United States Patent [19]

Roberts

[11] **3,866,406**

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

[54] **SOLID STATE ELECTRONIC WRISTWATCH**

[75] Inventor: **Dennis A. Roberts,** Washington Boro, Pa.

[73] Assignee: **Time Computer, Inc.,** Lancaster, Pa.

[22] Filed: **Oct. 16, 1973**

[21] Appl. No.: **406,941**

Related U.S. Application Data

[62] Division of Ser. No. 328,639, Feb. 1, 1973, Pat. No. 3,803,827.

[52] U.S. Cl. .... **58/4 A,** 58/55, 58/58, 58/85.5, 58/88 R

[51] **Int. Cl.. G04b 19/24,** G04b 37/00, G04b 27/00

[58] **Field of Search** .... 58/4 A, 23 R, 50 R, 52, 58/55, 58, 85.5, 88 R

[56] **References Cited**

UNITED STATES PATENTS

3,733,810 5/1973 Girard .... 58/50 R

3,759,031 9/1973 McCullough .... 58/50 R

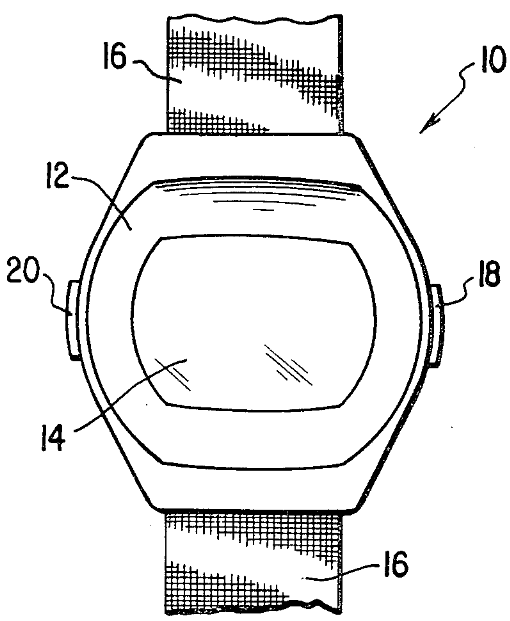
Primary Examiner—Edith Simmons Jackmon

Attorney, Agent, or Firm—LeBlanc & Shur

[57] **ABSTRACT**

Disclosed is a solid state electronic wristwatch incorporating a calendar display. The same electro-optical elements are used for the calendar display as are used to display time. The principal components of both the time and calendar circuits may be formed on a single large scale integrated circuit chip. The watch is of modular construction for ease of assembly and reliability. Also disclosed is a setting magnet for the watch stored in the watch bracelet.

3 Claims, 38 Drawing Figures



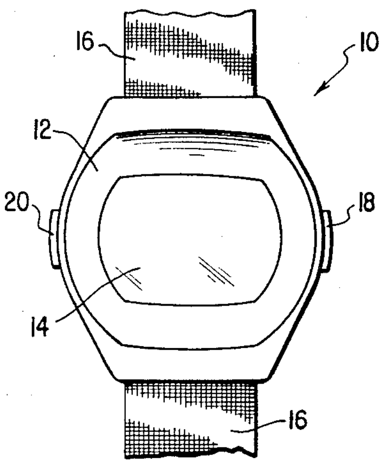


FIG. 1

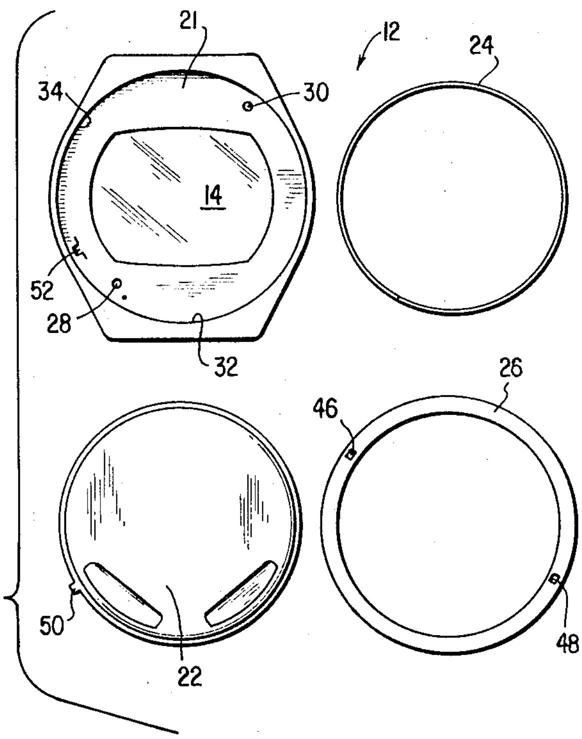


FIG. 2

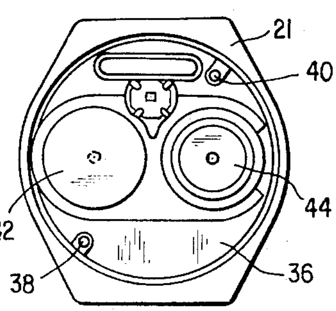


FIG. 3

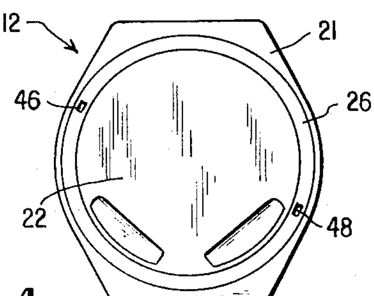


FIG. 4

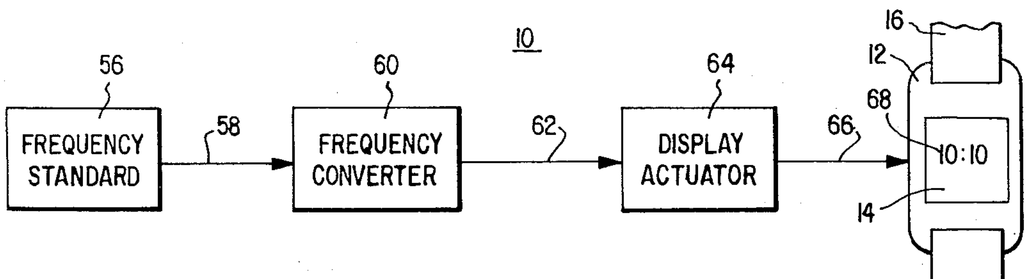


FIG. 5

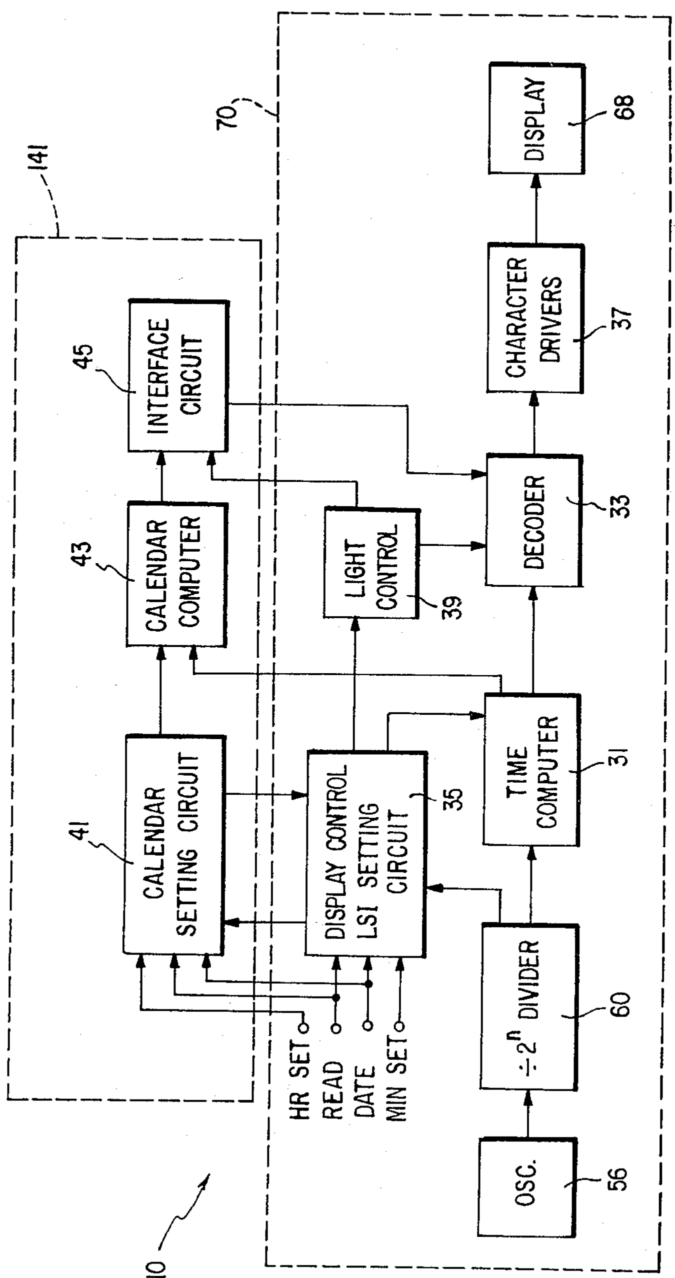

INTERFACE CIRCUIT
45
CALENDAR COMPUTER
43
CALENDAR SETTING CIRCUIT
41
141
70
DISPLAY
68
CHARACTER DRIVERS
37
DECODER
33
LIGHT CONTROL
39
TIME COMPUTER
31
DISPLAY CONTROL LSI SETTING CIRCUIT
35
÷2^n DIVIDER
60
OSC.
56
HR SET
READ
DATE
MIN SET
10

FIG. 6

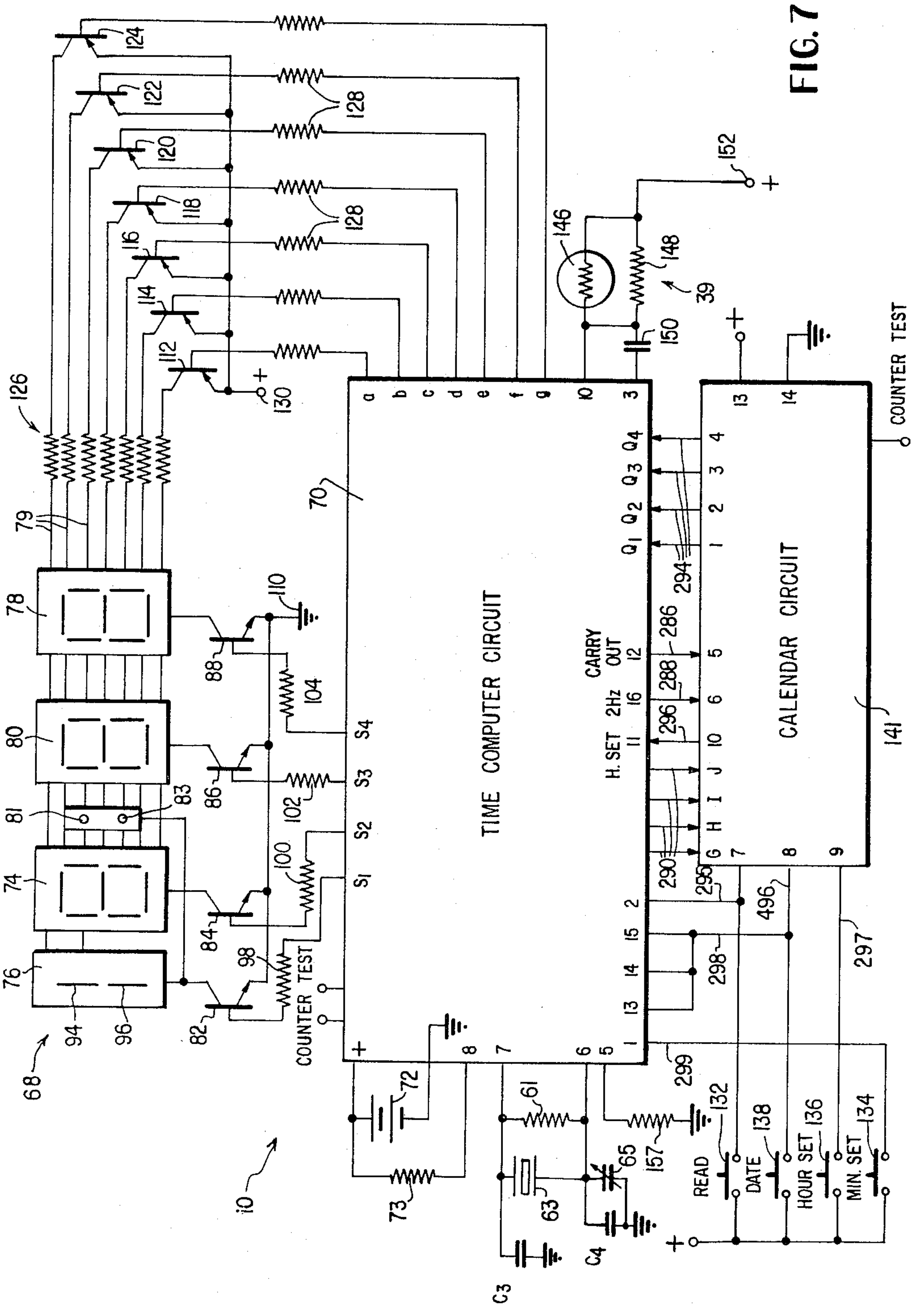
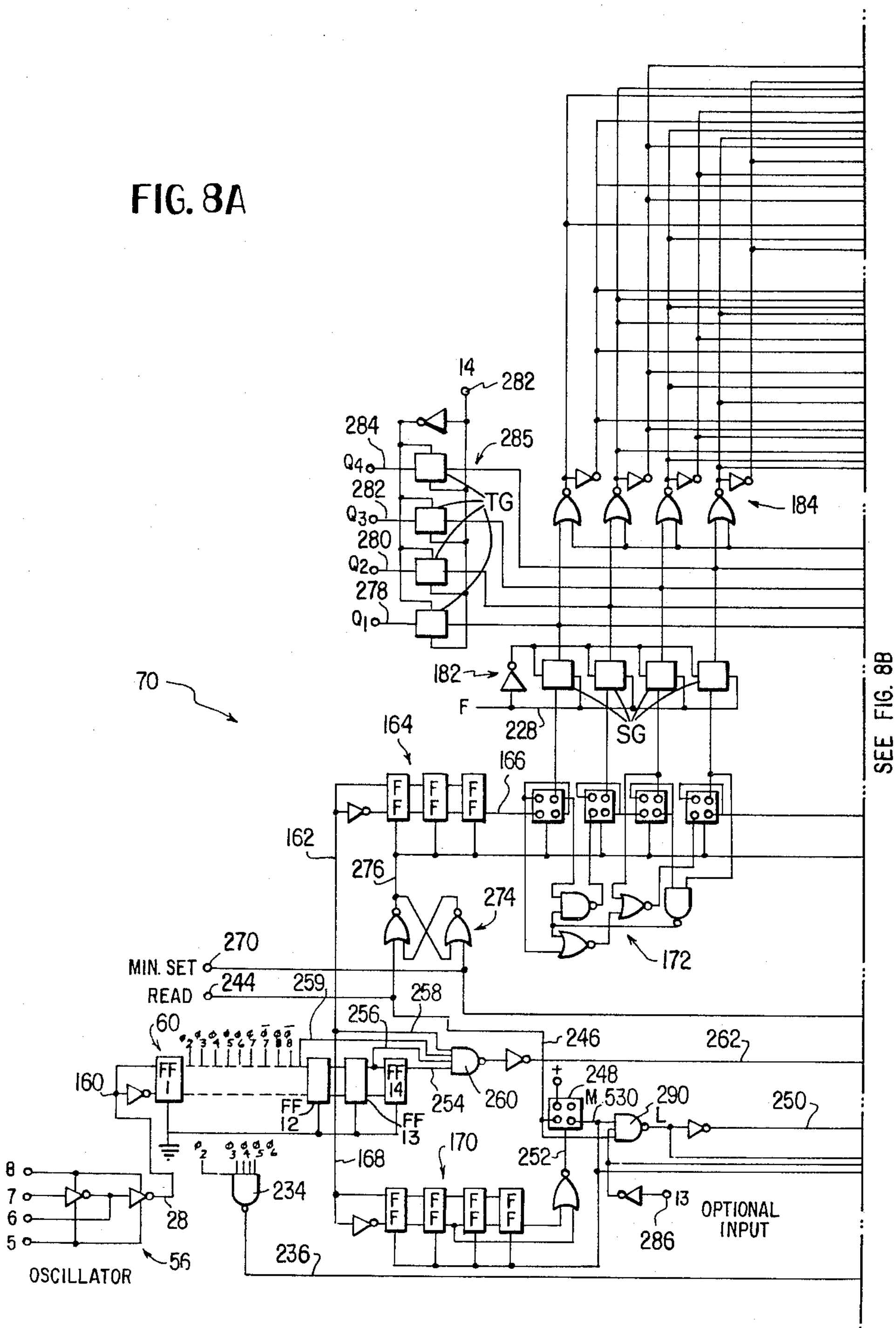

TIME COMPUTER CIRCUIT
CALENDAR CIRCUIT
COUNTER TEST
COUNTER TEST
CARRY OUT
H. SET
2Hz
READ
DATE
HOUR SET
MIN. SET

FIG. 7

FIG. 8A


14
282
284
285
Q4
282
Q3
TG
280
Q2
278
Q1
184
182
F
228
SG
164
166
162
276
274
172
270
MIN. SET
244
READ
259
258
256
246
262
60
260
248
530
290
250
160
FF 1
FF 12
FF 13
FF 14
254
252
168
170
234
8
7
6
5
28
56
OSCILLATOR
286
13
OPTIONAL INPUT
236
SEE FIG. 8B
70

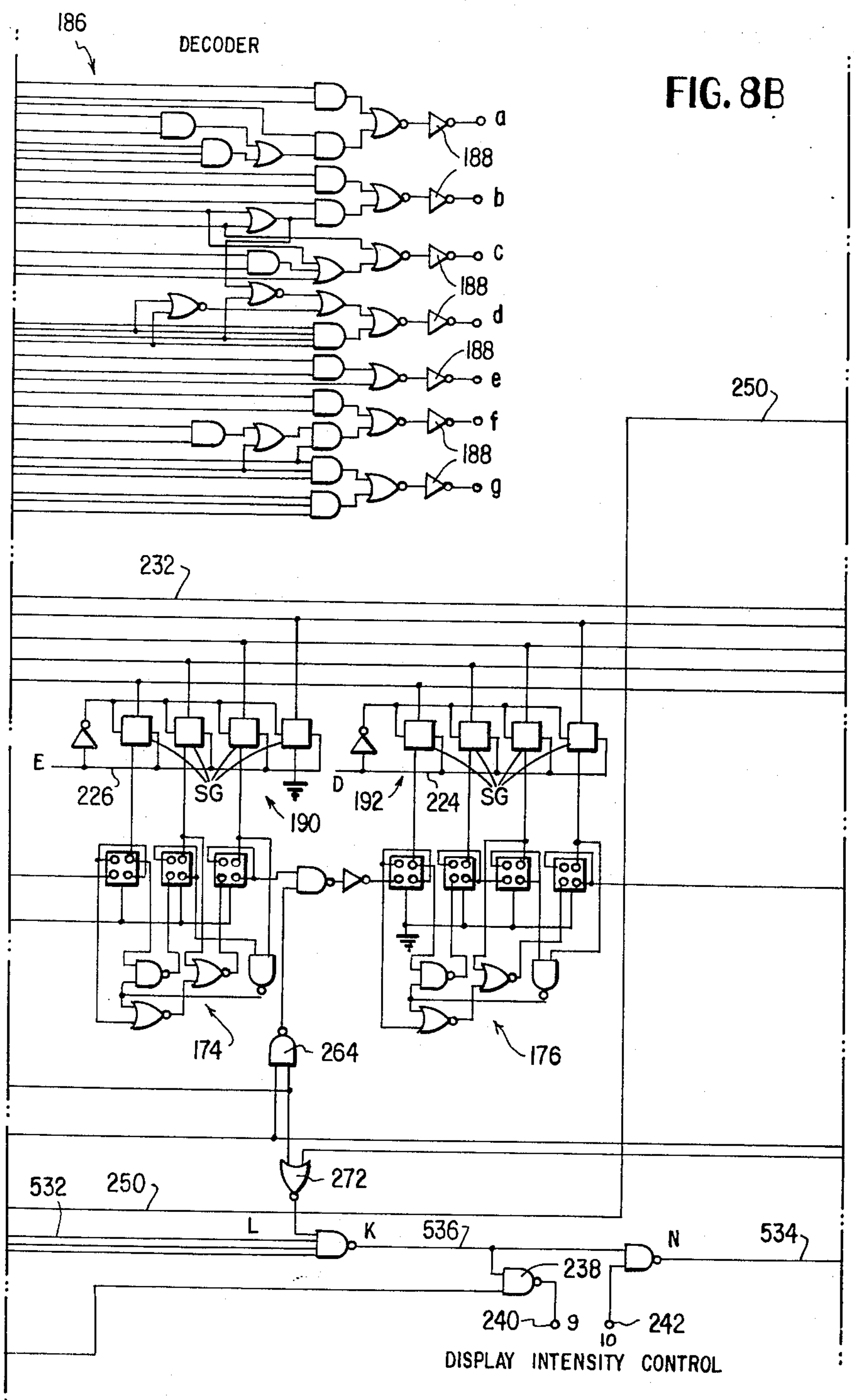
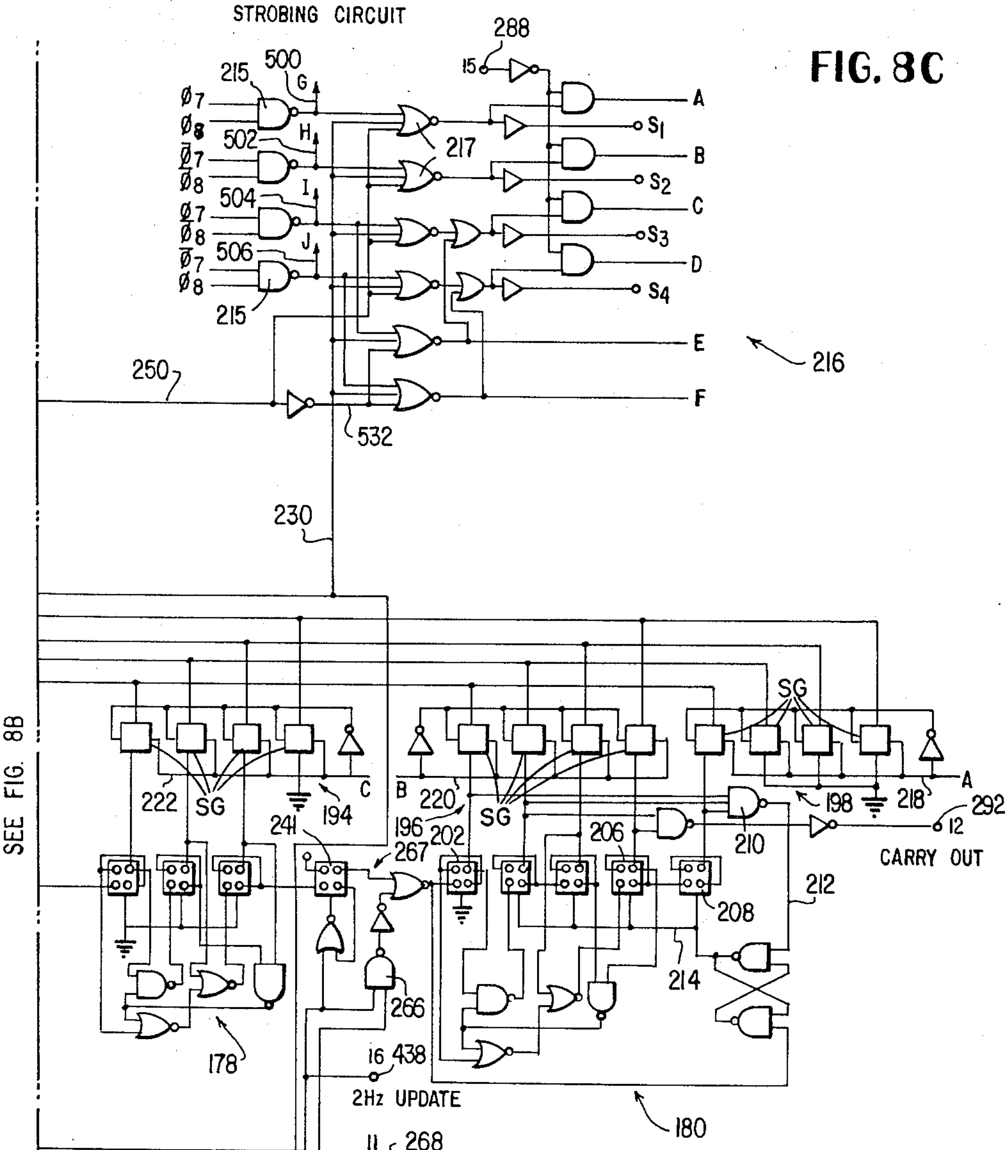


FIG. 8B

SEE FIG. 8A

SEE FIG. 8C

FIG. 8C


STROBING CIRCUIT
288
15
215
500
G
H
502
I
504
J
506
217
A
S1
B
S2
C
S3
D
S4
E
F
216
250
532
230
SG
222
194
C
B
220
196
202
206
198
218
292
12
CARRY OUT
210
241
267
208
212
214
266
178
180
16
438
2Hz UPDATE
11
268
HOUR SET
534
SEE FIG. 8B

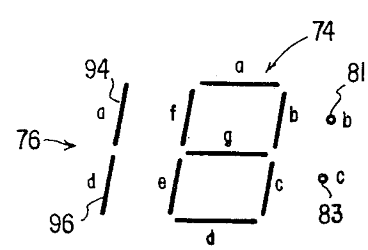
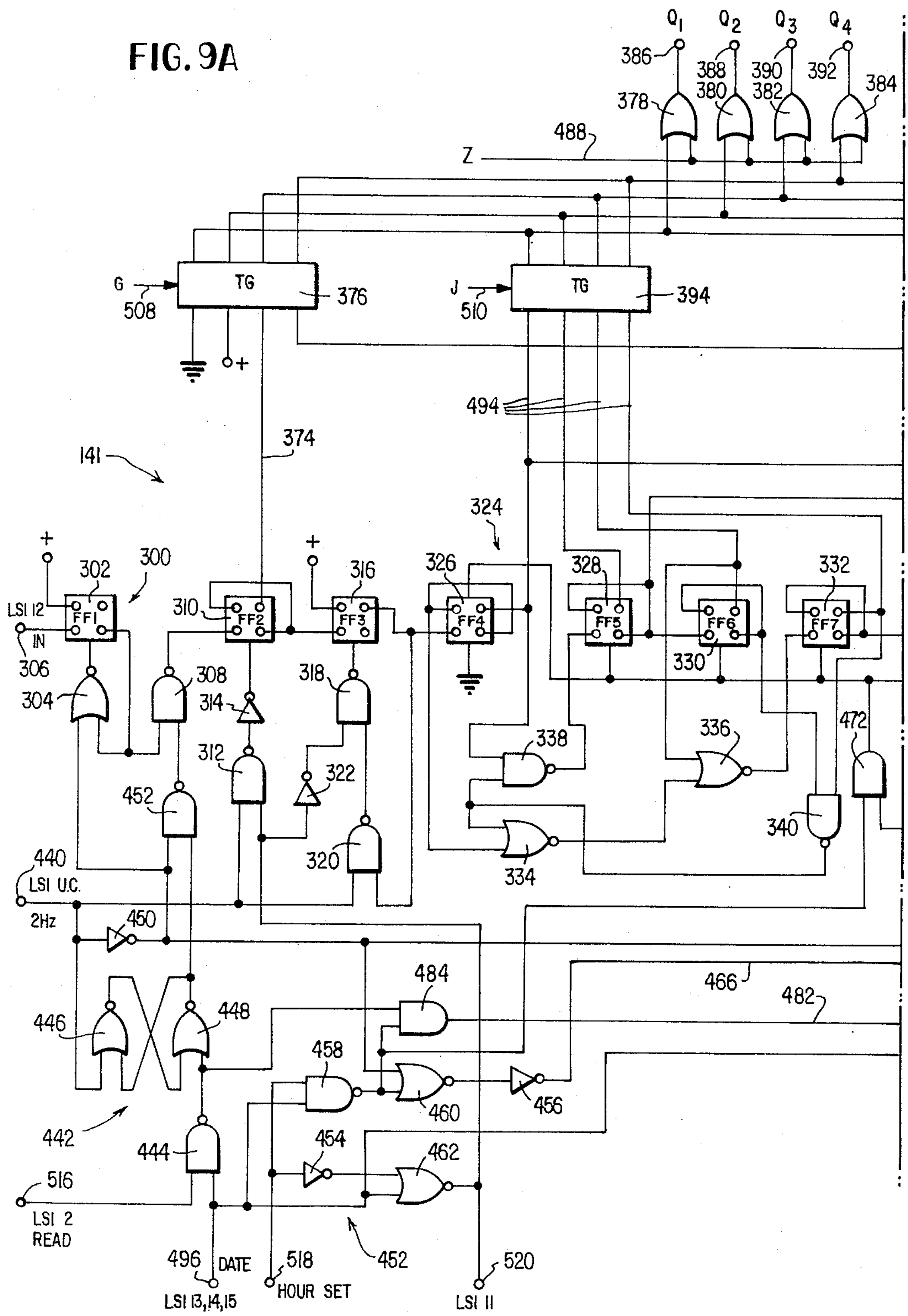

74
94
81
76
96
83
a
b
c
d
e
f
g

FIG. 8D

FIG. 9A


Q1
Q2
Q3
Q4
386
388
390
392
378
380
382
384
488
Z
G
508
TG
376
J
510
TG
394
494
374
141
324
+
302
300
LSI 12
FF1
IN
306
310
FF2
+
316
FF3
326
FF4
328
FF5
FF6
330
332
FF7
304
308
314
318
312
322
338
336
472
452
320
334
340
440
LSI U.C.
2Hz
450
484
466
482
446
448
458
460
456
442
444
454
462
516
LSI 2
READ
452
496
DATE
LSI 13,14,15
518
HOUR SET
520
LSI 11

3,866,406

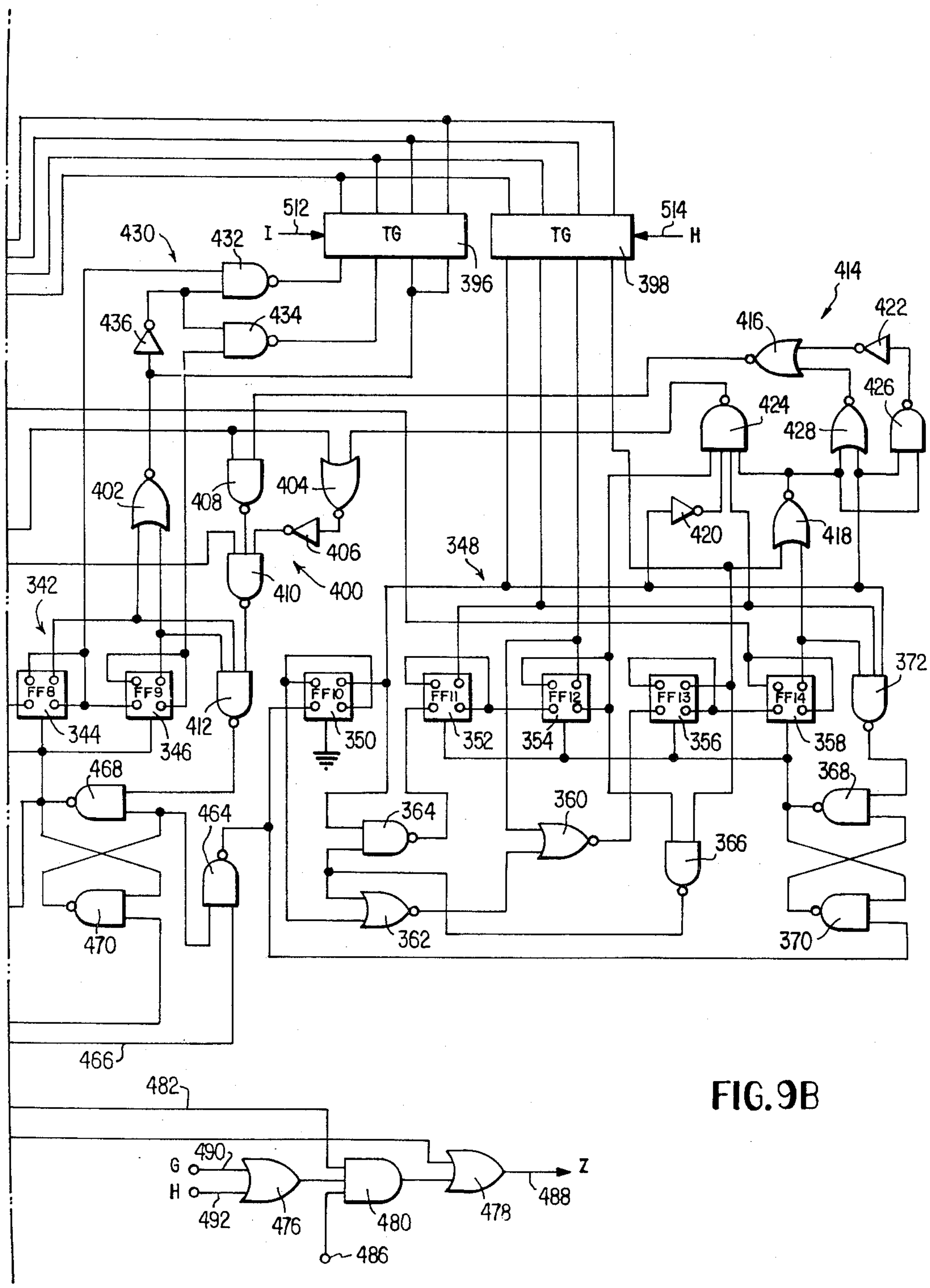


FIG. 9B

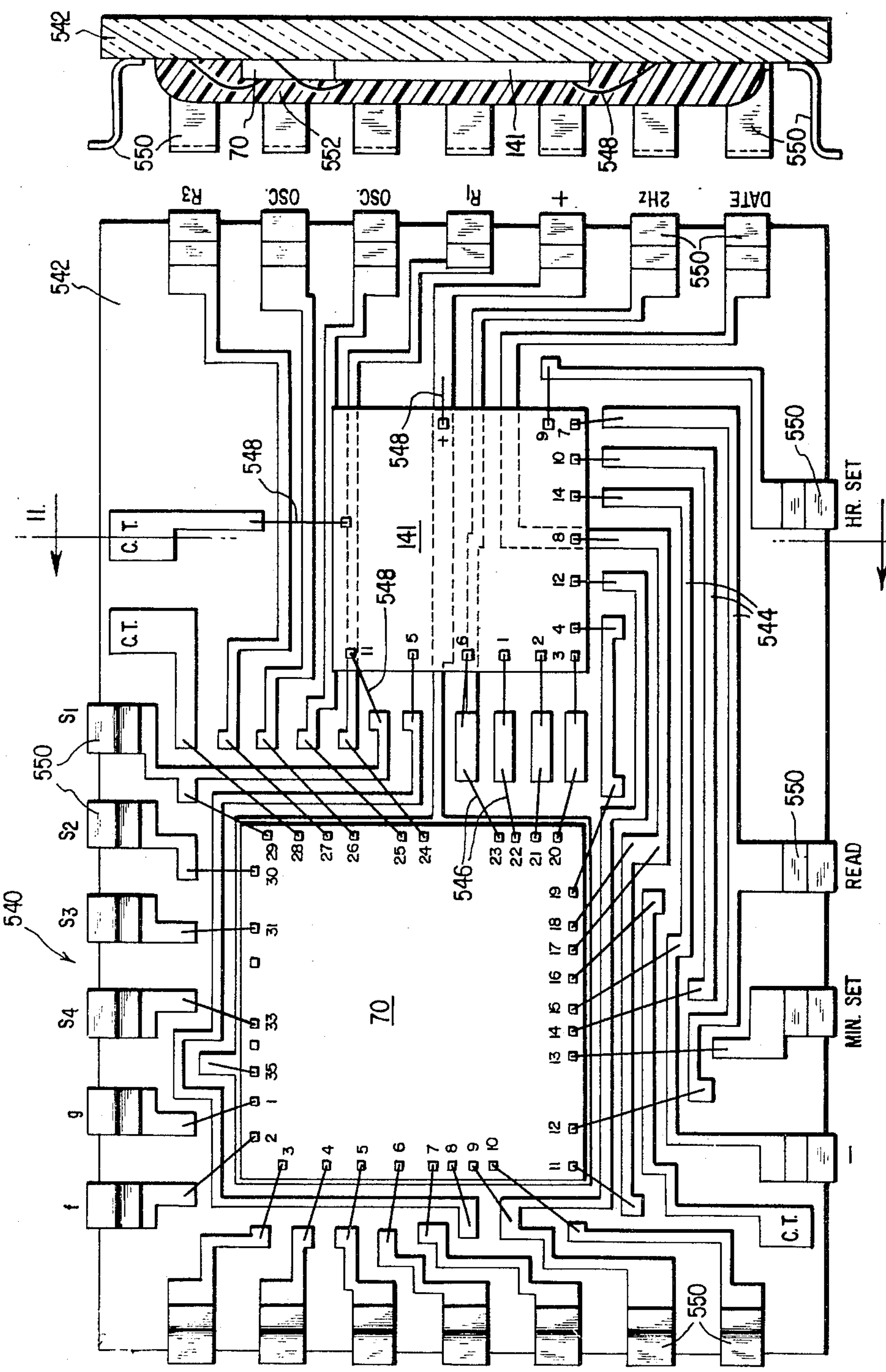

542
550
70
552
141
548
R3
OSC.
R1
+
2Hz
DATE
C.T.
544
546
540
S1
S2
S3
S4
g
f
e
c
d
b
a
HR. SET
READ
MIN. SET
-
II
70

FIG. 11

FIG. 10

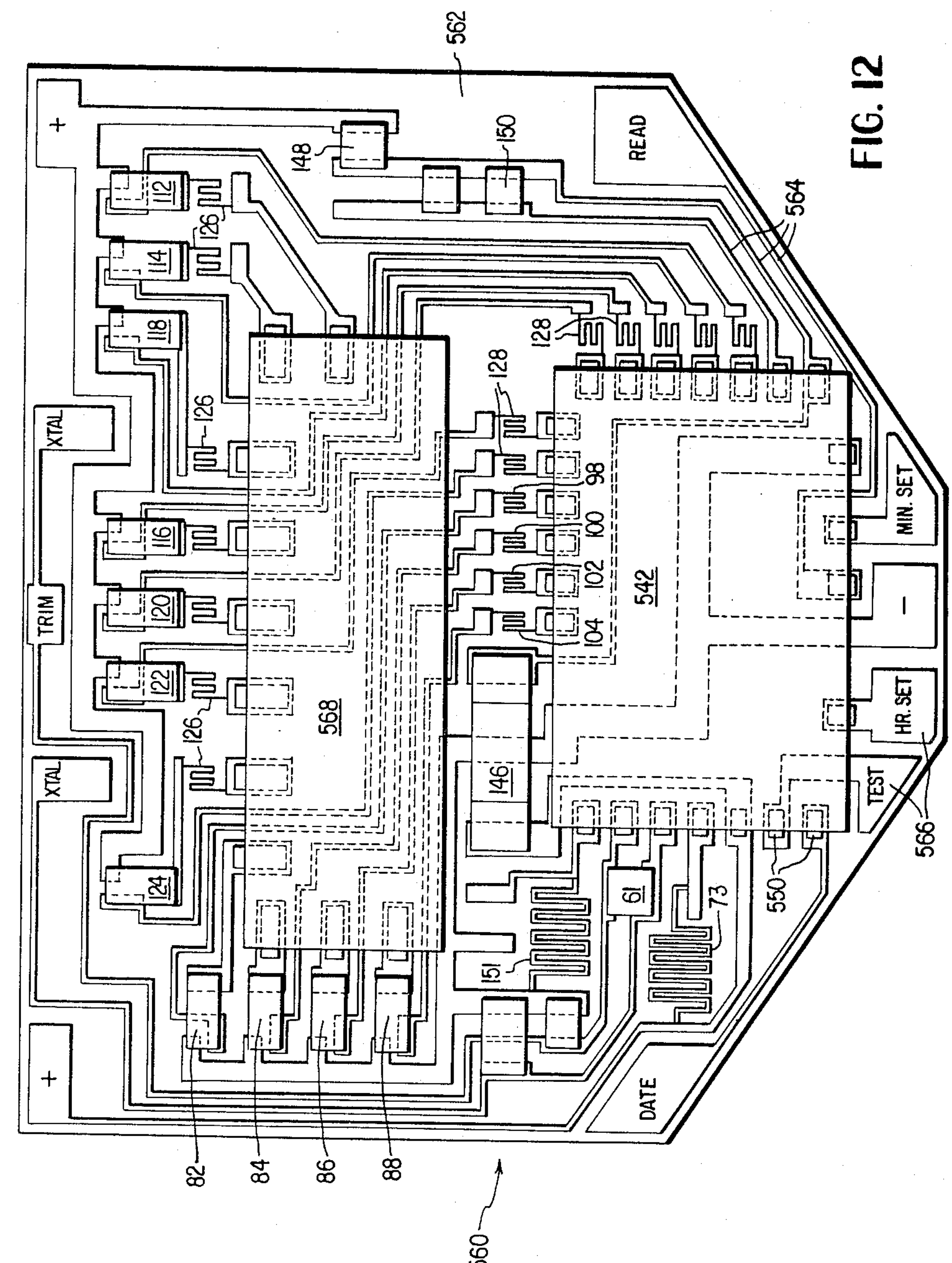

562
+
READ
148
150
564
112
114
118
126
128
XTAL
TRIM
116
120
122
124
568
542
98
100
102
104
146
61
73
151
550
MIN. SET
−
HR. SET
TEST
566
DATE
+
82
84
86
88
560

FIG. 12

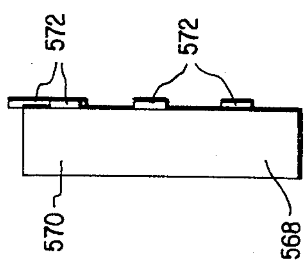


FIG. 14

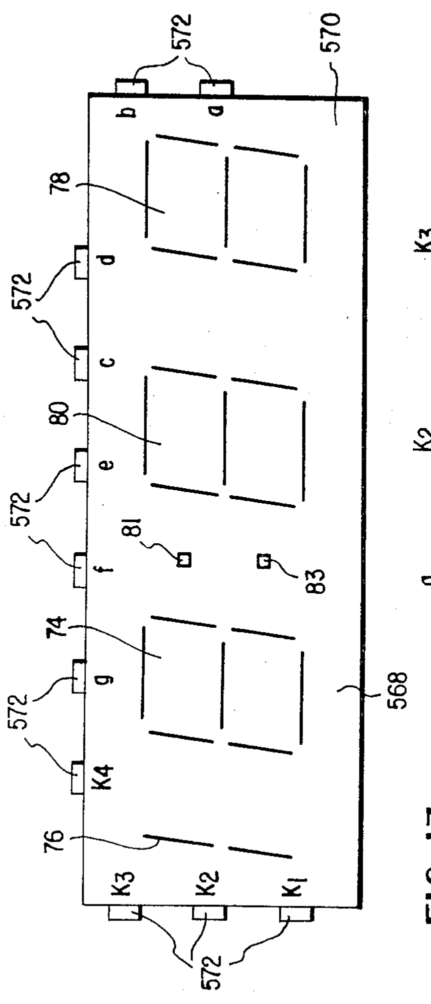


FIG. 13

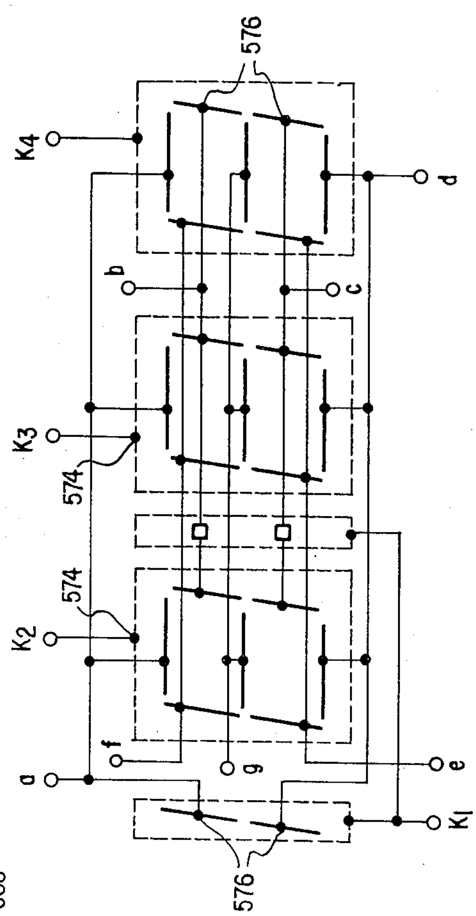


FIG. 15

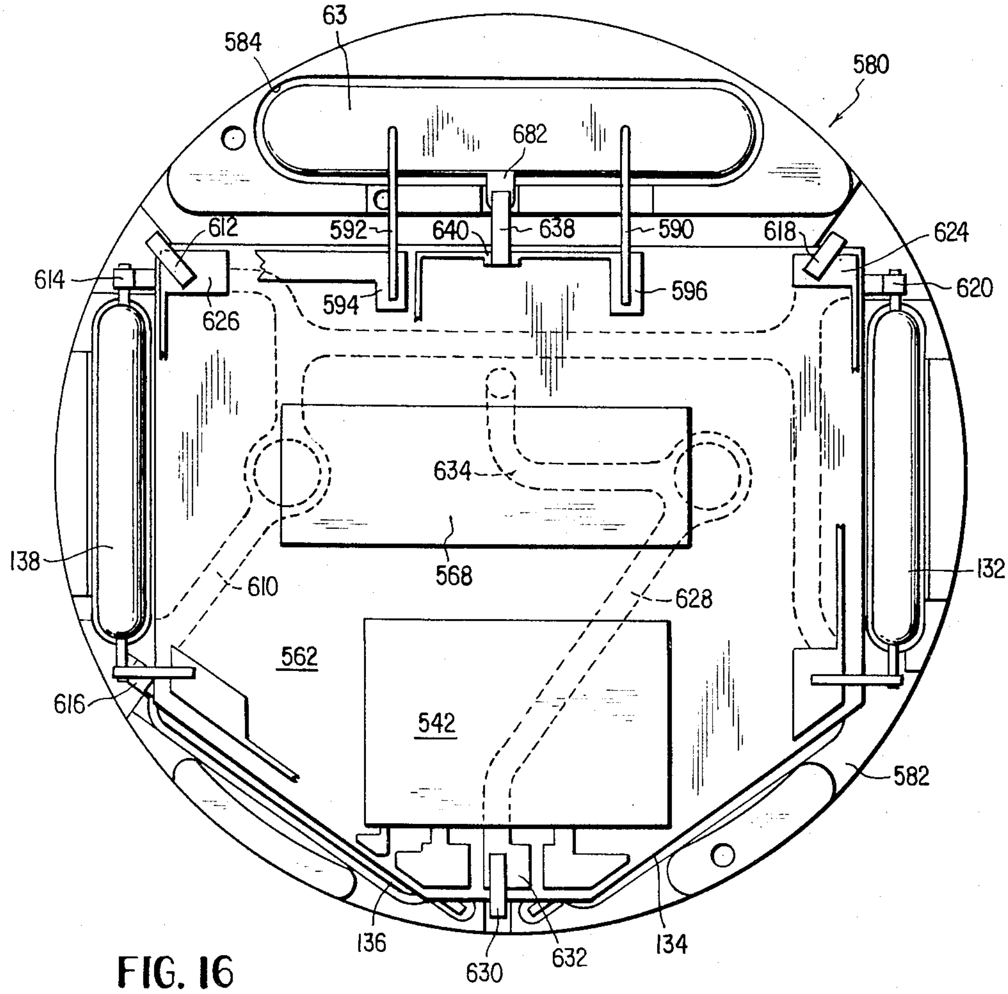

63
584
580
682
612
592
640
638
590
618
624
614
626
594
596
620
634
568
138
610
628
132
562
542
616
582
136
630
632
134

FIG. 16

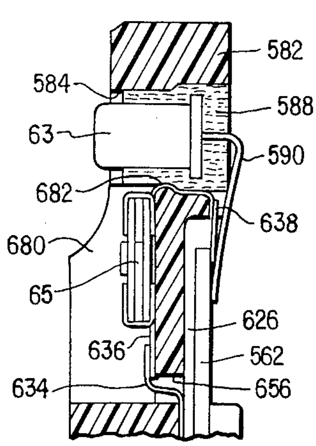
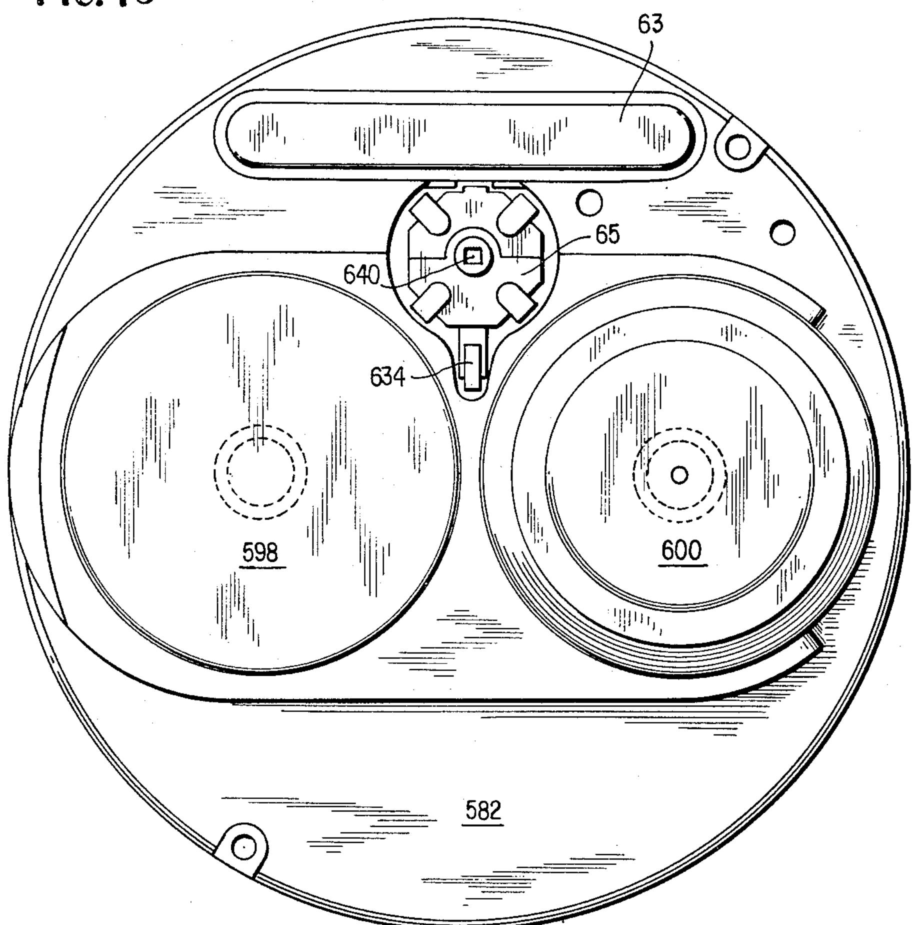

582
584
588
63
590
682
638
680
65
626
636
562
634
656

FIG. 17

FIG. 18


63
65
640
634
598
600
582

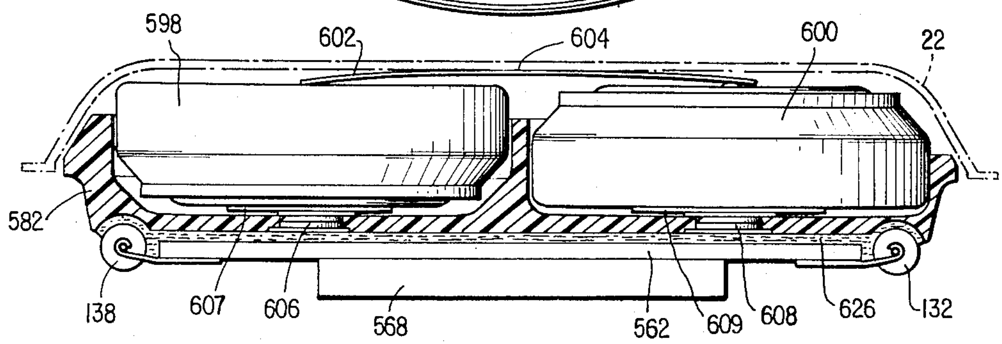

598
602
604
600
22
582
138
607
606
568
562
609
608
626
132

FIG. 19

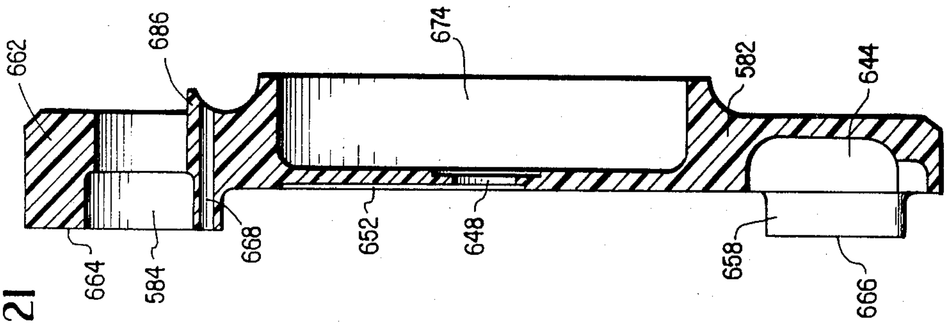

662
686
674
582
644
664
584
668
652
648
658
666

FIG. 21

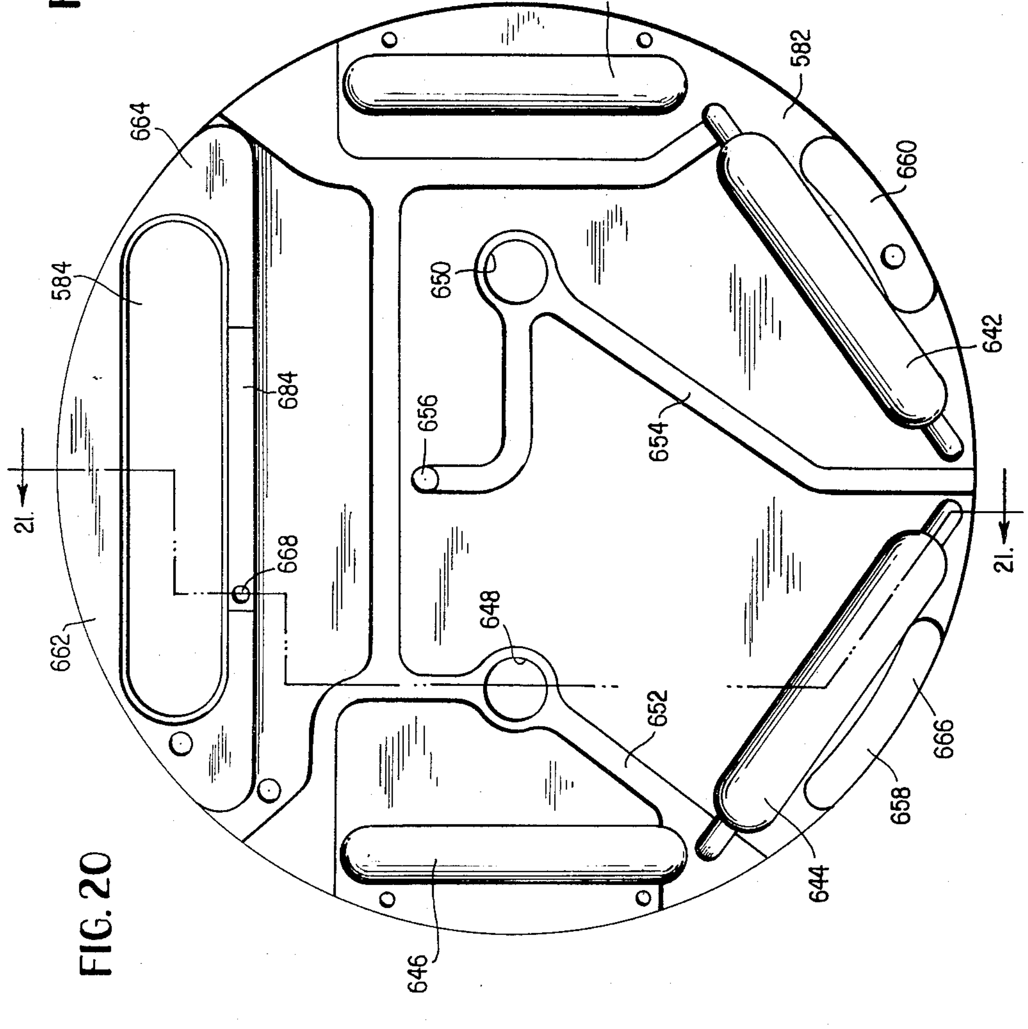
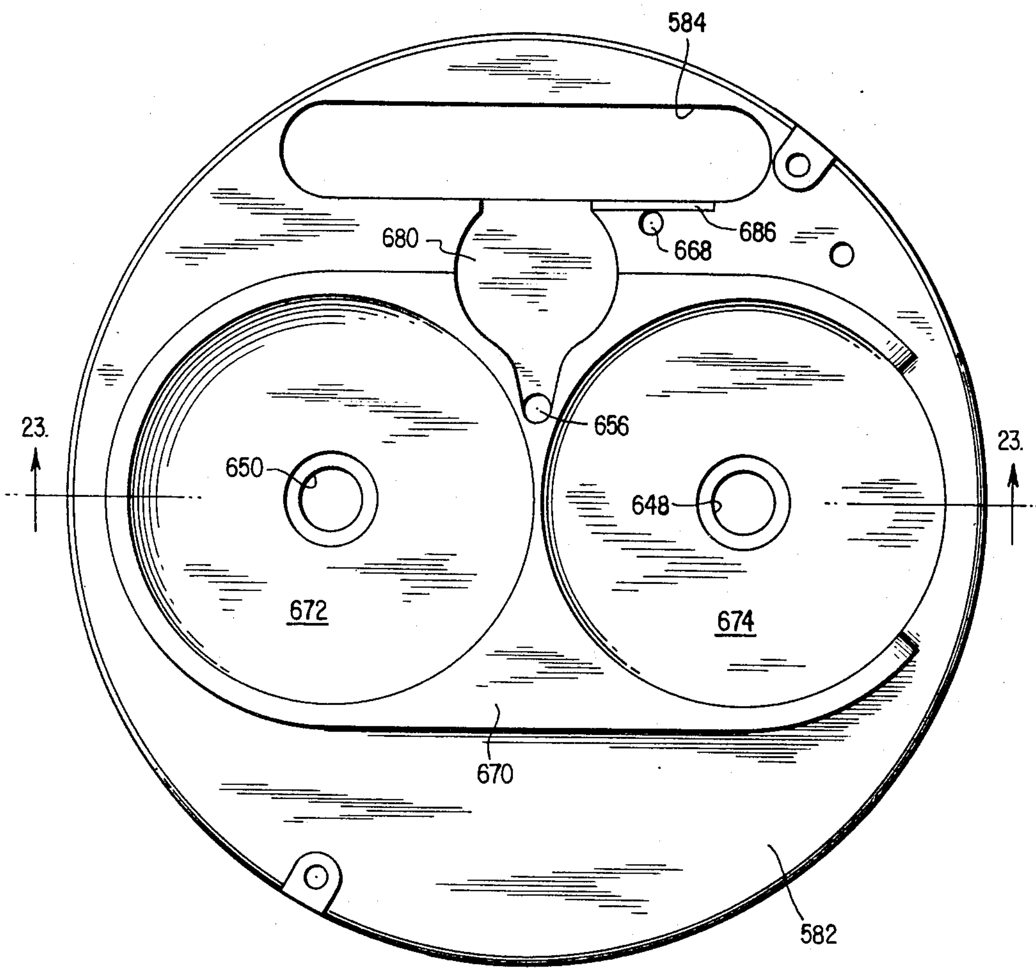

664
640
582
584
660
650
684
642
656
654
21
668
21
648
662
652
666
658
644
646

FIG. 20

FIG. 22


584
680
686
668
656
23.
650
648
23.
672
674
670
582

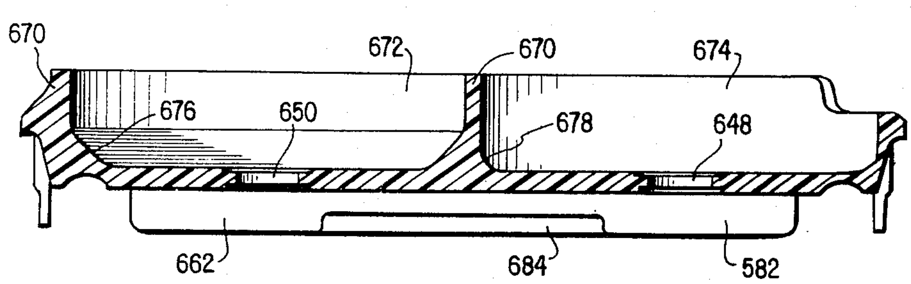

670
672
670
674
676
650
678
648
662
684
582

FIG. 23

FIG. 24

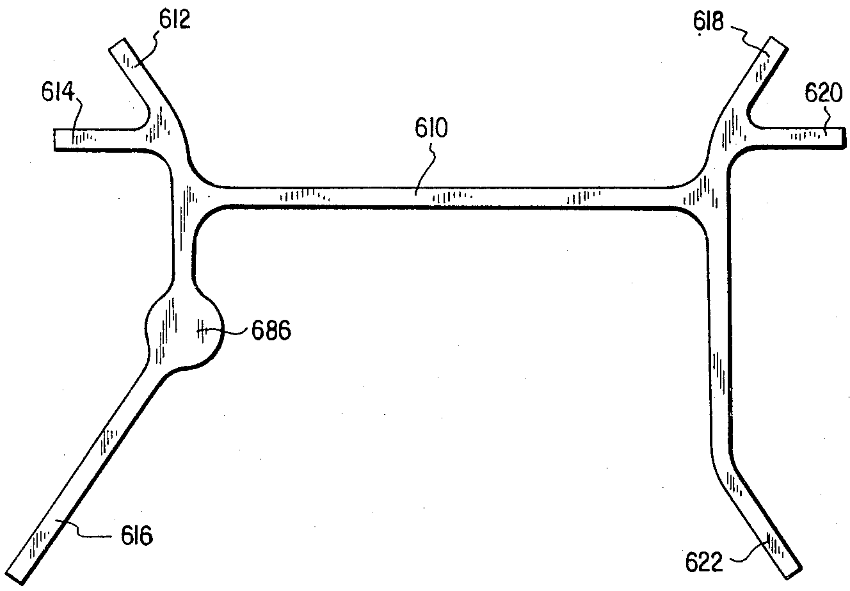


FIG. 25

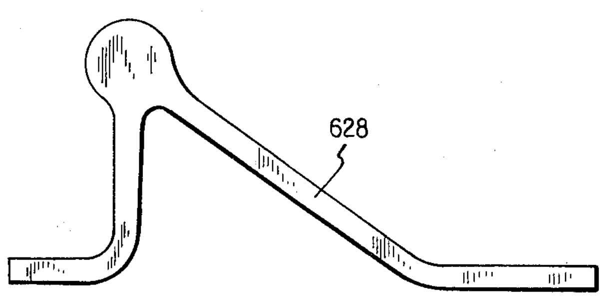


FIG. 26

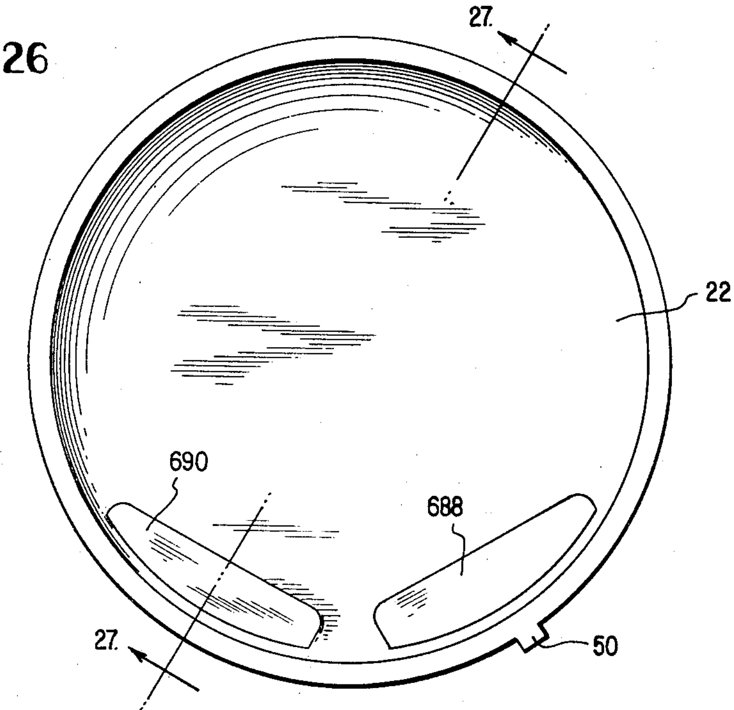


FIG. 27

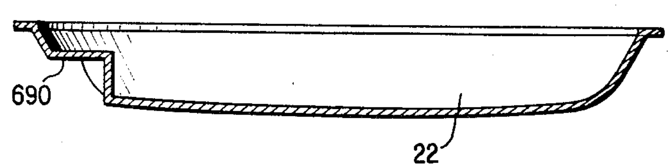
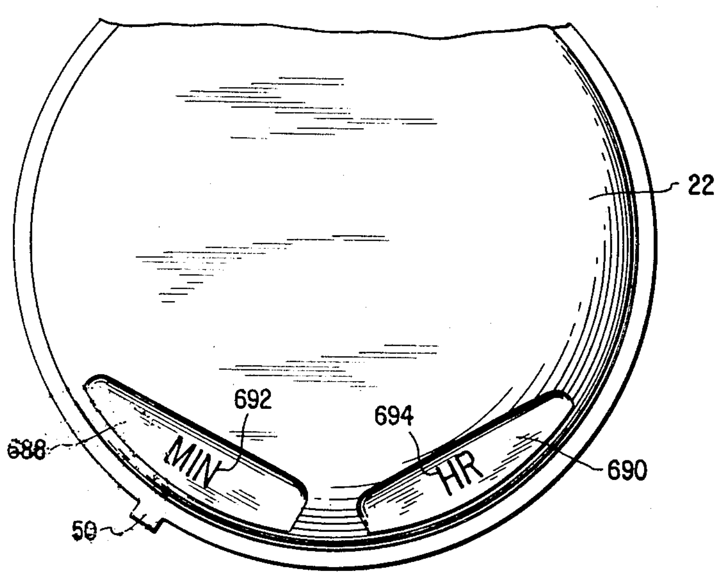


FIG. 28



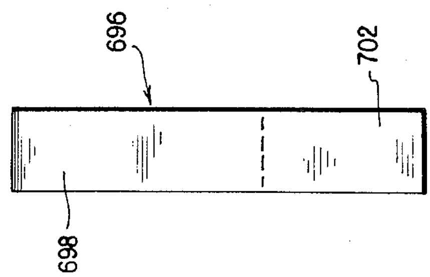


FIG. 30

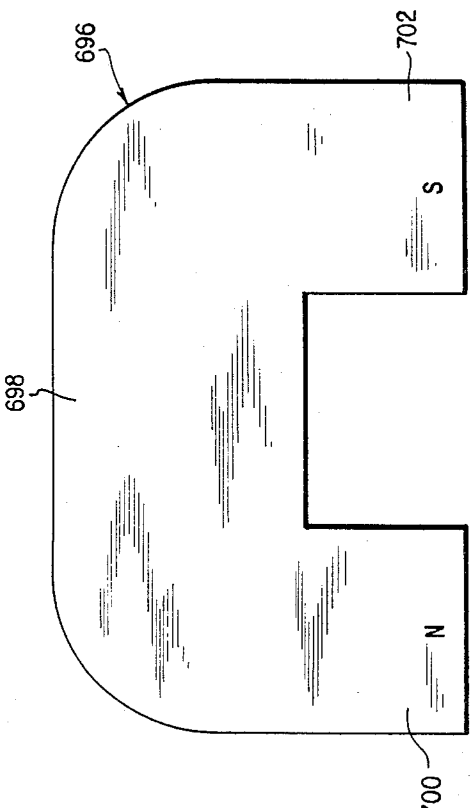


FIG. 29

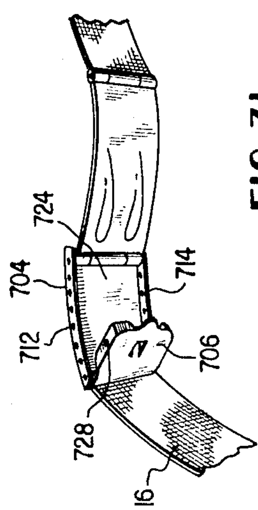
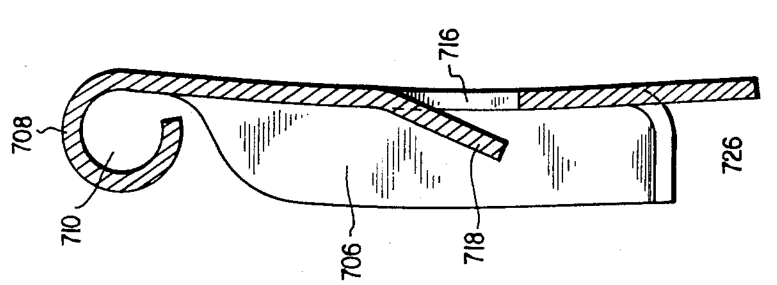


FIG. 31

FIG. 33



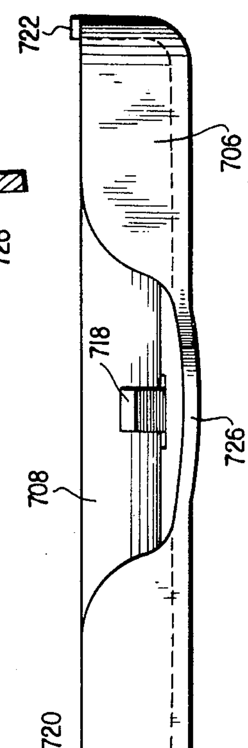


FIG. 34

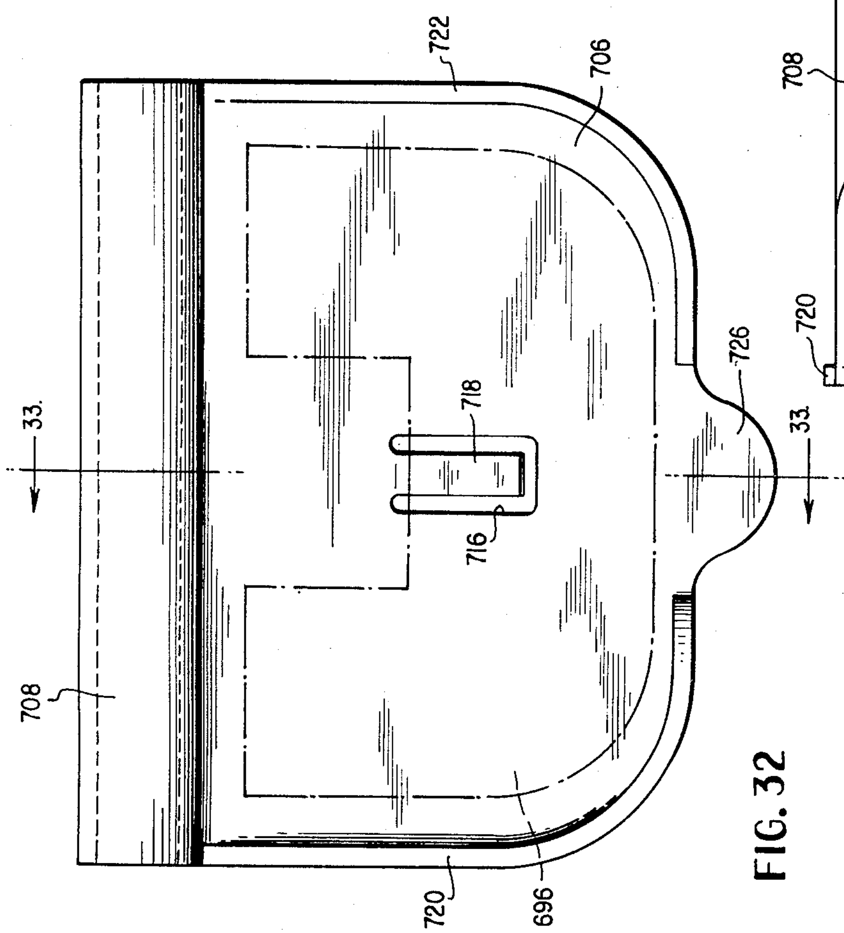


FIG. 32

SOLID STATE ELECTRONIC WRISTWATCH

This application is a division of copending application Ser. No. 328,639, filed Feb. 1, 1973, now U.S. Pat. No. 3,803,827.

This invention is directed to improvements to the watch construction disclosed and claimed in U.S. application Ser. No. 219,953 filed Jan. 24, 1972 in the name of Bruno Dargent and U.S. application Ser. No. 220,922 filed Jan. 26, 1972, now U.S. pat. No. 3,759,031 in the names of Robert E. McCullough and Cleon W. Hougendobler, assigned in common with the present application.

This invention relates to a solid-state timepiece and more particularly to an electronic watch which employs substantially 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. In particular the present invention is directed to a modular wristwatch construction incorporating calendar display features 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 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 water display through a divider formed of low power complementary MOS transistor circuits. In assignee's U.S. Pat. No. 3,567,099 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 U.S. Pat. No. 3,672,155 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 one or two large scale integrated circuit chips 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 which is less expen-

sive to manufacture and which 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 display actuator to an electro-optical digital display in the form of a plurality of light emitting diodes. Mounted in the wristwatch case is a rugged impact resistant one piece frame which houses the entire 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 these 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, one (or at the most two) large scale integrated circuit chips, 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 timed 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 push-button 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 the demand 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 switch. Computation of the precise time is continuous and completely independent of whether or not time is displayed.

Setting is accomplished by actuating either an hour set switch or a minute 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 minutese and seconds. Actuation of the minute set switch automatically zeros the seconds while advancing the minute to the desired setting.

The watch of the present invention is virtually shockproof and waterproof regardless of the environment in which it is placed. The electrical components are mounted in a one piece module frame and preferably incapsulated 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 solidstate solid-state components including the light emitting diode display have a virtually unlimited life.

Important features of the present invention include the use of an integrated circuit with a single decoder for decoding both time and calendar information to be displayed. That is, in addition to time the display can be used with the decoder to show day and month as well as a.m. and p.m. of time. The display digits are individually strobed and the final assembly of the module to the frame is effected by only 11 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.

A separate calendar circuit is connected to the basic LSI time computer circuit. A second demand switch, or date switch, is provided in the watch so that when the date switch is depressed the water shows on the hour display the month, on the colon display a.m. or p.m. (top dot is a.m. and bottom dot is p.m.) and on the minute/second display appears the date. As an option, the watch incorporates an arrangement for blanking the month display so that only the date appears as is desirable for use in Europe where the date and month are normally reversed. The circuit automatically counts to 30 or 31 days according to the month of the year and further automatically counts to 29 in February. The read or first demand switch and the hour set switch are used to set the calendar in conjunction with the date switch. When the hours are set in the watch a.m./p.m. (of the calendar) is automatically reset at a.m. without changing the date.

To set the days, the date button switch is depressed so that the date is shown on the display and then the read or first demand switch is depressed. Days are advanced at one day a second and at the same time the a.m./p.m. indication is advanced at the rate of 2Hz. When the read switch is released the days stay set at the desired date and the desired a.m. or p.m. To set the month the date button is depressed to display the date. The hour set switch is then closed to run the month at two months a second rate. When the hour set switch is reopened the month is set as desired. The display always shows the date (both day and month) every time the date switch is closed and this display continues as long as the date switch is closed no matter what is done to the other switches.

Modular construction allows the substitution of other assemblies 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 at most only two large scale integrated circuit chips which include 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 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 an improved solid-state wristwatch having a calendar display.

Another object of the present invention is to provide a visual display solid-state wristwatch in which the calendar information is displayed by the same visual display elements as are used to display time.

Another object of the present invention is to provide a solid-state wristwatch having an automatic calendar display.

Another object of the present invention is to provide a completely solid-state electronic wristwatch in which the display is in the form of a plurality of light emitting diodes providing both time indications and calendar indications at the option of the wearer.

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. 3 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 timekeeping portion of the wristwatch of the present invention.

FIG. 6 is a slightly more detailed block diagram of both the timekeeping portion and calendar portion of the wristwatch of the present invention.

FIG. 7 is an overall electrical circuit diagram of the watch of the present invention, showing the timekeeping and calendar LSI chips in block form.

FIGS. 8A, 8B and 8C taken together constitute a detailed circuit diagram of the timekeeping portion of the circuit of FIGS. 6 and 7.

FIG. 8D shows the arrangement of the light emitting diode bar segments.

FIGS. 9A and 9B taken together constitute a detailed circuit diagram of the calendar portion of the circuit of FIGS. 6 and 7.

FIG. 10 shows the LSI module or minor substrate on which the LSI timekeeping and calendar circuits are mounted.

FIG. 11 is a cross section through the LSI module taken along line 11—11 of FIG. 10.

FIG. 12 shows the circuit module or main substrate on which the LSI module of FIGS. 10 and 11 is mounted.

FIG. 13 is a top plan view of the diode display module or package of FIG. 12.

FIG. 14 is an end view of the package of FIG. 13.

FIG. 15 shows the wiring connections for the segments of the light emitting display diodes.

FIG. 16 is a top plan view of the watch module which fits inside the watch case.

FIG. 17 is a partial cross section through the module of FIG. 16.

FIG. 18 is a rear or bottom plan view of the module of FIG. 16.

FIG. 19 is a cross section through the module of FIG. 18 showing the manner of mounting the battery cells.

FIG. 20 is a top plan view of the module frame.

FIG. 21 is a cross section along the line 21—21 of FIG. 20.

FIG. 22 is a bottom plan view of the module frame of FIG. 20.

FIG. 23 is a cross section through the module frame taken along line 23—23 of FIG. 22.

FIG. 24 is a plan view of the positive lead frame.

FIG. 25 is a plan view of the negative lead frame.

FIG. 26 in an inside plan view of the back plate of the watch case.

FIG. 27 is a cross section through the back plate taken along line 27—27 of FIG. 26.

FIG. 28 is an outside plan view of the watch case back plate.

FIG. 29 is a plan view of the permanent setting magnet.

FIG. 30 is an end view of the setting magnet.

FIG. 31 is a partial perspective view of the watch bracelet showing a buckle mounting or compartment for retaining the setting magnet of FIGS. 29 and 30.

FIG. 32 is a plan view of the magnet holder of FIG. 31.

FIG. 33 is a cross section through the magnet holder taken along line 33—33 of FIG. 32 and

FIG. 34 is an edge view of the magnet holder.

Referring to the drawings, FIG. 1 is a top plan view of a wristwatch constructed in accordance with the present invention. The watch generally indicated at 10 comprises a non-magnetic 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 ruby material. Attached to case 12 is a wristwatch bracelet 16 and mounted on the case is a push-button demand switch 18. Also mounted on the watch case at the edge opposite from demand switch 18 is a similar date switch 20. Watch case 12 is preferably constructed from a cover 21 and back plate 22 so that no shafts or electrical connections pass through the watch case to the interior of the watch and all elements are sealed from the outside. Push-button switches 18 and 20 are preferably of identical construction and carry permanent magnets so that when they are depressed reed switches inside the watch case are actuated, as more fully shown and described in assignee's copending application Ser. No. 138,557 filed Apr. 29, 1971, now U.S. Pat. No. 3,782,102 the disclosure of which is incorporated herein by reference.

FIG. 2 is an exploded view showing the components of the watch case 12. These comprise a cover 21 mounting the light filter 14, a back plate 22, an O-ring sealing gasket 24 and an externally threaded attachment ring 26. Cover 21 is provided with a pair of mounting holes 28 and 30 which extend only part way through the cover and which are adapted to receive the ends of mounting screws for mounting a module frame inside case cover 21. The cover is also internally stepped as at 32 to receive and engage with external threads on attachment ring 26.

FIG. 3 shows the cover 21 with a module frame of circular configuration illustrated at 36, as completely received within the cover. Frame 36 is attached to the cover solely by a pair of mounting screws 38 and 40 which pass through the frame and are threadedly received in the mounting holes 28 and 30 illustrated in FIG. 2. Frame 36 is provided with a pair of circular cavities 42 and 44, each of which is adapted to receive a 1½ volt one-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. 2, 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, frame 36 is first inserted into the cover 21 and secured by the screws 38 and 40. O-ring seal 24 is then inserted onto 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 is rotated into tight threaded engagement with the internal threads 34 on cover 21. It is a feature of the assembly that the screws 58 and 40 automatically angularly orient or align the frame 36 with the cover 21 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 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 timekeeping components of the watch of the present invention. 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 supplied to a display actuator 64 which in turn drives an electro-optipcal 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 push-button 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 nomral operation, time is continuously being kept but is not displayed through the window 14. That is, no indication is visible through the window and this is the normal condition which previals in order to converve battery energy in the watch. However, even though the time is not displayed through the window 14, it is understood that the watch can continuously keep 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 push-button 18 with his finger and the correct time is immediately displayed at 68 through 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 one and one-quarter seconds, irrespective of whether or not the push-button 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 push-button 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 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 push-button switch 18 is released.

Push-button 18 is a read switch or a demand switch which is depressed when the wearer desires the time to be displayed. Incorporated in the watch 10 of FIG. 1 is a second push-button switch 20 identical in construction and hereafter referred to as the date switch. When the push-button 20 of the date switch is depressed the date, month and the a.m. or p.m. of time are displayed by the same diodes that display time in response to depression of push-button 18. However, contrary to the former, when the date button 20 is depressed, the day, month and a.m. or p.m. of times are displayed so long as button 20 remains depressed and are immediately extinguished when the date button 20 is released.

FIG. 6 is a circuit diagram of the watch 10 of the present invention with like parts bearing like reference numerals. The integrated circuit portion of the time computing part of the watch is illustrated by the dashed block 70. This block is formed by using large scale integrated circuit techniques. Connected to the circuit in dashed block 70 is a second integrated circuit or calendar circiut enclosed in dashed block 141 which controls the calendar display of the watch 10. Again the calendar circuit 141 is formed using large scale integrated circuit techniques. Circuits 70 and 141 will be described as separate chips but if desired more advanced techniques can be used so that the circuits 70 and 141 are formed on a single integrated circuit chip. Thus, it is seen that the present invention provides a wristwatch where the two principal circuits 70 and 141 are formed as one or at the most two large scale integrated circuit chips. In FIG. 6 the principal components of the time circuit 70 are the oscillator 56, divider 60, a time computer 31, decoder 33, character drivers 37 and the electro-optical display 68. Also forming a part of it are the display control and setting circuit 35 and the light control circuit 39. The calendar circuit 141 comprises a setting circuit 41, a calendar computer 43 and an interface circuit 45 for interfacing with the time circuit 70.

FIG. 7 is an overall circuit diagram of the wristwatch of this invention. In addition to the integrated circuits 70 and 141 the watch comprises a battery 72 which by way of example only may comprises a conventional 3 volt wristwatch battery formed from two 1½ volt cells connected in series. Connected to the positive side of the battery is a resistor 73 and the battery energizes the light emitting diode display 68 which is shown in FIG. 7 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 and 83 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 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 NPN junction transistors 82, 84, 86 and 88. 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 (except the hours tens station) as more fully described below. However, all the cathodes of each station are connected in common through the NPN junction transistor for that display. The two bar segments 94 and 96 for the hours tens display have their cathodes connected to the transistor 82 as do the colon dots 81 and 83. All the 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 and station 80 has the cathodes of all diodes connected to the transistor 86 and all the cathodes of display station 78 are similarly connected to transistor 88. These transistors have their bases returned to the integrated circuit 70 through current limiting resistors 98, 100, 102 and 104, the emitters of the transistors being connected in common to ground, i.e., the negative side of the power supply battery 72 is indicated 110.

The anodes of the bar segment diodes are energized from bipolar driver transistors 112, 114, 116, 118, 120, 122, and 124. Since the greatest number of bar segments in 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 to the positive side 130 of power supply battery 72.

The external components of the oscillator frequency standard 56 in FIG. 7 are the crystal 63, the variable capacitor 65 (tuning capacitor or trimmer), the bias resistors 61 and 73 and the two π network feedback capacitors C_3 and C_4 illustrated. By way of example only, the oscillator 56 may be of the general type shown and described in assignee's U.S. Pat. No. 3,664,118. The remaining portions of the oscillator 56 are incorporated in the integrated circuit 70 of FIG. 7 as more fully disclosed in assignee's copending U.S. Pat. application Ser. No. 143,492, filed May 14, 1971, the disclosure of which 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 hour set switch **136.** These switches are connected between the positive side of the battery **72** and the time computer circuit **70** or the calendar circuit **141** as more fully described below.

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 **39** in FIG. **7** 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 a capacitor **150.**

FIGS. **8**A, **8**B and **8**C taken together (hereinafter referred to as FIG. **8**) show a detailed block diagram of the integrated circuit **70** of FIGS. **6** and **7.** In FIG. **8** like parts bear like reference numerals. FIG. **8D** illustrates the arrangement of the light emitting diode segments of the display.

Referring to FIGS. **8**A through **8**D, a signal having a frequency of 32,768 Hz is supplied from oscillator **56** over lead **28** to the divider input **160.** The divider **60** is a 14-stage non resettable counter forming the frequency converter **60** of FIG. **5.** The counter is formed from fourteen stages of binary flip-flops in a counting chain and each stage is comprised of complenentary MOS transistors. The output of the twelfth stage of the divider (ϕ**12**) having a frequency of 8 Hz is applied by way of a lead **162** to the input of a 3-stage resettable counter **164** comprising three stages of MOS complementary symmetry transistor flip-flops which produce an output on lead **166** having a frequency of 1 Hz. The **8** Hz signal from the divider is also applied by way of a lead **168** to a 4-stage flip-flop and decade counter **170,** the output of which counter or controlled timer **170** controls a 1¼ second timing flip-flop **248.**

The 1 Hz signal on lead **166** is applied to a seconds unit storing register **172** which divides by **10** and whose output is in turn connected to a seconds tens register **174** which divides by **6.** The seconds tens register in turn has its output connected to a minutes units register **176** which again divides by **10** and the output of this register is connected to a minutes tens register **178** which divides by **6.** The output of register **178** is in turn connected to a divide by **12** hours register generally indicated at **180.** These registers are all comprised of binary chains of complementary MOS transistor flip-flops and the individual stages except for the control terminals are in all respects similar to the individual stages of the binary dividers **60** and **164.** For a detailed discussion of an individual stage forming a stage of either the divider **60,** divider **164** or one of the registers **172, 174, 176, 178** and **180** reference may be had to assignee's U.S. Pat. No. 3,560,998.

Output signals indicative of seconds units of time are developed in register **172** and these are applied through four selection gates or transmission gates **182** and through four input gates **184** to a decoder **186.** The decoder **186** converts the **8-4-2-1** binary coded decimal signals from the register **172** into suitable drive signals for the displays which are applied to the light emitting diodes of the display through the buffer amplifiers **188.**

The individual bar segments are labelled *a* through *g* and the relationships of the segments and their interconnections to the outputs of the buffer amplifiers **188** is illustrated in FIG. **8**D. That Figure shows the hours tens station **76** and the hours units station **74** along with the colon dots **81** and **83.** While only the station **74** is illustrated in FIG. **8D** it is understood that the outputs of the buffer amplifiers **188** are also connected to the corresponding bar segments of the combination minute and second stations **78** and **80** of FIG. **7,** each of these stations being in all respects identical to station **74.** That is, the output from the top buffer amplifier **188** is not only connected to the " *a*" bar segment of station **74** but is also connected to the corresponding segment of station **78** and **80** of FIG. **7.** The correspondingly labelled other outputs of buffer amplifiers **188** are connected to the corresponding other bar segments of each of the stations **74, 78** and **80.** Outputs "*b*" and "*c*" are also connected to the anodes of the colon-dot diodes and outputs "*a*" and "*d*" from the buffer amplifiers **188** are connected to the anodes of the two diodes **94** and **96** forming the hours display. These diodes are simultaneously on or off to display a **1** or nothing at all in correspondence with the hours tens digit of time.

Register **174** in FIG. **8** is similarly connected through four transmission gates **190** to the input gates **184** and to the decoder **186,** the input gates **184** and decoder **186** being common to all the registers. Register **176** is connected to the input gates **184** through selection gates **192** and register **178** is similarly connected to the input gates through selection gates **194.** Finally, hours register **180** is connected to the input gates through two sets of selection gates, a first set **196** and second set **198.** The integrated circuit **70** of FIG. **8** performs the functions of time base generation, time storage, and information decoding, as well as the miscellaneous functions of display timing, automatic intensity control, and display selection. The circuit is designed to operate at 2.2 to 3.2 volts and to use 0.100 inch light emitting diode display. The time base generator portion of the circuit consists of external components (crystal, resistor, fixed capacitors, and trimming capacitor) and an inverter used as an oscillator. The divider comprises a 14-stage non-resettable counter **60** as well as the **3**-stage resettable counter **164.** The 14-stage counter **60** provides the frequencies used throughout the system to form such functions as timing, setting, resetting, switching, and display intensity control. The 3-stage counter **164** is resettable because it acts as a "hold" circuit during minute setting. After the minutes have been set, this counter remains in the reset mode which keeps a signal from passing into the seconds storage register **172** until the read or demand button **18** of FIG. **1** has been depressed and the read switch **132** of FIG. **7** closed. This counter consists of three stages so that the error upon restarting is no greater than one-eighth of a second.

The time storage portion of the circuit consists of three registers, two divide by **60** and another divide by **12.** The first divide by **60** register is resettable and is used to accumulate seconds. Both divide by **60** registers are subdivided into divide by **10** and divide by **6** sections such that the first divide by **60** register is formed by the register sections **172** and **174** and the second divide by **60** register is formed by register sections **176** and **178.** This division is provided because the time information must be displayed in decimal numbers. The divide by **12** register **180** displays the numbers 1 through 12 and resets to 1. This is accomplished by making the first flip-flop 202 non-resettable. The first three flip-flops in combination with the associated logic circuitry forms a divide by 10 section, the next flip-flop 206 controls the tens of hours and the last flip-flop 208 is used to ensure positive resetting. At the count of ten, eight and two are detected. This sets the tens of hours flip-flop 206 and triggers the resetting flip-flop 208 which resets stages 2, 4, and 8. Stage 1, i.e., flip-flop 202, is already at 0 so the units of hours decodes to b 0 . However, at the count of 13 AND-gate 210 reads the tens of hours and stages 1 and 2. This toggles the tens of hours flip-flop 206 by way of lead 212 back to 0 and resets stages 2, 4 and 8 by way of lead 214. Stage 1, i.e., flip-flop 202, is not reset and therefore number 1 is decoded. However, this happens so rapidly that the number 13 is never displayed.

It is a feature of this invention that only one decoder 186 is used in conjunction with the strobing circuit, generally indicated at 216, by means of which the digits are individually strobed. The six strobe outputs labelled A, B, C, D, E, and F of the strobe circuit 216 are applied to the corresponding and similarly labelled lines 218, 220, 222, 224, 226, and 228 of the transmission gates 182, 190, 192, 194, 196, and 198, such that these selection gates are enabled in accordance with the strobe outputs. A second set of strobe circuit outputs, labelled S_1, S_2, S_3 and S_4 are applied as correspondingly labelled inputs in FIG. 7 to the strobe transistors 82, 84, 86, and 88. The strobing outputs are such that the sequence of the display is as follows: a) tens of hours and colon dots, b) units of hours, c) tens of minutes, d) units of minutes, or a) nothing, b) nothing, c) tens of seconds, d) units of seconds if seconds are displayed, and the cycle repeats.

It is apparent from FIG. 8 that a common decoder 186 is used for all numerals to be displayed. The high frequency output of oscillator 56 is lowered in frequency by a series of binary divider stages in divider 60. This divider produces several output frequencies including an 8 Hz output which is fed into the register 164 to produce a 1 Hz output on lead 166. The 1 Hz output is fed into the counting registers 172, 174, 176, 178 and 180 where it is further divided by 10, 6, 10, 6, and 12, corresponding to the digits needed to display seconds, minutes and hours of time. The binary coded decimal outputs of all the dividers in the counting registers are fed into corresponding selection gates 182, 190, 192, 194, 196 and 198. These gates are controlled by the strobe circuit 216 and the number passing through the input gates 184 into the decoder/driver 186 is determined by this strobe circuit. The outputs A, B, C, D, E, and F from strobe circuit 216 applied to the selection gates determines at any instant what timing information is supplied to the diodes. The outputs S_1, S_2, S_3 and S_4, applied to the base of transistors 82, 84, 86 and 88 determine what stations display the timing information selected by the selection gates. In addition, the strobing circuit strokes at a greater than visible speed so that a minimum number of diodes are on at any one time while at the same time giving the appearance of a continuous display.

In the operation of the system, the timer 170 controls the strobing circuit. when the demand switch is depressed, the minutes and hours are displayed for 1 ¼ seconds and if the demand switch remains depressed, the display automatically switches to seconds. Therefore, it is necessary for the strobe circuit to strobe only four numerals at any one time, although it controls all six numerals. After the strobing circuit 216 selects the register to be read, the time stored in that register (in binary coded decimal form) passes through the set of selection gates opened by the strobe circuit and through the input gates 184 which act as an interface to the decoder 186. This decoder changes the BCD information into the output necessary to form intelligible numerals. The strobing circuit 216 not only chooses which counting register will be read, but also completes the annode circuit for the corresponding numeral diode. Therefore, only one numeral can be on at any one time but because the strobing action takes place so rapidly it appears that as many as four numerals are lighted simultaneously.

Divider 60 produces a 256 Hz output ($\phi 7$ and $\bar{\phi}7$) and a 128 Hz output ($\phi 8$ and $\bar{\phi}8$) which are applied to selective ones of four NAND gates 215 in strobe circuit 216. These signals are in turn passed through six NOR gates 217 which also receive a signal by way of lead 250 from the timer control flip-flop 248. The outputs A, B, C, D, E, and F from strobe circuit 216 are applied to the corresponding set of selection gates 182, 190, 192, 194, 196, and 198 to control which time signals are to be displayed as described above. The other strobe outputs S_1, S_2, S_3 and S_4 are applied to the bases of transistors 82, 84, 86 and 88 of FIG. 7 to complete the annode-cathode circuits of the display diodes. In this way it is possible for the strobe circuit to control which information from which register will pass to the decoder 186 and this BCD information must pass through the input gates 184 which are provided to prevent interference between the several outputs from the selection gates as they enter the decoder. The output of the decoder/driver 186 provides power by way of driver transistors 112, 114, 116, 118, 120, 122, and 124 in FIG. 7 to those segments or display diodes which are to be activated to display the number corresponding to the BCD input number.

Display intensity control is obtained by varying the duty cycle of the strobe drive signal supplied to the strobing circuit 216 by way of a lead 230, this signal also being supplied as an ON-OFF signal by way of the lead 232 to the inputs of gates 184. The signal on lead 232 insures that the diode, even when on, will blink on and off, but at a rate such as 128 Hz so as to give the appearance of being continuously energized. The ON-OFF lead 232 and the strobe drive signal on lead 230 are, therefore, bth as 128 Hz signal or series of short width pulses having a repetition rate of 128 Hz in which the pulse width may be varied to vary the average duty cycle of the signal. This is accomplished by taking signals from the second, third, fourth, fifth, and sixth stages of divider 60, which signals are identified as $\phi 2$, $\phi 3$, $\phi 4$, $\phi 5$, and $\phi 6$, and applying them to the five inputs of a NAND gate 234. The output from this gate on lead 236 is a series of 512 Hz pulses having a very short pulse width. These are applied through a NAND gate 238 by way of terminal 240 (labelled terminal 9) to the display intensity control circuit 39 of FIG. 7. Resistor 152 in series with light sensor 146 and parallel resistor 148 gives increased linearity and the circuit in essence acts as a multivibrator which is triggered at a rate of 512 Hz from the divider 60 and NAND gate 234. The length of the output pulse generated by the multivibrator 39 and applied to terminal 242 (labelled terminal

10 in FIG. 8) is determined primarily by the fixed capacitor **150** and the light sensitive resistor **146** in FIG. 7. These 512 Hz pulses, having a variable width and therefore a variable duty cycle in accordance with ambient light intensity, are supplied to strobe circuit **216** by way of lead **230** and as ON-OFF blinking signals to the input gates **184** to control the illumination duty cycle of the display diodes. The duty cycle in each digit is a maximum of 25 percent modulated by the light control network **39** to as low as 0.78 percent in the dark (3.12 of 25 percent). The strobing signals used for the minutes are also used for the seconds since in the preferred embodiment illustrated the minute display is also used for displaying seconds.

The display timer is generally indicated at **170** in FIG. **8.** This timer automatically turns off the hours and minutes after 1 ¼ seconds. A momentary depression of the read or demand button **18** produces a corresponding closure of the manual switch **132** in FIG. **7** and this completes a setting circuit, i.e., connects B+ to terminal **244** in FIG. **8A**, which is connected by way of lead **246** and acts to set timing flip-flop **248.** This flip-flop is reset only after the decade counter **170** has counted ten pulses of an **8** Hz signal applied to it over lead **168.** As long as flip-flop **248** is in the set condition, it puts the proper signal on lead **250** so that only the hours and minutes are displayed. If the read or demand button remains depressed after the decade counter **170** has completed a cycle and supplied a reset signal by way of lead **252,** the display automatically reverts to a display of seconds.

Divider **60** is a 14 stage binary device and produces a 2 Hz output on lead **254** which is combined with a 4 Hz signal on lead **256,** an 8 Hz signal on lead **258,** and a 16 Hz signal on lead **259** into NAND gate **260** to produce a 2 Hz setting signal on lead **262** which has a very short pulse width. This signal is applied through NAND gate **264** to the input of minutes register **176** and through NAND gate **266** to the input of hours register **180.** Closure of the hours set switch **136** in FIG. **7** applies B+ to terminal **268** of FIG. **8C** and the short pulse width 2 Hz setting signal passes through NAND gate **266** to the hours register, setting the hours display at the "fast" rate of 2 hours per second. Closure of minutes set switch **134** in FIG. **7** applies B+ to minutes set terminal **270** of FIG. **8A** causing the 2 Hz setting signal to pass through gate **264** to the input of minutes units register **196.** This is a "slow" or fine setting with the minutes advanced at 2 per second. A display during setting is assured by connecting hour set terminal **268** and minutes set terminal **270** through NOR gate **272** to the display intensity control circuit connected to terminals **240** and **242.** A flip-flop **241** is connected between the minutes and hours registers **178** and **180** to act as a pulse shaper. This flip-flop and its associated circuit makes the hours setting signal noise free and transforms the long pulse going from the minute counter output to the hour counter input into a 32 millisecond pulse.

Operation of the minutes set switch applies a reset impulse to minute set terminal **270** and through NOR gates **274** to lead **276** which resets counter **164** and the seconds registers **172** and **174** to zero. In this way the seconds display is automatically zerod when the minutes are set. Counting is resumed in the seconds register as soon as the push-button **18** is depressed and the read switch **132** is closed.

Decoder **186** is used to convert the **8-4-2-1** binary coded decimal signals from the registers into a **7** segment display code for the display stations. It is used for the units and tens of seconds, for the units and tens of minutes, and for the units of hours. As previously described, the tens of hours are either on or off to display a "one" or nothing. The tens of hours display is connected to the *a* and *d* outputs of the decoder while the colon is connected to the *b* and *c* outputs so that a BCD "one" turns on the colon only and a BCD "zero" turns on the colon and the tens of hours. The proper timing information is generated in the large scale integrated circuit **70** itself.

A feature of the decoder **186** is that special information can be fed into it according to the following table:

TABLE I

BCD input	Q1	Q2	Q3	Q4	Display			
	0	0	0	0	1	:		
	1	0	0	0		:		hours
	0	1	0	0	1	·	AM	
	0	1	1	0	1	·	PM	
								month
	0	1	0	1		·	AM	
	0	1	1	1		·	PM	

That is, the display can be used with the decoder to show date and month, a.m. and p.m. being shown with one or the other dot of the colon. This special information is introduced through leads **278, 280, 282** and **284,** labelled $Q1_1$, Q_2, Q_3 and Q_4, respectively, all under the control of a date input which is connected to the transmission gate control lead **298** in FIG. **7.** This date input connected to terminal **282** in FIG. **8A** allows or prevents any signal to pass through the corresponding transmission gates **285.** If the date input terminal **282** is connected to B+, the transmission gates **285** are short circuits and pass information to the decoder from inputs **278, 280, 282,** and **284.**

In the present invention this feature is utilized to incorporate a calendar display circuit **141** for displaying on the same display stations **74, 76, 78** and **80** (and colon dots) the date, month and a.m. or p.m. of time. The month in decimal number is displayed on stations **74** and **76,** the day of the month in decimal number on stations **78** and **80.** Illumination of colon dot **81** indicates a.m. of time and illumination of colon dot **83** is used to indicate p.m. of time. The calendar circuit **141** is illustrated in FIG. **7** as interconnected with the time computer integrated circuit **70** and with the read or demand switch **132,** the minutes set switch **134,** the hour set switch **136,** and with a date switch **138,** which is closed in response to depression of the button **20** of FIG. **1.** The calendar circuit **141** receives from the time computer circuit **70** (a) an input signal over lead **286** to calendar circuit terminal **5** from the LSI carry out terminal **12,** (b) on lead **288** a short 2 Hz update signal to calendar circuit terminal **6** from the LSI time computer terminal **16,** and (c) on the leads **290** strobe signals for the calendar circuit.

Calendar circuit **141** provides to LSI **70** (a) a BCD signal on leads **294** from terminals **1, 2, 3,** and **4** of the calendar circuit to the LSI **70** terminals Q_1, Q_2, Q_3 and Q_4, and (b) an hour set signal on lead **296** from calendar circuit terminal **10** to LSI **70** terminal **11.** Both circuits **70** and **141** have in common (a) a "read" input on lead **295** applied to LSI terminal **2** and calendar circuit terminal 7 and (b) a date input on lead 298 from date switch 138 applied to LSI 70 terminals 13, 14 and 15 and to calendar circuit 141 at terminal 8 by lead 496.

The hour set signal from switch 136 is applied by lead 297 only to the calendar circuit terminal 9 and the minute set signal from minute set switch 134 is applied by lead 299 only to the LSI 70 terminal 1.

FIGS. 9A and 9B taken together, and hereafter referred to as FIG. 9, show a detailed circuit diagram of the calendar circuit 141 of FIG. 7. In FIG. 9 like parts bear like reference numerals and the calendar circuit terminals are numbered to correspond to the terminals previously described and labelled in FIG. 7. In FIG. 9A the circuit comprises a pulse shaper indicated generally at 300 and comprising a flip-flop 302 and NOR gate 304. Flip-flop 302 is connected to input terminal 306 which forms the input for the calendar circuit 141 and which receives a signal from the carry out terminal 292 of the LSI circuit of FIG. 8C. Pulse shaper 300 is connected through a NAND gate 308 to an a.m./p.m. flip-flop 310. Also connected to flip-flop 310 is a NAND gate 312 and inverter 314 which together form a reset circuit to reset flip-flop 310 to its a.m. state when the hours are reset. A flip-flop 316 along with NAND gates 318 and 320 and inverter 322 form a short pulse shaper and act as a hold circuit for holding when the hours are set.

A days counter generally indicated at 324 is formed by flip-flops 326, 328, 330 and 332 along with NOR gates 334 and 336 and NAND gates 338 and 340. These four flip-flops and their gates form a decade counter or days unit counter. They act as a storage register and similarly to the registers previously described are preferably formed as a binary counting chain of complementary symmetry MOS transistors. The days tens counting unit or register section generally indicated at 342 is formed by flip-flops 344 and 346. The days counter formed by registers 324 and 342 count automatically to 29, 30 or 31, depending upon the month, in a manner more fully described below.

The month counter is generally indicated at 348 and is comprised of the five flip-flops labelled 350, 352, 354, 356 and 358. Also forming a part of the month counter or register are NOR gates 360 and 362 and NAND gates 364, 366, 368, 370 and 372. The month counter 348 counts from 1 to 12.

A.M./P.M. flip-flop 310 which acts as a counting flip-flop is connected by way of a lead 374 to an a.m./p.m. transmission gate 376 which is in turn connected by way of NOR gates 378, 380, 382 and 384 to the output terminals 386, 388, 390 and 392 labelled Q_1, Q_2, Q_3 and Q_4, respectively. These terminals constitute the output terminals for the calendar circuit 141 and supply the necessary a.m./p.m., day and month information to be displayed by the light emitting diode display stations. NOR gates 378, 380, 382 and 384 act as buffers or interface circuits for interfacing from the calendar to the LSI 70 BCD input terminals 278, 280, 282, and 284 of FIG. 8A. The BCD output of the days units register 324 is connected to the calendar output terminals through a days units transmission gate 394, the days tens register 342 has its BCD output connected to the calendar output through the days tens transmission gate 396 and the month register 348 has its BCD output connected to the calendar output terminal through the month transmission gate 398.

As previously indicated, registers 324 and 342 form a day counter which counts to either 29, 30 or 31 depending upon what month it is. These registers from in effect a programmable counter and the total count is determined by a program circuit generally indicated at 400 which program circuit comprises NOR gates 402 and 404, inverter 406 and NAND gates 408, 410, and 412. The state of the month counter 348 is sensed by a month discriminator circuit generally indcated at 414 and this circuit acts through the program circuit 400 to modify the total count of the days counters 324 and 342. The month discriminator is formed by NOR gates 416 and 418, inverters 420 and 422, NAND gates 424 and 426 and NOR gate 428. Also connected to days tens register 342 is a blanking circuit generally indicated at 430 comprising NAND gates 432 and 434 and inverter 436 which blanking circuit acts to blank out tens of days when the tenths is zero so that instead of displaying zero, nothing is displayed for the tens of days.

The day and month of the calendar circuit are reset at a rate of 2 Hz by means of a 2 Hz signal update signal received from terminal 438 of the LSI circuit 70 of FIG. 8C onto terminal 440 of the calendar circuit 141 of FIG. 9A. Only the month and day are reset, the a.m./p.m. indication always being returned to a.m. when the days are set. The day registers 324 and 342 are reset through a day set and antibounce circuit generally indicated at 442 comprising NAND gate 444, cross-connected NOR gates 446 and 448, inverter 450 and NAND gates 452 and 308. The month register 348 is reset through a month setting circuit 452 comprising inverters 454 and 456, NAND gate 458, and NOR gates 460 and 462. Also forming a part of the month set circuit 452 is a NAND gate 464 connected to inverter 456 by way of a lead 466. NAND gates 468 and 470 along with AND gate 472 form a resetting circuit generally indicated at 474 which resets all the counting registers of the calendar circuit to zero with the exception of the first flip-flop 326 of the day register and the first flip-flop 350 of the month register which are not resettable and are at one. This resetting only occurs when allowed by AND gate 472 as determined by the month discriminator 414 and its controlled program circuit 400.

Finally, incorporated in the calendar circuit is a USA/Europe option. In the USA it is customary to list first the month and then the day. In Europe the listing is customarily reversed. Provision is made in the circuit of FIGS. 9A and 9B for blocking out the month display and just displaying the days when the watch is used in Europe. To this end the circuit is provided with a pair of OR gates 476 and 478 and an AND gate 480. An input of AND gate 480 is connected by a lead 482 to the output of an additional AND gate 484 also forming a part of this circuit. Another input of AND gate 480 is connected to a terminal 486 and the potential at terminal 486 determines whether the watch operates according to the USA or European option. The output of OR gate 478 labelled Z and indicated at 488 is applied as an input to the interface OR gates 378, 380, 382 and 384.

When the potential at terminal 486 is indicative of a binary zero the USA option obtains and when the potential at terminal 486 is indicative of a binary one the European option obtains. When the potential on terminal 486 equals one (Europe) then the strobing signals

G and H on the input leads **490** and **492** to OR gate **476** are allowed to pass through gates **480** and **478** unless the calendar is set which setting causes the output of AND gate **484** to become zero thus blocking AND gate **480**. This passage through gates **480** and **478** produces an output on lead **488** which is applied to the OR gates **378, 380, 382** and **384**. These strobe signals blank the display only when transistors **82** and **84** of FIG. 7 (S_1 and S_2) would otherwise be energized which causes the display to be blanked out for those two digits. The month signals are blanked but the date signals passed by transistors **86** and **88** (S_3 and S_4) of FIG. 7 are shown on the display at stations **78** and **80**.

When the calendar is set, i.e., when the date switch is closed along with the hour set switch or read switch, then AND gate **484** has a low output, AND gate **480** is blocked and output Z on lead **488** remains zero for the time being. The display is "ON", i.e., the month and a.m./p.m. are decoded and read on the display. When the potential on lead **486** is indicative of a binary "zero" then AND gate **480** is blocked all the time and the day and the month and a.m./p.m. are displayed all the time when the date switch is depressed. The potential on terminal **486** is selected for either the USA or the European option by permanently connecting it to either the positive or negative side of the power supply.

In the operation of the calendar circuit **141** of FIGS. **9**A and **9**B, at 12 hours, 00 minutes and 00 seconds the signal on terminal **306** of the calendar circuit which is received by way of lead **292** of the time computer **70** of FIGS. **8**A, **8**B and **8**C goes high and sets flip-flop **302** in FIG. **9**A. This flip-flop is used only to make a short signal (less than 0.5 seconds) through NOR gate **304** out of a one hour signal. That is, the output from the LSI **70** on lead **306** is high for one hour, i.e., from 12 hours 00 minutes and 00 seconds to 12 hours, 59 minutes and 59 seconds and flip-flop **302** converts this one hour signal to a short signal of less than 0.5 seconds. This short signal through NAND gate **308** drives flip-flop **310** which is the a.m./p.m. flip-flop. Flip-flop **316** makes a short signal from the output of flip-flop **310**. Flip-flops **326, 328, 330** and **332** constitute a decade counter and flip-flops **344** and **346** are used for the tens of days. The output from the a.m./p.m. flip-flop **310** is applied by lead **374** to transmission gate **376**, the output of the days unit counter comprising counter **324** is applied to transmission gate **394** by leads **494** and the output of the days ten counter **342** is applied through gates **432** and **434** to transmission gate **396**. These gates in combination with inverter **436** blank out the tens of days when it is zero. Flip-flops **350, 352, 354**, 356 and **358** form the month counter **348** which counts from 1 to 12. The month discriminator **414** and control circuit **400** cause the days counters **324** and **342** to count to **30** and **31** during appropriate months of the year and to **29** in February.

When button **20** in FIG. **1** is depressed, the date switch **138** of FIG. **7** is closed, applying positive power supply potential from the battery to the calendar terminal **8** of FIGS. **7** and **9**A labelled **496**. When the signal is applied to the calendar terminal **8**, it is also applied to terminal **14** of LSI **70** labelled **282** in FIG. 8A. It is also applied to terminal **15** labelled **288** and to terminal **13** labelled **286**. On the LSI **70** the date signal turns on the display (terminal **13**), opens the transmission gates controlling the Q_1, Q_2, Q_3 and Q_4 inputs (terminal **14**) and locks internally the time through the transmission gates **198, 196, 222** and **224** by applying signals to leads **218, 220, 222,** and **224** labelled A, B, C, and D, respectively (terminal **15**). This means that it is possible to display any BCD information entered on the Q_1, Q_2, Q_3 and Q_4 inputs of the LSI **70** over leads **278, 280,** 282 and 284 in FIG. 8A.

Strobing signals are generated by the strobe circuit **216** of FIG. **8**C through the receipt of appropriate frequency signals from various stages of the divider **60**. Since strobing signals are available in the LSI circuit **70**, it is not necessary to duplicate these circuits in the calendar circuit **141**. However, since the calendar circuit only energizes four digits, two for the days and two for the months, only four strobe signals need be applied to the calendar circuit. The strobe signals are derived from the strobe circuit **216** of FIG. **8**C by way of leads **500, 502, 504** and **506**, labelled G, H, I and J, respectively. These signals are applied as enabling signals to the corresponding leads **508, 510, 512** and **514** of the calendar transmission gates **376, 394, 396** and **398**, respectively, to strobe the calendar display. The signals G and H are also applied to the input of OR gate **476** forming a part of the USA/European option as previously described to blank the month display when the watch is used in Europe. By using strobing signals generated in the LSI **70** to strobe the calendar display there is no need in generating separate strobing signals in the calendar circuit and the accompanying synchronization problems are eliminated.

In order to set the calendar reading, it is first necessary to close and keep closed the date switch **138** of FIG. **7** by a continued depression of push-button **20** which applies a B+ or logic "one" to calendar terminal **8** labelled **496** and allows the date and month to be displayed by the diodes through the LSI circuit **70**. If the read switch **132** is now closed, a logic "one" (B+) is applied to the calendar terminal **7** labelled **516** in FIG. **9**A and the output of NAND gate **444** goes low and sets the flip-flop formed by NOR gates **446** and **448**. This allows the **2** Hz signal at terminal **6** labelled **440** to drive flip-flop **310** through gate **452** and **308**. This means that a 2 Hz signal is substituted on the C L terminal of flip-flop **310** for the input signal which sets the date at 1 Hz and the a.m./p.m. at 2 Hz. To set the month, the same thing is done with the date switch and the hours set switch **136**. With both of these switches closed, a logic "one" is applied to the calendar circuit terminal **8** labelled **496** and **9** labelled **518** in FIG. **9**A, which passes through gates **458, 460**, inverter **556** AND gate **464**, substituting for the output of the date counter by way of lead **466** a **2** Hz signal which drives the month counter at a 2 Hz rate.

When the hour set switch **136** is closed, a logic "one" is applied to calendar terminal **9** labelled at **518** and if there is a logic "zero" on calendar terminal **8** labelled **496**, this produces a logic "one" at calendar terminal **10** labelled **520**, which is applied to LSI **70** by way of LSI terminal **268** (terminal **11**) to set the hours of the watch and this signal is also passed through gate **312**, inverter **314**, inverter **322** and gate **318** to reset flip-flop **316** or keep it reset while the gate **312** is ready to let the next short 2 Hz signal reset flip-flop **310** through inverter **314** so that the a.m./p.m. counter is eventually reset at a.m. without changing the date.

In the calendar circuit **141** the days are accumulated in the counter comprising registers **324** and **342** which is programmed to count either **29, 30,** or **31**, depending upon the state of the month counter 348. This programming is accomplished through the month discriminator circuit 414 which senses the month in counter 348 and with the program control 400 which programs the days counter in accordance with the month count in register 348 and under the control of discriminator 414. The logic of the available program is based upon the odd or eveness of the month and the number of days in that month according to the following relationship.

Month	Days	Month	Days
1st	31	7th	31
2nd	29	8th	31
3rd	31	9th	30
4th	30	10th	31
5th	31	11th	30
6th	30	12th	31

Discriminator 414 is constructed to detect and determine three different conditions, namely, (1) is the month below 8, (2) is the month odd or even, (3) is the month number 2.

In accordance with the above, five possible states can exist.

a. When the month is below 8 and odd the days counter counts to 31.

b. When the month is below 8 and even but not 2 the days counter counts to 30.

c. When the month is below 8 and even and 2, the days counter counts to 29.

d. When the month counter is 8 or above and odd, the days counter counts to 30, and

e. When the month counter is 8 or above and even, the days counter counts to 31.

In February of those years which are not leap years the counter still counts to 29. In those instances at the end of the 28th day in February the wearer must manually set the days and month for the next day. In all other cases, the calendar display automatically advances to the appropriate day and month without any adjustment.

Following is a truth table for the display segment of the light emitting diodes for both time and calendar operation.

TABLE II

	BCD	Segments							Digits	
No.	A B C D	*a*	*b*	*c*	*d*	*e*	*f*	*g*	1	2,3,4
0	0 0 0 0	0	0	0	0	0	0	1	1 :	0
1	1 0 0 0	1	0	0	1	1	1	1	:	1
2	0 1 0 0	0	0	1	0	0	1	0	1 ·	2
3	1 1 0 0	0	0	0	0	1	1	0		3
4	0 0 1 0	1	0	0	1	1	0	0		4
5	1 0 1 0	0	1	0	0	1	0	0		5
6	0 1 1 0	0	1	0	0	0	0	0	1 .	6
7	1 1 1 0	0	0	0	1	1	1	1		7
8	0 0 0 1	0	0	0	0	0	0	0		8
9	1 0 0 1	0	0	0	0	1	0	0		9
10	0 1 0 1	1	0	1	1	X	X	X		
11	1 1 0 1	X	X	X	X	X	X	X		
12	0 0 1 1	X	X	X	X	X	X	X		
13	1 0 1 1	X	X	X	X	X	X	X		
14	0 1 1 1	1	1	0	1	X	X	X		
15	1 1 1 1	1	1	1	1	1	1	1		

The first column of the table lists the sixteen decimal numbers obtainable from a 4-bit binary code, i.e., the decimal numbers 0 through 15. The next column labelled A, B, C, D, shows the corresponding numbers in binary coded decimal format. The next seven columns labelled *a* through *g* represent the display segments illustrated in FIG. 8D. The next column shows the hours tens digits and colon dots whereas the final column shows one of the other three display stations, all three of them being identically connected. The truth table (Table II) indicates what segments must be "ON" or "OFF" (or do not matter) according to the BCD input. An "X" in the table stands for "ONE" or a "ZERO" indicating it does not matter which it is. Because of the way the display is driven a "ON" segment is shown with a 0 and an "OFF" segment with a 1. The first digit at station 76 in FIG. 7 is used to display the tens of hours and the tens of months. In both cases, it displays either nothing or a one. The second digit station 74 is used for the units of hours and the units of months in the calendar. It counts from zero to nine in both cases. The third digit at station 80 is used for the tens of both minutes and seconds and for the tens of days in the calendar. For the tens of minutes and seconds it counts from zero to five. For the calendar it counts from one to three and shows nothing (BCD 15) for a zero on the calendar. Digit 4 at station 78 of FIG. 7 is used for units of both minutes and seconds of time and the units of days in the calendar and in all instances it counts from zero to nine. The colon for the time display is " ON" all the time and the tenths is nothing (BCD 1) or one (BCD 0). A.M. of time for the calendar is shown by illuminating the top dot and p.m. by illuminating the bottom dot of the colon. This is accomplished through the decoder with BCD numbers 2, 6, 10 and 14 in the above Table II.

In FIG. 8A the letter M is used to indicate the signal on the output lead 530 from timing flip-flop 248. This signal depends on the timer and M = 0 for hours and minutes while M = 1 for seconds when the display is off. In FIG. 8B a signal L is illustrated on lead 532 forming a part of the strobing circuit 216. $L = 13 + \overline{M} + \overline{2}$ where 13 is the signal at terminal 13 labelled 286 in FIG. 8A and $\overline{2}$ is the complement of the read input to terminal 2 labelled 244 is FIG. 8A. This signal also appears on the output of NAND gate 290. The signal N on lead 234 in FIG. 8B is the percentage duty cycle as determined by the photoresistor 146 in FIG. 7 plus $\overline{K}$. A signal K appears on lead 536 of FIG. 8B where $K = 1 + 11 + L$ where 1 is the input signal to terminal 1 labelled 270 in FIG. 8A, 11 is the signal at terminal 11 labelled 268 in FIG. 8C and L is as defined above.

FIGS. 10 and 11 show the minor substrate or printed circuit board mounting the LSI timing circuit 70 and the LSI calendar circuit 141. While these two circuits are shown as separate chips it is understood that if desired they may be combined in a single chip as previously described. The chips 70 and 141 of the minor substrate generally indicated at 540 in FIG. 10 are mounted on a rigid ceramic insulating board 542. Etched or otherwise suitably imprinted on the board are the printed circuit strips 544 for establishing electrical connection to the external resistors, capacitors, and bipolar transistors illustrated in FIG. 7. Electrical connection from LSI chip 70 to the printed circuit is by way of electrical leads 546 and from LSI chip 141 by a plurality of similar electrical leads 548. The printed circuit strips 544 are electrically connected to corresponding connectors such as connectors 550 by means of which electrical connection is established to the battery and other components of the watch. When the assembly has been completely wired, it is preferably potted in epoxy 552 with only the connectors 550 exposed.

FIG. 12 is a plan view of the main substrate or circuit module generally indicated at 560. Again, this assembly comprises a ceramic insulating board 562 on which are etched or otherwise suitably applied the printed circuit leads 564. Also printed on the board are a plurality of pads such as the conductive pads 566 for establishing electrical connection to the connectors 550 of the minor substrate or printed circuit board 542 and for connection to the watch battery and other components of the watch. Also mounted on the main substrate or main printed circuit board 562 is the light emitting diode display package 568 which contains the diodes forming the display stations 74, 76, 78 and 80 of FIG. 7. Other electrical components including resistors, capacitors, and bipolar transistors are mounted on the circuit board 552 of FIG. 12 and bear the same reference numerals as previously identified in FIG. 7.

FIGS. 13 and 14 are front and side views, respectively, of the display package 568 containing the light emitting diode display stations. This package is formed from a rectangular multilayer or laminar block of black ceramic indicated at 570 on the front surface of which are mounted the display diodes. Attached to the rear surface of block 570 are flat connector plates 572. The annode plates are labelled a through g and the cathode connectors are labelled K_1 through K_4. These connectors make electrical contact with the diodes on the front surface of the package by means of electrically conductive gold plated pins which pass through the package. These pins are illustrated in FIG. 15 with the cathode pins indicated at 574 and the annode pins at 576. The entire assembly with the exception of the electrical connectors 572 when completed is preferably potted in a thin protective coating of clear epoxy.

FIG. 16 is a front or top plan view of the main module or principal assembly of the watch generally indicated at 580. It comprises a generally circular module frame 582 preferably formed from an impact resistant, one piece, injection molded plastic material and in the preferred embodiment is S—2/30 type 6–10 nylon which is a fiber filled nylon material. The frame 582 is of circular or disc shape one piece plastic construction and mounted on the front of the frame in the light emitting diode display package 568 and the LSI circuit chip package 542. The front surface of the module frame 582 is recessed to receive four reed switches, namely, the date switch 138, demand or read switch 132, minute set switch 134 and hour set switch 136. Near its top the module disc 582 is apertured as at 584 as best seen in cross section in FIG. 17 to receive the piezoelectric crystal 63. The crystal is preferably encased as illustrated in a silicone rubber potting compound 588 which acts as an adhesive to secure the crystal in the module frame, and to support it against excessive vibration. The crystal is provided with a pair of electrical leads 590 and 592 which attach to the pads 594 and 596 to make electrical connection to the remainder of the circuitry mounted on substrate 562.

FIG. 18 is a rear plan view of the module frame 582 and FIG. 19 is an end view showing the battery cells 598 and 600. Each of these cells is a conventional 1½ volt wristwatch battery cell and they are connected in series to provide a three volt power supply. The positive side of battery 598 is connected to the negative terminal of battery cell 600 by a flexible electrically conductive metallic spring 602 secured to but electrically insulated from the inside of central portion 604 of the watch back plate indicated in phamton in FIG. 19 at 22. The negative terminal of battery cell 598 is connected to an electrically conductive pin 606 (preferably by a spring 607) which passes through a suitable aperture in module 582 and the positive terminal of cell 600 is connected by spring 609 to a similar pin 608. Pin 608 makes electrical connection with a flat positive lead frame indicated by dash lines at 610 in FIG. 16 and this electrical lead frame has a plurality of turned over ends such as those indicated at 612, 614, 616, 618, 620 and 622. Ends 612 and 618 of the positive lead frame make electrical connection with the conductive pads 624 and 626 on substrate 562 whereas the other four ends of the positive lead frame each establish a connection to one end of the reed switches 132, 134, 136 and 138. Referring to FIG. 19 the reed switches and the substrates are preferably adhesively secured and retained against vibration by a silicone rubber potting compound as illustrated at 626 in that figure. Similarly, battery pin 606 which contacts the negative side of the power supply has its other end in contact with a flat negative lead frame indicated in phantom at 628 in FIG. 16. This lead frame has a first end 630 turned over and soldered or otherwise suitably connected to conductive pad 632 on the substrate 562. It also has a second end 634 which passes through the module frame and connects to one terminal 636 of the trimmer or tuning capacitor 65 as best seen in FIG. 17. The other terminal of the trimmer capacitor is connected by an electrically conductive strip 638 to the conductive pad 640 on substrate 512. Trimmer capacitor 65 by way of example only may be of the typy manufactured by the Johanson Manufacturing Corporation of Boonton, New Jersey identified as 9410-1—PC and it is provided with a small square adjusting hole 640 to adjust the capacitance value of the capacitor.

FIG. 20 is a front or top plan view of the module frame 582. FIG. 21 is a cross section taken along line 21—21 of FIG. 20. FIG. 22 is a bottom or rear plan view of the module frame 582 and FIG. 23 is a cross section taken along line 23—23 of FIG. 22. The module frame is provided on its front surface with the recesses 640, 642, 644 and 646 for receiving the respective reed switches 132, 134, 136, and 138. It is provided with central apertures 648 and 650 for receiving battery pins 606 and 608 of FIG. 19 and is provided with a shallow groove 652 for receiving the positive battery lead frame and a shallow groove for receiving the negative battery lead frame, these lead frames being illustrated at 610 and 628 in FIGS. 24 and 25. The aperture 584 previously described is for receiving the crystal 63 and a central aperture 656 is for passage of the upper ends 634 of the negative lead frame to make contact with the trimmer. Module frame 582 also has on its front surface bosses or projections 658 and 660. The upper portion 662 of the module frame as illustrated in FIGs. 20 and 21 is enlarged so that its front surface 664 is in the same plane as the front surfaces of projections on bosses 658 and 660 such as the front surface 666 of boss 658 as illustrated in FIG. 21. Passing through enlarged portion 662 is the aperture 584 for the cyrstal and a mounting aperture 668 for the screw 40 of FIG. 3.

The bottom or rear side of the module frame 582 is illustrated in FIG. 22 and FIG. 23 is a cross section taken through the center of the module frame. It comprises an enlarged central portion **670** provided with a pair of circular wells **672** and **674** for receiving the battery cells. These wells are slightly offset from the center of the module frame and are of slightly different configuration with well **672** having a tapered edge **676** and well **674** having a straighter edge **678** so that the battery cells **498** and **600** of FIG. **19** cannot be inserted into the wells with the wrong polarity. The rear surface of the module frame is recessed as at **680** to receive the trimmer **65** and passing through the module frame in this recess is the aperture **656** through which passes one end of the negative lead frame **628**, namely, end **634** as shown in FIG. **16.** Referring to FIG. **17** end **634** of the negative lead frame connects to one terminal **636** of the trimmer **65.** The other terminal of the trimmer indicated at **682** in FIG. **17** passes through aperture **584** and is connected by strip **638** to the conductive pad **640** of substrate **562** as is illustrated in FIG. **16.** Enlarged portion **662** of the module frame is notched as at **684** to provide for the passage of trimmer terminal **682,** strip **638** and the crystal lead **592** of FIG. **16.**

FIg. **24** is a plan view of the positive battery lead frame **610.** It has a central solid circular portion **686** adapted to make electrical contact with the positive battery pin and the extending arms **612, 614, 616, 618,** 620 and **622** as previously described. The battery frame is received in the corresponding shallow grooves in the module frame and is formed from a flat blank of lead-free brass having a thickness of approximately 0.0045 inch. It is preferably fully annealed and plated with copper and bright tin. The negative lead frame **628** shown in FIG. **25** is of identical construction except for its different shape as indicated in that figure.

FIGS. **26, 27** and **28** illustrate the details of the back plate **22** of the watch case. FIG. **26** is an inside view of the back plate. FIG. **27** is a cross section through the center of the back plate and FIG. **28** is an outside view of the back plate. The plate is bent or curved into a dish shape as illustrated in FIG. **27** and is provided near its outer edge with a pair of indentations **688** and **690.** These indentations are adapted to receive a permanent setting magnet which because of the indentations may be brought closer to either the minutes set switch **134** or hour set switch **136.** The indentations are preferably suitably labelled as indicated at **692** and **694** in FIG. **28.**

FIG. **29** is a plan view and FIG. **30** is an end view of a permanent magnet which may be inserted into the indentations **688** and **690** of the back plate of the watch case, to set the minutes and hours of the watch. It is also used for setting the calendar in the manner previously described in conjunction with push-button **20.** The magnet **696** is generally a horseshoe type configuration defining a body **698** and legs **700** and **702** forming respective north and south poles as illustrated in FIG. **29.** The magnet is preferably formed as an integral piece of alnico-5 material and it is magnetized to 1000 gauss minimum as measured at the pole faces. Typical overall dimensions for the permanent magnet **696** are an overall length of ½ inch, an overall width of 0.312 inch and a thickness of 0.060 inch. The legs **700** and **702** are typically 0.125 inch in length and the gap between the symmetrical legs is 0.188 inch.

In the present invention the bracelet **16** is provided with a holder for housing the setting magnet **696** of FIGS. **29** and **30.** To this end, as illustrated in FIG. **31,** a portion of the bracelet includes a buckle **704** hinged to the remainder of the bracelet at each end and provided with a pivotally mounted magnet holder **706** shown in FIG. **31** rotated to its substantially open position. Holder **706** is configured to receive the magnet **696** of FIGS. **29** and **30.** FIG. **32** is a cross section through the center of the holder and FIG. **34** is a front view of the holder **706.** It comprises a flat plate preferably of spring brass to match the bracelet **16** rolled over at its ends **708** to define aperture **710** for receiving a pivot pin on the buckle **704** of FIG. **31.** The buckle is provided with flanges **712** and **714** in FIG. **31** which support the ends of a pivot pin passing through aperture **710** so that the magnet holder is free to pivot about the pin from the closed position to the opened position illustrated in FIG. **31.** A central portion of the holder **706** is cut away as at **716** to define a central tab **718** which is bent inwardly of the plate body as illustrated in FIG. **33** preferably at an angle of about 30°. The edges of the plate forming the holder **706** are turned over to define the flanges **720** and **722** to abut the central portion **724** of the buckle **704** of FIG. **31** when the holder is in the closed position to provide a completely closed compartment for retaining the permanent magnet. An area of the holder adjacent the flanges **720** and **722** extends outwardly from the body portion of the holder to define a lifting tab **726** adapted to be engaged by the finger of the wearer to move the holder to the open position as illustrated in FIG. **31.** The flange **712** of the buckle is preferably provided with a recess and the holder is provided with a mating bump or projection **728** to act as a resilient detent for normally retaining the holder in the closed position. The magnet is preferably inserted in the holder to assume the dash line position illustrated in FIG. **32** with the resilient tab **718** bearing against the magnet and acting as a spring urging it against the body **724** of the buckle so that it is tightly retained and not free to move about in the holder with the movement of the wearer's wrist. Access to the magnet is gained by lifting the tab **726** with the tip of the finger and removing the magnet. The watch timing circuit, calendar circuit or both, is set by inserting the legs **700** and **702** into the appropriate recess **692** or **694** in the watch back plate to close the respective minute set switch **134** or hour set switch **136.**

It is apparent from the above that the present invention provides an improved solid-state watch and particularly a solid-state watch incorporating a calendar display. The same display diodes that are used to display the time information are also used to display the calendar information. The calendar information appears in decimal number form as showing the number of the day of the month, and the number of the month of the year. By alternately lighting one or the other of the colon dots it is also possible to display a.m. and p.m. of time. While the time circuit and calendar circuit have been shown and described as separate large scale integrated circuit chips, it is understood that the simplifications offered by the present invention make it readily possible to manufacture both the time circuit and the calendar circuit as a single large scale integrated circuit chip. Of particular importance in the present invention is the provision of a common strobing circuit for both the time and calendar displays, thus eliminating the need for a separate calendar strobe generator and the corresponding problems of synchronization. The strobing is at a sufficiently high rate to give the visual appearance of a continuous display but by lighting successive display stations, the amount of current drawn from the battery at any instant is kept at a minimum. Only four display stations are required to display the hours, minutes and seconds of time as well as the days and months of the year.

In the preferred embodiment the light emitting diodes take the form of gallium arsenide phosphide LEDs of the type more fully shown and described in assignee's U.S. Pat. No. 3,576,099 issued Apr. 27, 1971. However, it is understood that the display can assume any one of several forms. For example, the optical display may be formed of 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 ferroelectric crystals or electroluminscent displays and others. Similarly, the switches may take any desired form but in the preferred embodiment the read switch **132**, date switch **138**, hour set switch **136**, and minutes set switch **134** are all formed of magnetic reed switches of the type shown and described in assignee's copending U.S. patent application Ser. No. 138,557 filed Apr. 29, 1971, now U.S. Pat. No. 3,782,102, entitled SOLID STATE WATCH WITH MAGNETIC SETTING, the disclosure of which is incorporated herein by reference. Preferably, demand switch **132** and date switch **138** are actuated by permanent magnets carried in their respective push-buttons **18** and **20.** Hour set switch **136** and minutes set switch **134** are operated by a separate permanent magnet manually applied to the exterior of the watch case adjacent the respective switches in the manner described. The present invention also provides a USA/Europe option such that a portion of the calendar display is blank when the watch is used in Europe.

The wristwatch of this invention is of simplified, inexpensive construction and one that is easy to assemble and reliable in operation. The large scale integrated circuit chips are completely enclosed in potting compounds and the electro-optic display package is preferably coated with a transparent lacquer or other coating so as to likewise be completely enclosed and substantially impervious to the elements. Other components of the watch as illustrated are 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 battery cells. The construction provides durable lead frame connections between the cells and the substrate and all components are individually sealed before going in the sub assemblies or main assembly. The trimmer capacitor is easily accessible to adjust the crystal oscillator frequency and the final assembly of substrate subassembly to module frame has only eleven 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 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 embodiments are therefore to be considered in all respects as illustrative and not restrictive, the scope of the invention being indicated by the appended claims rather than by the foregoing description, and all changes which come within the meaning and range of equivalency of the claims are therefore intended to be embraced therein.

What is claimed is:

1. A wristwatch comprising a wristwatch case having a front window and a removable back plate, a one-piece frame of electrical insulating material in said case having one side adjacent said back plate and its other side adjacent said window, said frame including cavities on said one side, a trimmer capacitor in one of said cavities, the other of said cavities being adapted to removably receive a battery, a substrate mounted on said other side of said frame, an electro-optical display comprising a plurality of light-emitting diode digital display stations, a time computing circuit comprising at least a minute counter and an hour counter and a calendar circuit, said display, time computing circuit and calendar circuit all being on said substrate, both said time computing circuit and said calendar circuit being formed as large scale integrated circuits and coupled to said display, said frame including four additional cavities, magnetic field responsive reed switches in each of said four cavities, said switches comprising a time demand switch for coupling said time computing circuit to said display, a date demand switch for coupling said calendar circuit to said display, a minute set switch for setting said minute counter, and an hour set switch 2 for setting said hour counter, a pushbutton on said case adjacent each of said time demand and date demand switches for actuating them, a first permanent magnet receiving identation on said back plate adjacent said minute set switch, and a second permanent magnet receiving identation on said back plate adjacent said hour set switch whereby insertion of a permanent magnet into one of said indentations actuates the adjacent switch.

2. A wristwatch according to claim **1** including a wristband connected to said case and having a support for a permanent magnet insertable into said indentations in said back plate.

3. A wristwatch according to claim **2** including a generally horseshoe shaped permanent magnet received in said support.

* * * * *

UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,866,406 Dated February 18, 1975

Inventor(s) Dennis A. Roberts

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

Col. 1, line 42, "water" should read --watch--; line 57, "in" should read --In--.

Col. 2, line 42, "minutese" should read --minutes--; line 57, "solidstate solid-state components" should read --solid-state electrical components--.

Col. 3, line 8, "water" should read --watch--.

Col. 6, line 53, "electro-optipcal" should read --electro-optical--; line 64, "nomral" should read --normal--; line 67, "previals" should read --prevails--; line 67, "converve" should read --conserve--.

Col. 8, line 4, "comprises" should read --comprise--.

Col. 11, line 11, "b 0" should read -- 0 --; line 60, "strokes" should read --strobes--; line 65, "when" should read --When--.

Col. 12, line 50, "bth as" should read --both a--.

Col. 14, line 31, "$Q1_1$" should read --O_1--.

Col. 26, line 40, claim 1, "switch 2 for" should read --switch for--.

Signed and sealed this 17th day of June 1975.

(SEAL)
Attest:

RUTH C. MASON
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents
and Trademarks

UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,866,406 Dated February 18, 1975

Inventor(s) Dennis A. Roberts

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

Col. 1, line 42, "water" should read --watch--; line 57, "in" should read --In--.

Col. 2, line 42, "minutese" should read --minutes--; line 57, "solidstate solid-state components" should read --solid-state electrical components--.

Col. 3, line 8, "water" should read --watch--.

Col. 6, line 53, "electro-optipcal" should read --electro-optical--; line 64, "nomral" should read --normal--; line 67, "previals" should read --prevails--; line 67, "converve" should read --conserve--.

Col. 8, line 4, "comprises" should read --comprise--.

Col. 11, line 11, "b 0" should read -- 0 --; line 60, "strokes" should read --strobes--; line 65, "when" should read --When--.

Col. 12, line 50, "bth as" should read --both a--.

Col. 14, line 31, "$Q1_1$" should read --O_1--.

Col. 26, line 40, claim 1, "switch 2 for" should read --switch for--.

Signed and sealed this 17th day of June 1975.

(SEAL)
Attest:

RUTH C. MASON
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents
and Trademarks

FORM PO-1050 (10-69)

USCOMM-DC 60376-P69
☆ U.S. GOVERNMENT PRINTING OFFICE : 1969 O—366-334