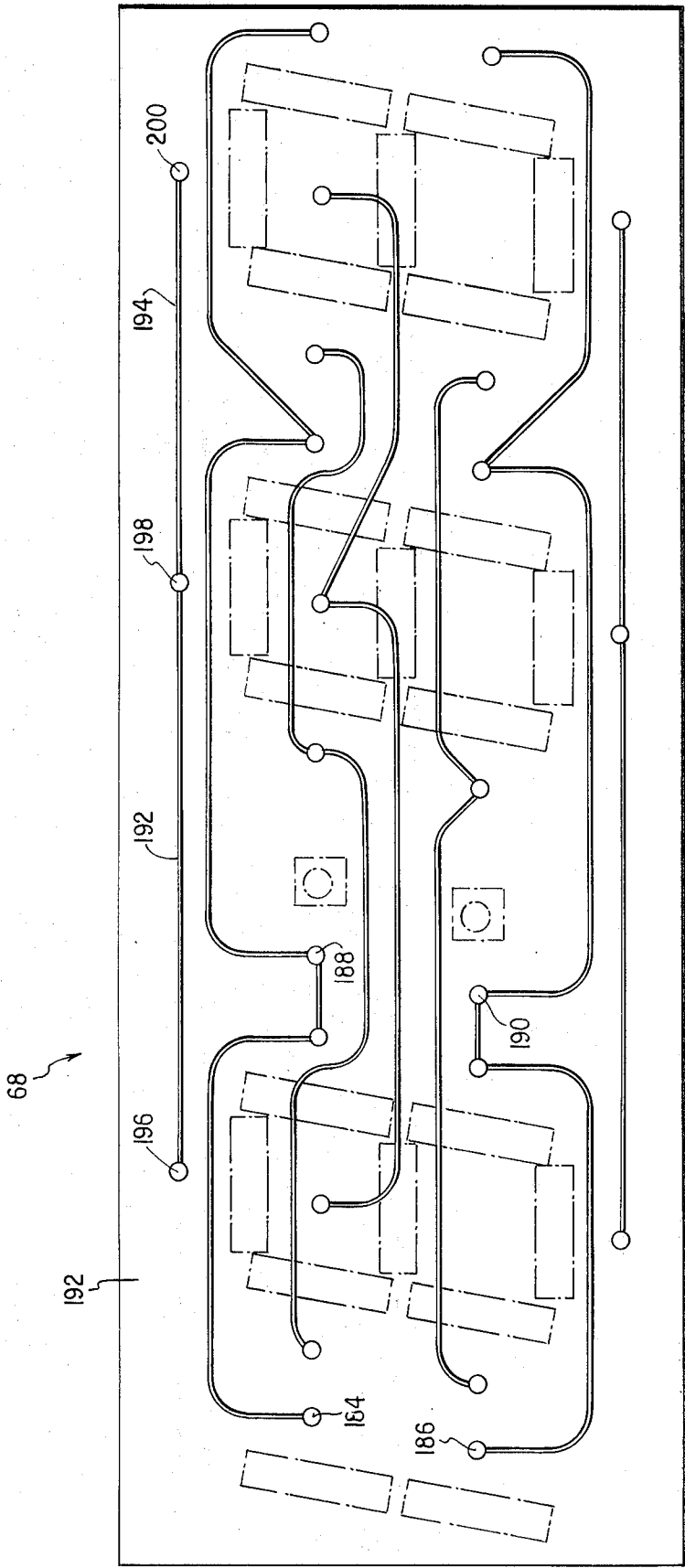


FIG. 15

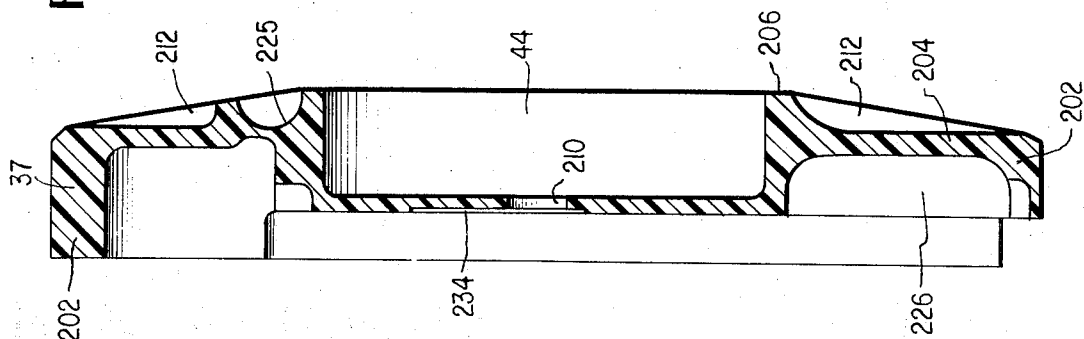


FIG. 14

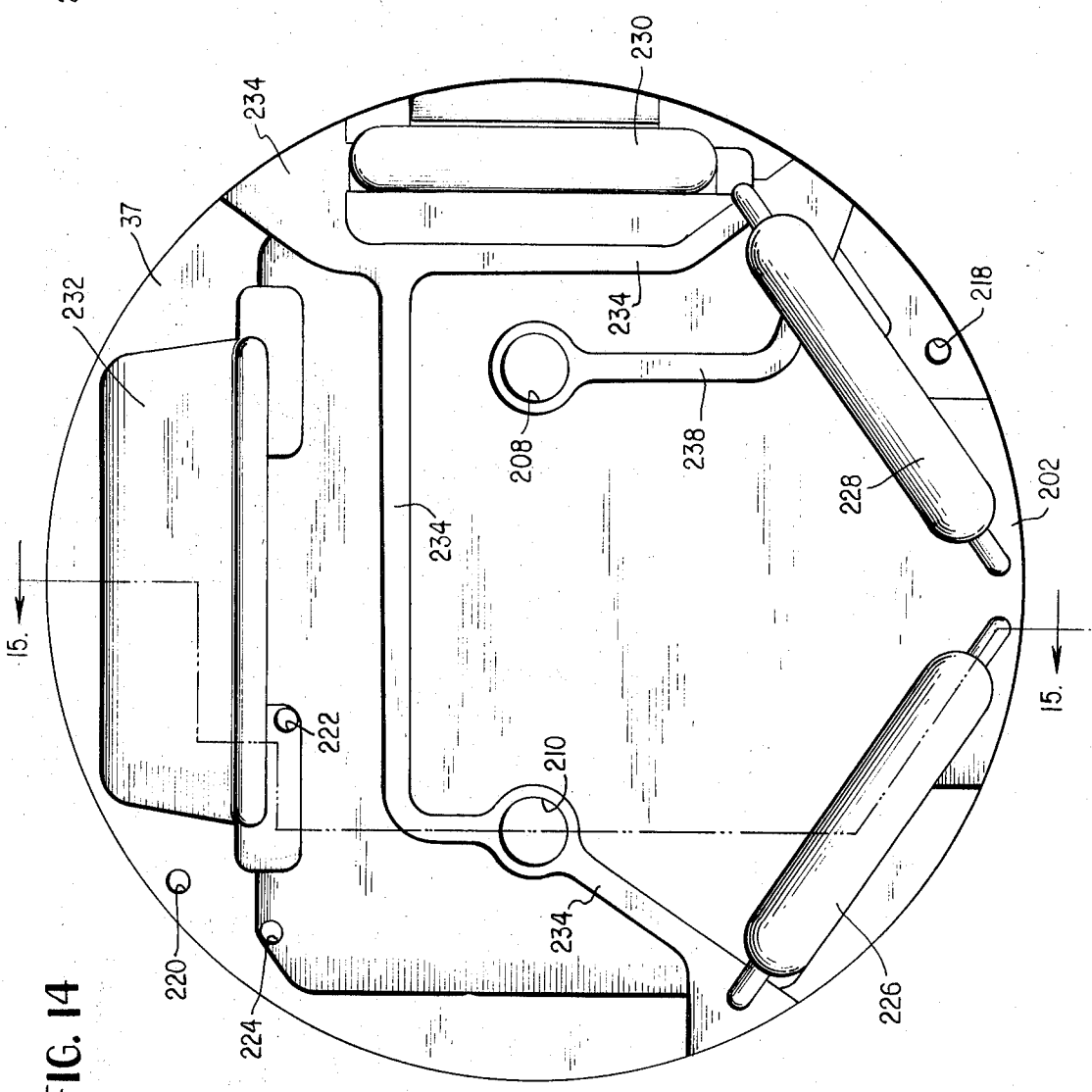


FIG. 16

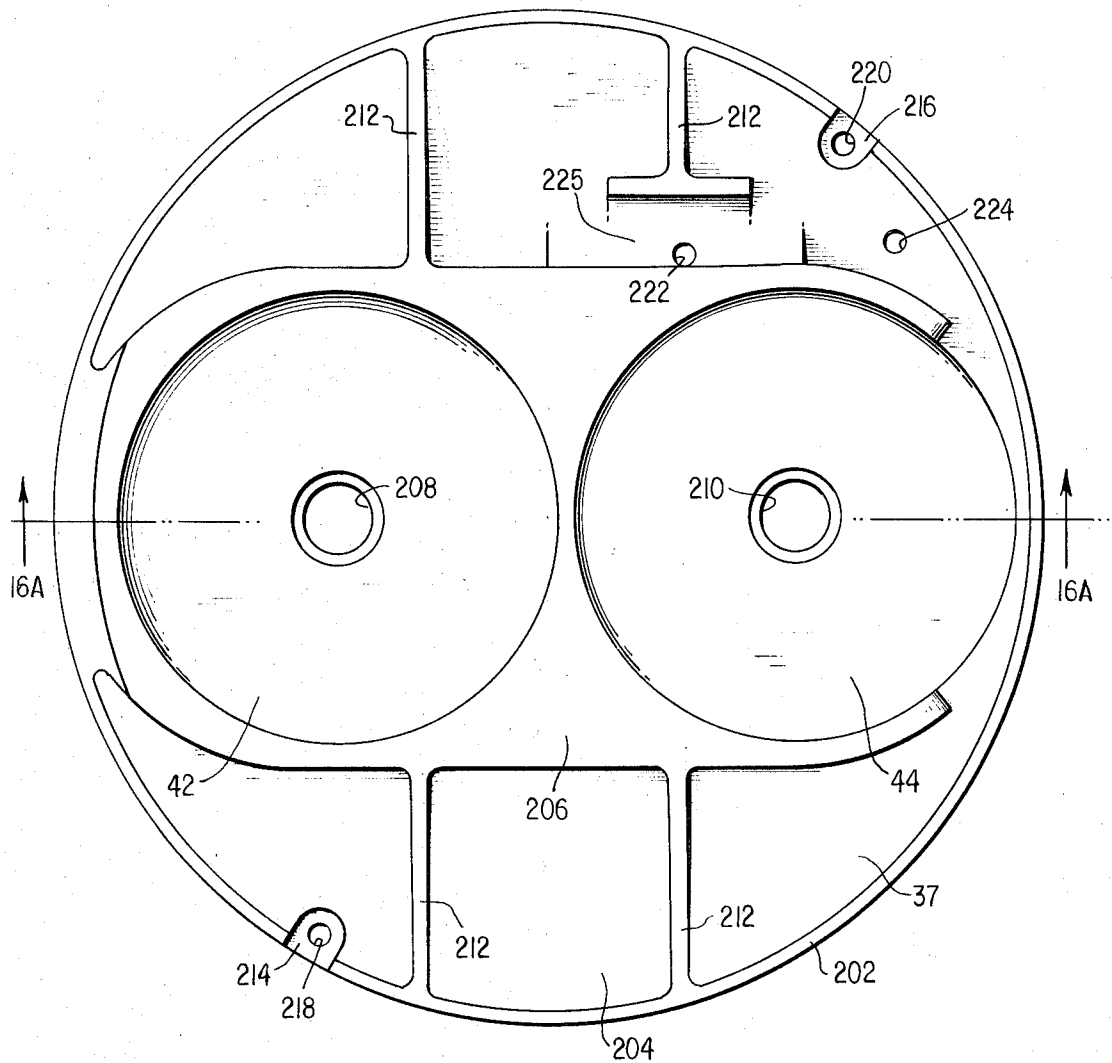


FIG. 16A

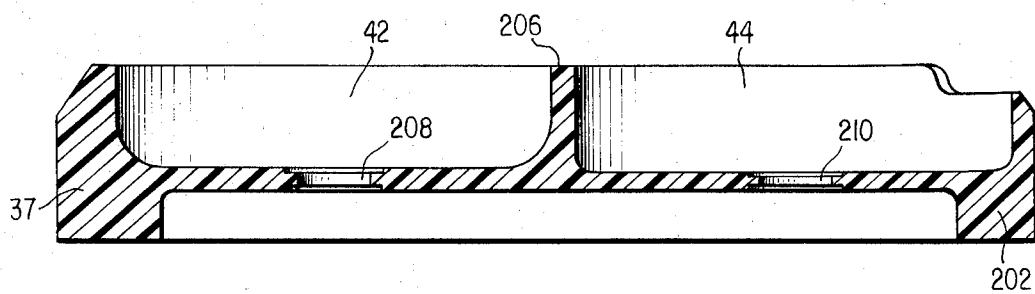


FIG. 17

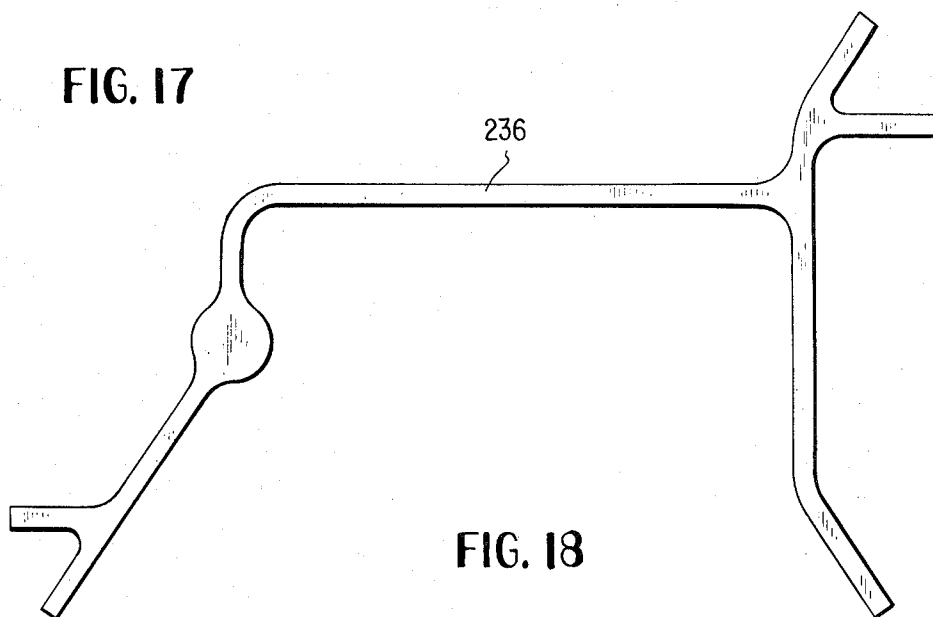


FIG. 18

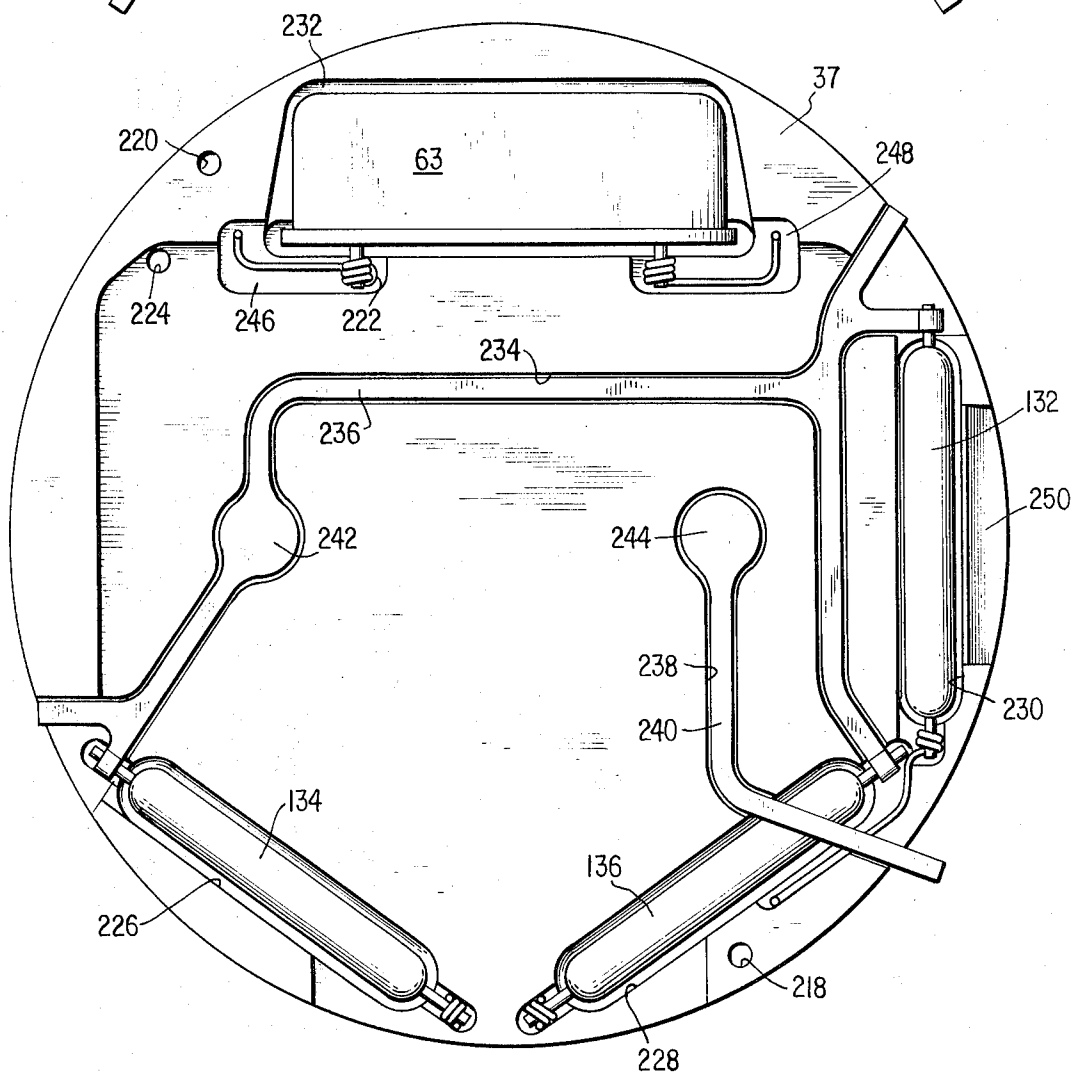


FIG. 19

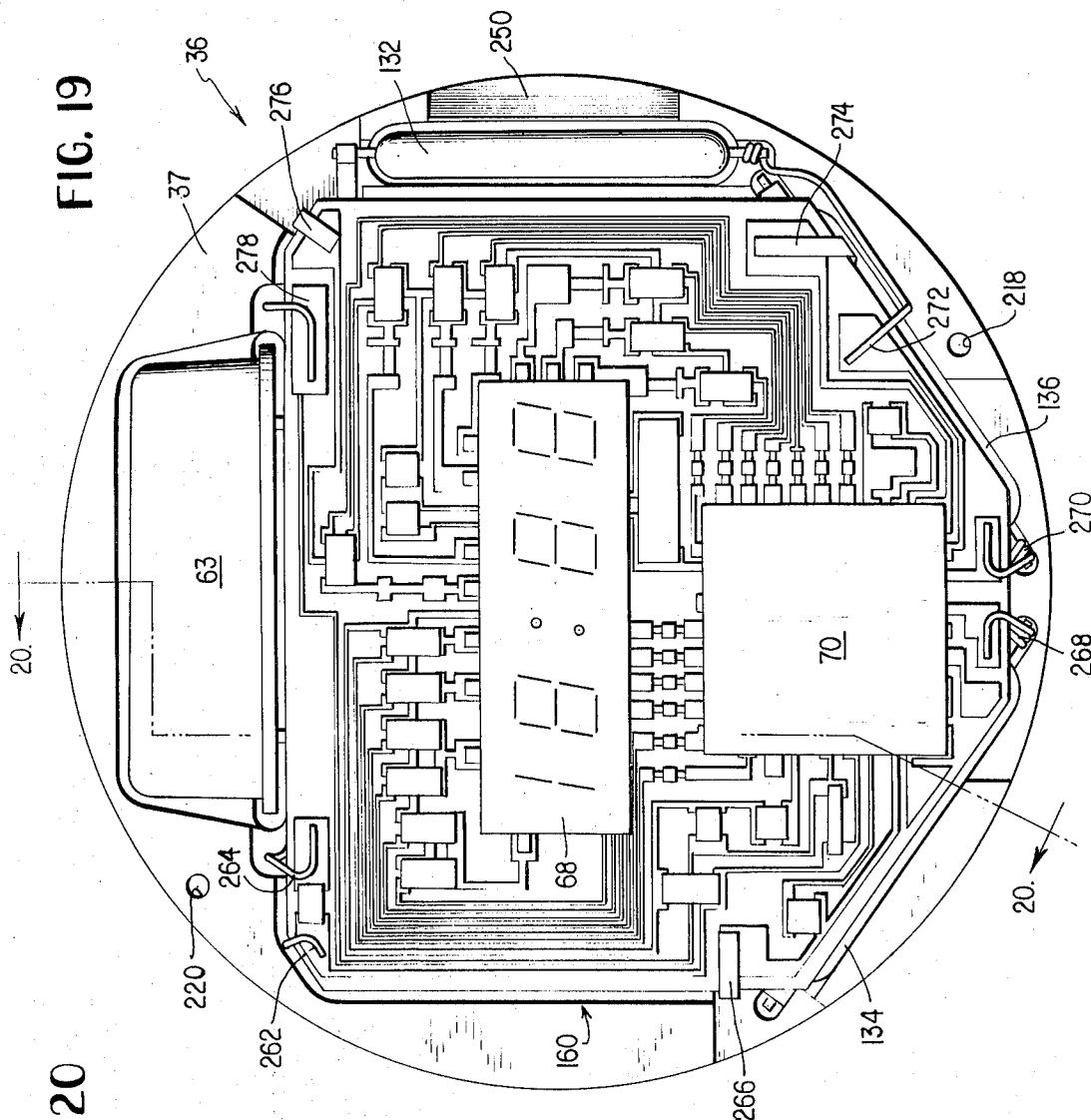


FIG. 20

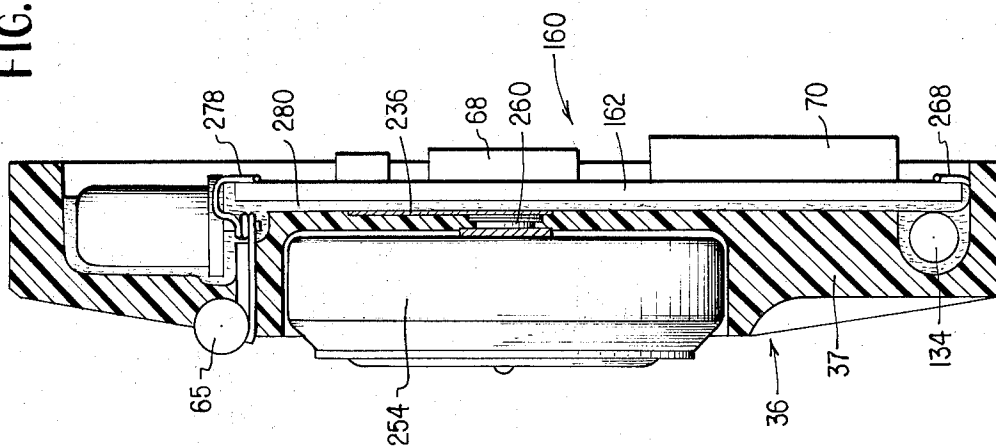


FIG. 21

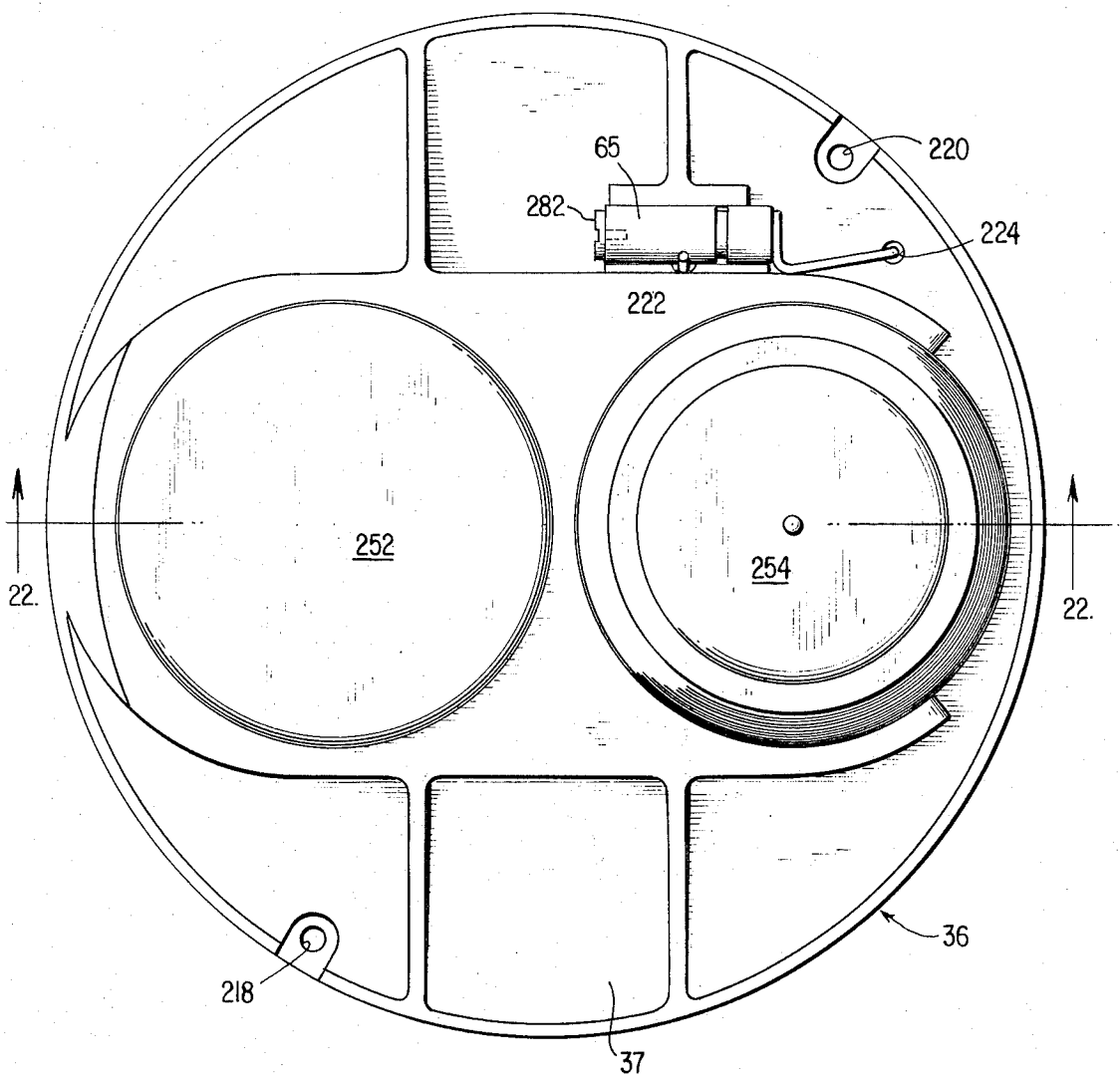
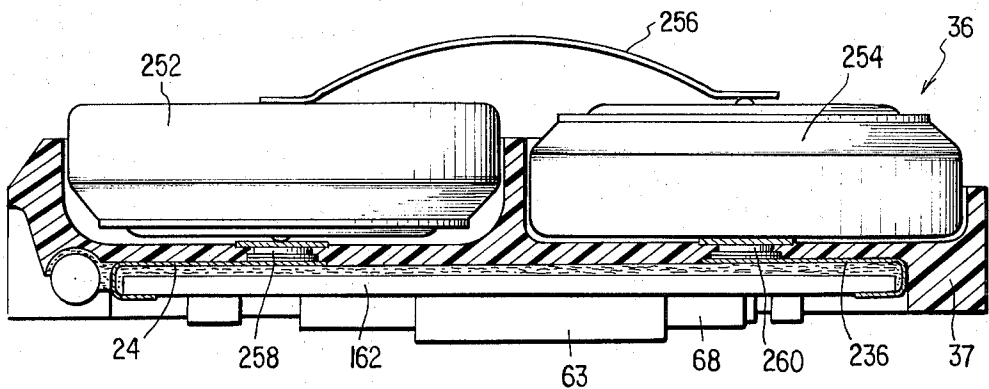


FIG. 22



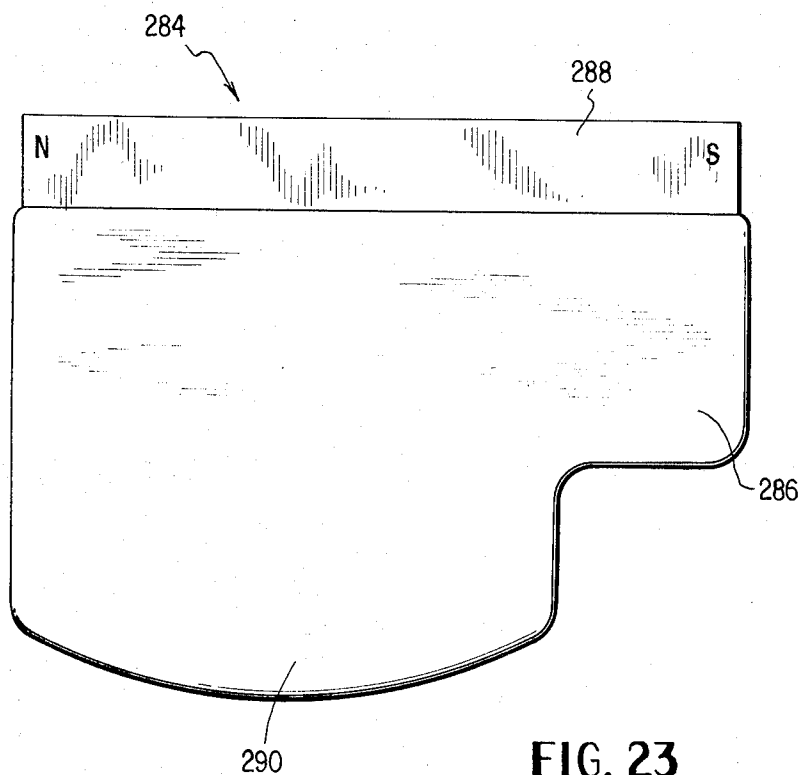


FIG. 23

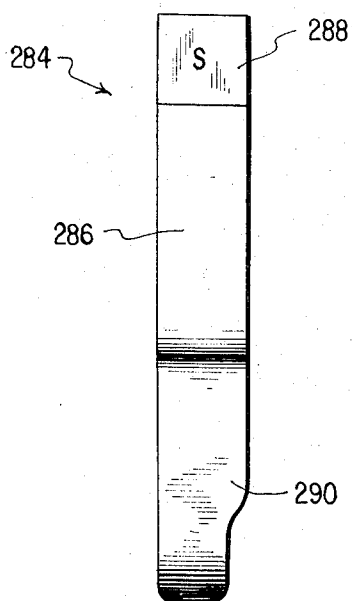


FIG. 24

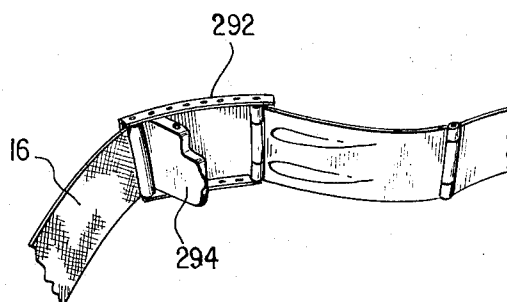


FIG. 25

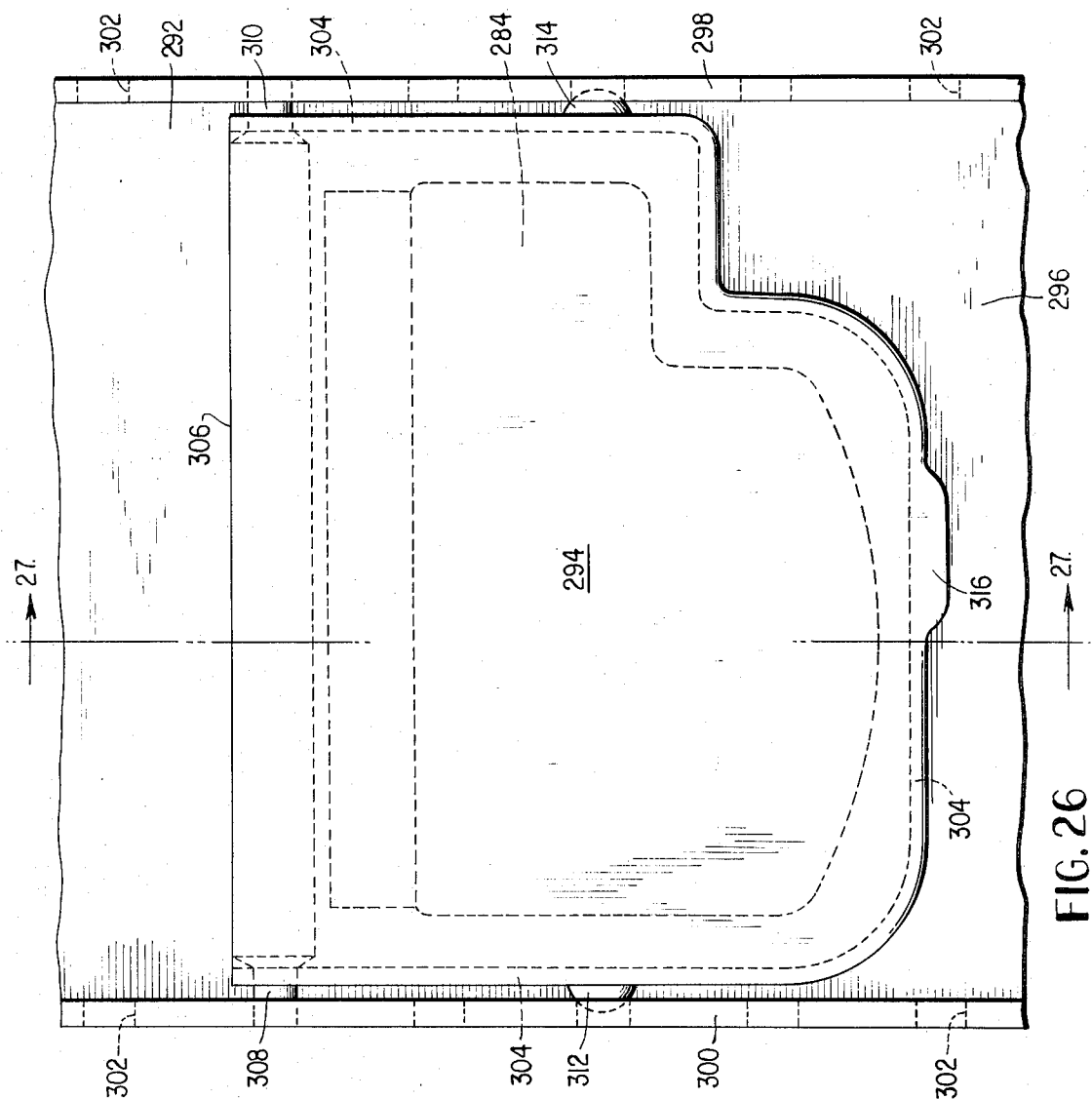


FIG. 26

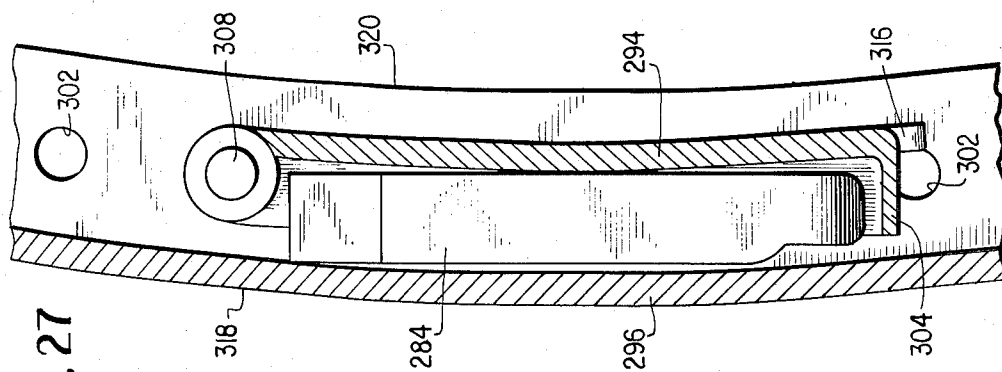


FIG. 27

MODULAR SOLID STATE WRISTWATCH

This invention relates to a solid state timepiece and more particularly to an electronic watch 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-optic display. In particular, the present invention is directed to a modular wristwatch construction in which substantially all the electrical circuitry is constructed using large-scale integrated circuit techniques and the various watch components are of modular construction for ease of assembly, replacement, and repair.

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 electromechanical type shown and described in assignee's U.S. Pat. No. RE.26,187, reissued Apr. 4, 1967, to John A. Van Horn et al. for ELECTRONIC WATCH.

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, in assignee's U.S. Pat. No. 3,560,998, issued Feb. 2, 1971, there is shown a wristwatch in which the master time reference is formed by a high frequency oscillator connected to the watch display through a divider formed of low power complementary MOS transistor circuits. In assignee's U.S. Pat. No. 3,576,099, issued Apr. 27, 1971, there is disclosed a watch construction in which the optical display is described as a plurality of light-emitting diodes which are intermittently energized to assure minimum power consumption and an increasingly long life for the watch battery. Improved watch constructions of this general type incorporating solid state circuits and integrated circuit techniques are disclosed in assignee's co-pending U.S. patent applications Ser. No. 35,196, filed May 6, 1970, now U.S. Pat. No. 3,672,155 and Ser. No. 143,492, filed May 14, 1971, among others.

The present invention is directed to an improved watch construction of the same general type as disclosed in the above-mentioned applications and patents and one which utilizes no moving parts to perform the timekeeping function. In particular, the present invention is directed to a modular electronic wristwatch construction in which substantially all of the electrical components are formed on a single large-scale integrated circuit chip and in which the other principal watch components are also of modular construction so that the watch may be manufactured utilizing standardized mass production techniques. The essentially one-piece construction of the watch of this invention provides for greater reliability, ease of assembly, ease of maintenance, and a resulting watch is less expensive to manufacture and evidences increased shock and impact resistance.

In the present invention, a frequency standard in the form of a crystal controlled oscillator is coupled through an integrated circuit frequency divider and a display actuator to an electro-optic digital display in the form of a plurality of light-emitting diodes. Mounted in the wristwatch case is a rugged impact-resistant, one-piece module frame which houses the en-

tire wristwatch assembly, including the wristwatch battery. Secured in the rear side of the module frame are a pair of battery cells and an oscillator trimmer capacitor so that ready access may be had to the cells and the trimmer by removal of the watch case back. Mounted on the upper side of the frame is the timekeeping assembly, including a wristwatch module comprising an electro-optical display, single large-scale integrated circuit chip, oscillator crystal, switches and associated watch components.

The watch display is visible through a red-colored filter and is formed from a plurality of light-emitting diodes which are preferably arranged in a seven-bar segment array. The light-emitting diodes are energized in appropriate time relationship with an effective brightness determined by an intensity control circuit utilizing a photosensitive detector. 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 1 1/10th seconds, with just a touch of the demand switch. Continued depression of this switch causes the minutes and hours data to fade and the seconds to immediately appear. The seconds continue to count as long as the operator depresses the demand button. Computation of the precise time is continuous and completely independent of whether or not time is displayed.

Setting is accomplished by actuating either an hours-set switch or a minutes-set switch, both of which are preferably magnetic field responsive reed switches. The hours-set switch rapidly advances the hours without disturbing the timekeeping of the minutes and seconds. Actuation of the minutes-set switch automatically zeros the seconds, while advancing the minutes to the desired setting.

The watch of the present invention is virtually shock-proof and water-proof, regardless of the environment in which it is placed. The electrical components are mounted in a one-piece module frame and preferably encapsulated in a potting compound so that no mechanical forces or corrosive elements can attack the principal components of the watch. Since there is no conventional stem for winding or setting, the small shaft sealing problem is eliminated. No maintenance or repair is normally necessary since the components are sealed and substantially inaccessible to influences from the outside world. All solid state electrical components, including the light-emitting diode displays, have a virtually unlimited life.

In addition to the modular construction, other important features of the present invention include the use of a large-scale integrated circuit in the form of a single chip. The display digits are individually strobed to reduce power consumption, and the final assembly of the module to the frame is effected by only nine simple electrical connections. In addition, provision is made in the watch bracelet for incorporating a permanent setting magnet by which the hours and minutes displays of the watch may be set.

Modular construction allows the substitution of other subassemblies of various components and provides a rugged, impact-resistant, one-piece construction. Durable lead frame connections between the cells and the electrical substrate are provided and all components are individually sealed and mounted in potting compound for adherence to the module frame and for high

shock resistance. A simplified arrangement for mounting the module in the watch case requires only two case screws and there is no mechanical or electrical linkage to the outside of the case.

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 completely solid state electronic wristwatch of improved modular construction.

Another object of the present invention is to provide a small, lightweight, portable timepiece suitable for use as a wristwatch incorporating a single large-scale integrated circuit chip which includes a vast majority of the electrical components of the timepiece.

Another object of the present invention is to provide an improved wristwatch construction in which substantially all modular components are mounted in a rugged, impact-resistant, one-piece, injection-molded modular frame.

Another object of the present invention is to provide an improved wristwatch in which the principal watch components are joined by a minimum of electrical connections during assembly.

Another object of the present invention is to provide a wristwatch bracelet including a compartment for storing a watch setting permanent magnet.

Another object of the present invention is to provide an improved wristwatch and wristwatch case assembly wherein rapid and easy access may be had to the watch batteries and to the time standard trimming capacitor for easy replacement or adjustment.

Another object of the present invention is to provide a watch construction in which the components are mounted in a resilient potting composition for both adherence to the module frame and for high shock resistance.

Another object of the present invention is to provide a wristwatch construction in which the major components are individually sealed before assembly.

Another object of the present invention is to provide a wristwatch construction in which electrical portions of the watch are interconnected by a durable lead frame.

Another object of the present invention is to provide a solid state watch incorporating a circular movement for ease of incorporation into a variety of wristwatch case constructions and designs.

Another object of the present invention is to provide a simplified and less expensive solid state watch having increased reliability of operation and increased resistance to shock.

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 plan view of a wristwatch and a portion of a wristwatch bracelet constructed in accordance with the present invention;

FIG. 2 is an exploded view showing the principal components of the watch case forming a part of the wristwatch of FIG. 1;

FIG. 3 illustrates the watch case of FIG. 2 with the timekeeping module inserted in the case;

FIG. 4 is a rear plan view of the watch of FIG. 1 showing the watch case completely assembled;

FIG. 5 is a simplified block diagram of the electrical circuit for the wristwatch of the present invention;

FIG. 6 is a more detailed block diagram of the electrical circuit;

FIG. 7 is a top plan view of the substrate assembly of the watch of the present invention illustrating the digital display;

FIG. 8 is a cross section showing the manner of mounting the single integrated circuit chip forming a part of the substrate assembly of FIG. 7;

FIG. 9 is a bottom plan view of the integrated circuit chip of FIG. 8;

FIG. 10 is a top plan view of the display module forming a part of the assembly of FIG. 7;

FIG. 11 is a bottom plan view of the display module of FIG. 10;

FIG. 12 illustrates the diode-to-pin connections for the display package of FIGS. 10 and 11;

FIG. 13 shows the pin interconnections for the display package of FIGS. 10 and 11;

FIG. 14 is a top plan view of the module frame;

FIG. 15 is a cross section through the module frame taken along line 15—15 of FIG. 14;

FIG. 16 is a bottom plan view of the module frame of FIGS. 14 and 15;

FIG. 16A is a cross section through the center of the module frame taken along lines 16A—16A of FIG. 16;

FIG. 17 is a top plan view of the positive lead frame for forming the battery connections in the wristwatch of the present invention;

FIG. 18 is a top plan view of the module frame of FIG. 14 with positive and negative lead frames, switches and crystal mounted in it;

FIG. 19 is a similar top plan view of the module frame with all components attached and illustrating the complete module;

FIG. 20 is a cross section through the module taken along line 20—20 of FIG. 19;

FIG. 21 is a bottom plan view of the module of FIGS. 19 and 20;

FIG. 22 is a cross section through the module taken along line 22—22 of FIG. 21;

FIG. 23 is a plan view of a setting magnet constructed in accordance with the present invention;

FIG. 24 is an end view of the magnet of FIG. 23;

FIG. 25 is a partial perspective view of the watch bracelet showing a buckle mounting for the setting magnet of FIGS. 23 and 24;

FIG. 26 is a plan view of the magnet holder of FIG. 25; and

FIG. 27 is a cross section through the magnet holder taken along line 27—27 of FIG. 26.

Referring to the drawings, FIG. 1 is a top plan view of the wristwatch constructed in accordance with the present invention, the watch, generally indicated at 10, comprising a non-magnetic metallic watch case 12 having a viewing window 14. The window is preferably formed by a suitable red light filter, such as a transparent red plastic or a ruby material. Attached to case 12 is a wristwatch bracelet 16 and mounted on the case is a pushbutton demand switch 18.

FIG. 2 is an exploded view showing the components of the watch case 12. These comprise a cover 20 mounting the light filter 14, a back plate 22, an O-ring sealing gasket 24, and an externally threaded attach-

ment ring 26. Cover 20 is provided with a pair of mounting holes 28 and 30 which extend only partway through the cover and which are adapted to receive the ends of mounting screws for mounting a time computer module inside case cover 20. The cover is also internally stepped, as at 32, to receive sealing ring 24 and is internally threaded, as at 34, to receive and engage with the external threads on attachment ring 26.

FIG. 3 shows the cover 20 with a time computer module of circular configuration, illustrated at 36, as completely received within the cover. Time computer module 36 is attached to the cover solely by a pair of mounting screws 38 and 40 which pass through the module and are threadedly received in the mounting holes 28 and 30, illustrated in FIG. 2. Module 36 is provided with a pair of circular cavities 42 and 44, each of which is adapted to receive a $1\frac{1}{2}$ volt, 1 cell battery. The batteries are connected in series to form a battery power supply of 3 volts.

FIG. 4 is a bottom plan view of a completely assembled watch case. As illustrated in FIG. 4, ring 26 is preferably provided with a pair of diametrically opposite indentations 46 and 48 adapted to be engaged by the ends of a bifurcated tool so that the ring may be rotated to tighten the assembly. In assembling the watch, the time computer module 36 is first inserted into the cover 20 and secured by the screws 38 and 40. O-ring seal 24 is then inserted on to the step 32 in the cover and the back plate 22 placed over the O-ring seal. Finally, attachment ring 26 is placed so that it overlies the outer edge of back plate 22 and the ring 26 is rotated into tight threaded engagement with the internal threads 34 on cover 20. It is a feature of the assembly that the screws 38 and 40 automatically angularly orient or align the time computer module 36 with the cover 20 and the viewing window 14. Back plate 22 is preferably also provided with an alignment tab 50 (FIG. 2) which slides into a shallow groove 52 in the cover so that the back plate 22 is also automatically aligned with the cover. Only attachment ring 26 is rotated to tighten the back plate to the cover and compress sealing ring 24.

FIG. 5 is a simplified block diagram of the principal operating components of the watch. These comprise a time base or frequency standard 56, preferably in the form of a crystal oscillator producing an electrical output on lead 58 at a frequency of 32,768 Hz. This relatively high frequency is supplied to a frequency converter 60 in the form of a divider which divides down the frequency from the standard 56 so that the output from the converter 60 appearing on lead 62 is at a frequency of 1 Hz. This signal is applied to a display actuator 64 which, in turn, drives an electrooptical display, indicated at 68, and viewable through window 14, by way of electrical lead 66. While only an hours and minutes display is shown, it is understood that with the operation of the pushbutton 18 of FIG. 1, the hours and minutes are first displayed for a predetermined time and if the pushbutton remains depressed, the hours and minutes are extinguished and the seconds become visible. The same display diodes are used for both minutes and seconds since these are not displayed simultaneously, thus minimizing the power drain from the watch battery.

In normal operation, time is continuously being kept but is not displayed through the window 14. That is, no time indication is visible through the window and this is the normal condition which prevails in order to con-

serve battery energy in the watch. However, even though the time is not displayed through the window 14, 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 or operator desires to ascertain the correct time, he depresses the pushbutton 18 with his finger and the correct time is immediately displayed at 68 through the window 14, which shows a light-emitting diode display giving the correct time reading of 10:10, namely, 10 minutes after 10 o'clock. The hours and minutes, i.e., 10:10, are displayed through the window 14 for a predetermined length of time, preferably $1\frac{1}{4}$ 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 (or hours) change during the time of display, this change is immediately indicated by advancement of the minute (or hour) reading to the next number, i.e., 11, as the watch is being read. If the pushbutton 18 remains depressed, at the end of $1\frac{1}{4}$ seconds the hours and minutes of the display are extinguished, i.e., they disappear, and simultaneously the seconds reading is displayed through the window 14 by the same diodes as previously displayed the minutes. The advancing seconds cycling from 0 to 59 continue to be displayed through window 14 until the pushbutton switch 18 is released.

FIG. 6 is a more detailed diagram of the electrical circuit of the watch 10 of the present invention. In FIG. 6, the electro-optic display is again illustrated at 68 and the majority of the electrical components of the watch are illustrated in FIG. 6 as incorporated in a single large-scale integrated circuit chip identified by the reference numeral 70. For a detailed disclosure of the electrical components incorporated in chip 70 and for a detailed discussion of the other components of the watch, reference may be had to assignee's copending U.S. patent application Ser. No. 143,492, filed May 14, 1971, which entire application is incorporated herein by reference. In addition to the integrated circuit chip 70, the watch comprises the frequency standard 26 which, in the preferred embodiment, takes the form of a crystal controlled oscillator formed from a complementary MOS FET inverter. Again, reference may be had to the above-identified copending U.S. patent application Ser. No. 143,492 for a detailed description of the oscillator. It comprises a piezoelectric frequency determining crystal 63, a variable capacitor or trimmer 65 for fine adjustment of the oscillator frequency, a bias resistor 61, and a pair of complementary MOS transistors (not shown) incorporated in circuit chip 70. This chip also includes the frequency converter 60 of FIG. 5 and a large portion of the display actuator 64. The watch also comprises a battery 72 which, by way of example only, may comprise a conventional 3 volt wristwatch battery formed from a pair of series connected $1\frac{1}{2}$ volt cells. Connected to the positive side of the battery 72 is a resistor 73. The battery energizes the display 68 which is shown in FIG. 6 as consisting of a pair of hours stations comprising the digits station 74 and tens station 76 and a pair of combination minutes and seconds stations comprising digits station 78 and tens station 80. In addition, the display 68 includes a pair of colon dots 81, each formed by a single light-emitting diode. The display stations 74, 76, 78, and 80

are preferably formed from a 7-bar segment array of light-emitting diodes, such as those formed from gallium arsenide phosphide which produce light in the visible red region. The display stations are energized from the integrated circuit chip 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 light-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, and 90. There is a separate lead 79 for the total number of bar segments in a display station, i.e., seven leads 79. That is, with a 7-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. The two bar segments 94 and 96 for the hours tens display 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 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 chip 70 through current limiting resistors 98, 100, 102, 104, 106, and 108, the emitters of the transistors being connected in common to 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. 6 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 corresponding 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 chip 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.

Also external to the integrated circuit chip 70 in FIG. 6 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 integrated circuit chip 70 are minutes set switch 134 and hours set switch 136. These switches are connected across battery 72 from the positive side of the battery to the negative side through respective series resistors 138, 140, and 142. The resistors associated with the 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.

A feature of the watch of the present invention is that the intensity of the light emitted from the display diodes is varied in accordance with ambient light. That is, the diode light intensity 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 is generally indicated at 144 in FIG. 5 and comprises a photo-sensitive resistor 146 mounted on the face of the watch connected to the positive side of battery 72 and to a resistor 148 and a capacitor 150. These components are connected to the positive side of the power supply through a series resistor 152. Other external components connected to integrated circuit chip 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 chip 70 is also provided with a carryout lead and terminal 159.

FIG. 7 is a top plan view of a substrate assembly 160 which comprises a mounting board 162 of ceramic or other suitable insulating material to which are secured the electrical components of FIG. 6 and on which are printed the connecting leads. Like parts in FIG. 7 are similarly numbered to those in FIG. 6 and also secured to the board or substrate is the integrated circuit chip, generally indicated at 70, and the display 68.

FIGS. 8 and 9 show the construction of the integrated circuit chip 70. FIG. 8 is a cross section through the assembly and FIG. 9 is a bottom plan view. The actual integrated chip itself, illustrated at 164 in FIG. 8, is mounted on the underside of a ceramic carrier 166. This carrier is provided with a plurality of spaced, stepped feet 168 which are provided with conductive layers 170 to which are attached leads 172 extending from the integrated circuit chip 164. The chip is mounted in a suitable silicone rubber potting compound, as illustrated at 174, which terminates short of the bottom of feet 168 so that the conductive surface 170 at the bottom is exposed for making electrical connections. Ceramic carrier arrangements of this type are well known and, by way of example only, are available under the trade name of Versapak from Frenchtown C.F.I. of Frenchtown, N.J.

FIG. 10 is a top plan view of the display package 68 and FIG. 11 is a bottom plan view of the display package. The diodes are suitably mounted on the top surface of the display package as illustrated at 176 in FIG. 10. External electrical connection to the display package is effected through electrical conductors 177 secured to the bottom surface of the package. The electro-optic display package is preferably of laminated construction and, by way of example only, may comprise three ceramic layers secured together and encapsulated in a clear coating material to protect it from the surrounding environment.

FIG. 12 shows the top layer with the diodes attached and illustrates the manner of connection to the anodes of the individual diodes. The two diodes 94 and 96, mounted on top ceramic layer or board 178, are connected by short electrical leads 180 and 182 to the ends of a pair of conductive pins 184 and 186 which extend through all three layers of the display package 68. Similar pins 188 and 190 are provided for the colon dot diodes 81, and the connections from the diodes to corresponding pins for the other display stations are also illustrated. The respective diodes for station 78 are labeled a-g and the display diodes for stations 74 and 80 are similarly arranged.

FIG. 13 is a plan view of the second layer or intermediate ceramic board 192 forming the middle part of the display package 68. The diodes are shown in dashed

lines in FIG. 13, it being understood that the diodes are mounted on the top surface of board 178 in FIG. 12 and the dashed line illustration is only for the purposes of understanding the relationship between the interconnections effected on this second layer 192. The pins which extend through all three layers are similarly numbered in FIG. 13. It can be seen from FIG. 13 that the diodes of each of the display stations 74, 78 and 80 have their anodes interconnected by the leads 192 and 194 connected to the anode pins 196, 198, and 200. The diodes 94 and 96 for the hours one stations are interconnected through pins 184 and 186 to the *b* and *c* diodes of each of stations 74, 80, and 78, as well as to the colon diodes 81, by way of pins 188 and 190. The small *d*, *e*, *f*, and *g* diode interconnections are also illustrated in FIG. 13.

As previously mentioned the interconnections illustrated in FIGS. 12 and 13 are for the diode anodes which receive signals from the leads 79 in FIG. 6. The cathodes of all diodes in the particular display station are interconnected by similar pins (not shown) engaging the back sides of the diodes and by leads on the bottom or third layer of the display package to provide a common cathode interconnection to the respective transistors 82, 84, 86, 88, 90, and 92, as illustrated in FIG. 6. Thus, the particular group of diodes energized is dependent upon the conductive state of the anode switching transistors 112, 114, 116, 118, 120, 122 and 124 in FIG. 6 and the particular display station energized depends upon the conductive state of the cathode transistors 82, 84, 86, 88, 90, and 92 in FIG. 6. The anode signals determine the number to be displayed, i.e., turn on the appropriate segments of the seven-bar segment display, whereas the cathode transistors determine the display station energized, i.e., the time being displayed whether it be hours, minutes or seconds. Each of the stations 76, 74, 80, and 78 is energized in sequence so that each station is turned on only approximately one-quarter of the time. In this way, only one display station is energized at any given instant, which effects a strobing action to balance out the power drain on the battery. To this end, the colon dot diodes 81 are tied in with the hours tens station 76 since that station includes only two diodes and normally draws less power than the other stations which each comprise seven-bar segment diodes. The diodes are, of course, lit in sequence at a sufficiently rapid rate to give the appearance of constant illumination of the time to be displayed. When hours and minutes are being displayed, all four stations are strobed in sequence. When only seconds is being displayed, the colon dots are not used and only stations 80 and 78 are strobed in sequence as determined by the signals to the seconds transistors 90 and 92.

FIG. 14 is a top plan view of the frame 37 for module 36 and FIG. 15 is a cross section through the frame taken along line 15—15 of FIG. 14. This frame is preferably formed from an impact-resistant, one-piece, injection molded plastic material and, in the preferred embodiment, is formed of fiber-filled S-2/30 type 6-10 Nylon which is a fiber-filled Nylon material. FIG. 16 is a bottom plan view of the frame 37. FIG. 16A is a cross section through the center of the module frame taken along line 16A—16A of FIG. 16. Referring to these FIGURES, the frame 37 is of circular or disc-shaped, one-piece plastic construction and comprises a circular rim 202 integral with a solid central section 204 having

an enlarged or thickened portion 206 provided with the cavities or wells 42 and 44, each adapted to receive a 1½ volt, 1 cell battery. At the bottom of each well is a through hole or aperture 208 and 210, each adapted to receive an electrically conductive metallic pin for establishing electrical connection from the batteries in wells 42 and 44 to the remainder of the circuit. Enlarged central portion 206 is connected to the rim by tapered ribs for added strength, such as are indicated at 212.

Referring to FIG. 16, the rim is provided with a pair of diametrically opposite cutouts 214 and 216 defining flats through which pass the mounting holes 218 and 220. These holes pass completely through the frame and provide passage for the mounting screws 38 and 40 of FIG. 3 by means of which the entire module assembly is attached to the watch case. Also passing completely through the module frame 37 are a second pair of apertures 222 and 224 which provide passage through the frame for leads establishing electrical connection to the trimmer capacitor 65 of FIG. 6 in a manner more fully described below. The trimmer capacitor is adapted to be mounted in an elongated shallow groove or well 225 provided in the back or bottom surface of the module frame and this trimmer capacitor, along with the batteries in circular wells 42 and 44, are the only components mounted on the back of the frame and the only components accessible after removal of the back plate 22 of the watch. Access to the batteries through the back plate is desirable for battery replacement and access to the trimmer capacitor is provided in order to make readily possible fine adjustment of the oscillator frequency acting as the time standard.

On the front and top surface of the module frame are three elongated cavities or wells 226 (FIG. 14), 228 and 230, each adapted to receive a magnetic reed switch. Well 230 receives the demand switch 132 of FIG. 6 operated by pushbutton 18, whereas cavities 226 and 228 receive the minutes and hours set switches 134 and 136 of FIG. 6. A larger cavity or well 232, near the top of the module frame in FIG. 14, is adapted to receive the quartz crystal 63 of FIG. 6 forming a part of the time base oscillator. A network of shallow grooves 234 are interconnected to an area surrounding the battery aperture 212 and these grooves 234 are adapted to receive corresponding portions of a conductive metal positive lead frame 236, shown in plan view in FIG. 17. The positive lead frame 236 is formed from a flat blank of conductive metal, and by way of example only, may have a uniform thickness of approximately ± 0.0045 inch, and may be formed of annealed copper plate or bright tin plate or lead-free brass. Similarly, joined to an area surrounding aperture 208 in FIG. 14 is a groove 238 adapted to receive a negative lead frame formed of the same material and having the same thickness as positive lead frame 236 of FIG. 17. Both lead frames are secured in the grooves by suitable adhesive. The module assembly 160 of FIG. 7 is placed over the lead frames in the grooves 234 and 238 in a manner more fully described below.

FIG. 18 is a top plan view, similar to FIG. 14, showing the demand switch 132 in the well 230 and the setting switches 134 and 136 in the wells 226 and 228. Positive lead frame 236 is shown as received in the grooves 234 and a similar negative lead frame 240 is shown secured in groove 238. The enlarged circular portions 242 and 244 of the lead frame engage the ends of conductive

pins passing through the battery well apertures 208 and 210 of FIG. 16A. FIG. 18 shows the lead connection to the switches and also shows the quartz crystal package 63 mounted in well 232 with the smaller adjacent cavities or wells 246 and 248 providing access for lead connection to the two terminals of the crystal 63. Finally, FIG. 18 shows the mounting slot or cavity 250 for the pushbutton 18 which carries a permanent magnet and when pushed in or depressed actuates reed switch 132. The pushbutton construction and the reed switches are not described in detail and reference may be had to assignee's copending U.S. application Ser. No. 138,557, filed Apr. 29, 1971, and entitled SOLID STATE WATCH WITH MAGNETIC SETTING, for a detailed description of these elements, the complete disclosure of which application is incorporated herein by reference.

FIG. 19 is a top plan view of the complete time computer module 36 with the substrate assembly 160 of FIG. 7 attached to the plastic module frame 37. FIG. 20 is a cross section through the module taken along line 20—20 of FIG. 19; FIG. 21 is a bottom plan view of the module of FIGS. 19 and 20; and FIG. 22 is a cross section through the module taken along line 22—22 of FIG. 21. These FIGURES illustrate the frame 37 as receiving batteries 252 and 254 which are illustrated in FIG. 22 as connected in series by a conductive spring 256 which, if desired, may be mounted on the back plate 22 of the watch case. The negative side of battery 252 is in conductive electrical engagement with a pin 258 and the positive side of battery 254 is similarly in conductive electrical engagement with a metal pin 260. Pin 258, in turn, engages the enlarged portion 244 (FIG. 18) of negative lead frame 240 and pin 260 engages enlarged portion 242 of the positive frame 236. Referring to FIG. 19, the trimmer capacitor leads which pass through the apertures 222 and 224 are soldered to the printed circuit of the substrate assembly 160 at 262 and 264. The positive lead frame connected to the positive side of the power supply is turned over the substrate assembly and soldered to the printed circuit pad at 266. The leads for the three switches 134, 136, and 132 are soldered to the printed circuit pads as respectively indicated at 268, 270, and 272. The negative lead frame is likewise turned over the edge of the substrate assembly 160 and soldered to the printed circuit at 274 in FIG. 19. A second positive lead frame power supply solder connection is shown at 276 and the crystal lead is soldered to a printed circuit pad at 278. Thus, it can be seen that during final assembly only nine large, simple and readily accessible solder connections need be effected to electrically connect the entire assembly.

In the preferred embodiment, all components are preferably embedded in a suitable potting compound and, in the preferred embodiment, the potting compound is a silicone rubber potting composition having good adhesive characteristics and good shock absorbing qualities. The potting compound is indicated by the hatching at 280 in FIGS. 20 and 22. As best seen in FIG. 21, the trimmer capacitor 65 is preferably provided with an adjustment screw 282 so that when the back plate of the case is removed, the screw 282 may be rotated by a small screwdriver to provide adjustment of the oscillator frequency.

FIG. 23 is a plan view and FIG. 24 is an end view of a setting magnet which may be used to actuate the set-

ting switches 134 and 136. For this purpose, the watch case, if desired, may be provided with suitable indentations adjacent these switches so that the face of the setting magnet may be placed in the indentations adjacent the desired hours or minutes setting switch. The setting magnet, generally indicated at 284 in FIGS. 23 and 24, comprises a holder 286 (preferably formed of non-magnetic material such as beryllium copper or the like), to which is soldered a permanent magnet 288. Holder 286 includes a projecting portion 290 which serves as a handgrip for grasping the setting magnet 284 between the thumb and forefingers. The holder 286 and magnet 288 are preferably gold-plated and the magnet 288 is preferably magnetized after plating to have a magnetism of 1,000 gauss minimum with the polarity indicated as measured at the poles. When the magnet 288 is placed adjacent either the hours setting reed switch or the minutes setting reed switch, i.e., placed against the outer surface of the case adjacent the switch, the switch is closed and appropriate setting effected.

A feature of the watch of the present invention is that the bracelet 16 is provided with a holder for housing the setting magnet 284. To this end, as illustrated in FIG. 25, a portion of the bracelet includes a buckle 292 hinged to the remainder of the bracelet at each end and provided with a pivotally mounted magnet holder 294 shown in FIG. 25 rotated to its substantially open position. Holder 294 is preferably configured to receive the magnet 284 illustrated in FIGS. 23 and 24. FIG. 26 is a bottom plan view of a portion of the buckle and magnet holder and FIG. 27 is a cross section taken along line 27—27 of FIG. 26. Referring to FIG. 26, the buckle 292 comprises a flat metal plate 296 with turned-over edges which form parallel perpendicularly extending flanges 298 and 300. These flanges are preferably provided with a plurality of apertures 302 adapted to receive pivots for attaching the buckle to the remainder of the bracelet 16. The magnet holder or cover 294 likewise comprises a flat metal plate bent over along three edges to define a flange 304. Rotatably received through suitable apertures in this flange adjacent back edge 306 are a pair of pins 308 and 310 which are secured in two of the buckle apertures 302 so that the holder 294 is free to pivot or rotate about pins 308 and 310. If desired, holder 294 may be spring-biased closed and it is preferably provided with a pair of ball-like projections 312 and 314 which act as snaps and snap into two of the apertures 302 in the buckle to retain the holder closed in the positions illustrated in FIGS. 26 and 27. Flange 304 is preferably turned up at 316 so that it may be engaged by the tip of the finger to lift the holder and rotate it about pins 308 and 310 to expose the setting magnet 284 so that it might be removed and used to set the watch. The buckle 296 may be hinged to the remainder of the wrist band in any conventional manner and, if desired, pivot bars may be passed through the endmost apertures for attachment to the wrist band. The buckle is preferably curved as illustrated at a suitable angle so as to conform to the wrist of an average wearer with the outermost surface 318 substantially flush with the outer surface of the wrist band and the inner edges 320 of the flanges in engagement with the wearer's wrist when the watch is worn. This assures that the wearer's wrist will prevent inadvertent opening of the magnet holder 294 and inadvertent loss of setting magnet 284 although the holder is

normally securely held closed by the snap buttons 312 and 314 and a bias spring (not shown) if desired.

It is apparent from the above that the present invention provides an improved wristwatch construction and particularly one that is of simplified, inexpensive construction and one that is easy to assembly and reliable in operation. The large-scale integrated circuit chip is completely enclosed in potting compound and the electrooptic display 68 is preferably coated with a transparent lacquer or other suitable coating so as to likewise be completely enclosed and substantially impervious to the elements. Other components of the watch as illustrated are preferably embedded in a suitable silicone adhesive which helps attach these components to the module frame and at the same time resiliently supports them against shock. The watch provides a rugged impact-resistant, one-piece, injection molded module frame which houses the entire module assembly including the cells. The construction provides durable lead frame connections between the cells and the substrate and all components are individually sealed before going into subassemblies or the main assembly. All components or subassemblies are mounted in silicone rubber for both adherence to the module frame and high shock resistance. The trimmer capacitor is easily accessible to adjust the crystal oscillator frequency and the final assembly of substrate subassembly to module frame subassembly has only nine simple solder connections. The modular construction allows the substitution of other subassemblies of variable components or circuit specifications in place of the original design and permits, for example, a smaller crystal can as a replacement, or a smaller substrate may be used without any other change in the module frame. Simplicity of mounting the module in the case is provided in that it requires only two case screws and there is no mechanical or electrical linkage from the watch to the outside of the watch case.

The invention may be embodied in other specific forms without departing from the spirit or essential characteristics thereof. The present embodiment is 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. A timepiece of sufficiently small size for use as a wristwatch comprising a case, a one-piece frame of electrical insulating material mounted in said case, a frequency standard and an electro-optical display in said case, a frequency converter and a display actuator coupling said frequency standard to said display, said frequency standard, frequency converter, display actuator and electro-optical display all being mounted in said case on said one-piece frame, a battery removably mounted on said frame, said battery being mounted on one side of said frame and said electro-optical display being mounted on the other said of said frame, said battery being electrically coupled to said display through apertures in said frame, said frequency standard comprising an oscillator including a trimmer capacitor, said capacitor being mounted on the same side of said frame as said battery.

2. A timepiece according to claim 1 wherein said case includes a removable back plate for easy access to said battery and said trimmer capacitor.

3. A timepiece according to claim 2 wherein said oscillator includes a crystal mounted on said other side of said frame.

4. A timepiece according to claim 3 including a substrate mounted on said other side of said frame, the remainder of said oscillator, said frequency converter, said display actuator and said display all being mounted on said substrate.

5. A timepiece according to claim 4 wherein said substrate carries printed circuit leads for interconnecting the components of said oscillator, frequency converter, display actuator and display.

6. A timepiece according to claim 4 wherein said frequency converter is formed by part of a single integrated circuit chip mounted on said substrate.

7. A timepiece according to claim 4 including a pair of pins passing through said frame for making electrical contact with the terminals of said battery, and positive and negative lead frames between respective ones of said pins and said substrate for establishing electrical connection from said battery to said components of said oscillator, frequency converter, display actuator and display.

8. A timepiece according to claim 7 wherein said lead frames each include at least one end turned over the edge of said substrate and connected to the side of said substrate remote from said pins.

9. A timepiece of sufficiently small size for use as a wristwatch comprising a one-piece circular frame of electrical insulating material, said frame including cavities on one side, a trimmer capacitor in one of said cavities, the other of said cavities being adapted to removably receive a battery, said frame including a cavity on its other side receiving a crystal, means passing through said frame electrically coupling said trimmer capacitor and said crystal, said trimmer capacitor and said crystal forming part of a crystal oscillator, a substrate mounted on said other side of said frame, said substrate carrying the remainder of said crystal oscillator, a divider on said substrate coupled to the output of said oscillator, a display actuator on said substrate coupled to the output of said divider, and an electro-optical display on said substrate coupled to the output of said display actuator.

10. A timepiece according to claim 9 wherein said display comprises a plurality of light-emitting diodes.

11. A timepiece according to claim 9 wherein said trimmer capacitor, said crystal and said substrate are secured to said frame by silicone rubber adhesive to absorb shock.

12. A timepiece according to claim 9 wherein said other side of said frame is provided with additional cavities, and a magnetic switch mounted in each of said additional cavities.

13. A timepiece according to claim 12 wherein said magnetic switches comprise a pair of setting switches and a demand switch.

14. A timepiece according to claim 13 wherein said switches are reed switches and are secured to said frame by silicone rubber adhesive potting material.

15. A timepiece according to claim 9 wherein said frame is provided with a pair of diametrically opposite mounting apertures for securing said frame to a watch case.

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16. A wristwatch comprising a casing, a wristband attached to said casing, timekeeping means in said casing including at least one magnetic setting switch, a permanent magnet for actuating said setting switch, and means on said wristwatch for mounting said permanent magnet when not in use.

17. A wristwatch according to claim 16 wherein said wristband comprises a bracelet, said mounting means being provided on said bracelet.

18. A wristwatch according to claim 17 wherein said mounting means comprises a plate with turned-over edges adapted to retain said magnet, said plate being

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pivoted to said bracelet.

19. A wristwatch according to claim 18 wherein said bracelet includes a buckle, said plate being attached to said buckle for pivotal movement of one end away from said buckle inwardly of said bracelet toward the wearer's wrist.

20. A wristwatch according to claim 19 including cooperating snap means on said buckle and plate for retaining said plate in its closed position substantially parallel with said wristband.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,759,031 Dated September 18, 1973

Inventor(s) Robert E. McCullough and Cleon W. Hougendobler

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 1, line 58, "is" should read --which is--.

Signed and sealed this 19th day of March 1974.

(SEAL)
Attest:

EDWARD M. FLETCHER, JR.
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents

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