

### [54] ELECTRONIC WRIST WATCH DISPLAY

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Dec. 28, 1971 Japan..... 46-2751

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[51] Int. Cl..... **G04b 19/30, H05b 39/09**

[58] Field of Search..... **G02f/1/26; 58/23 R, 50 R, 58/127 R; 340/336; 350/150**

### [56]

### References Cited

#### UNITED STATES PATENTS

3,540,209	11/1970	Zatsky et al. ....	58/50 R
3,695,747	10/1972	Maldonado .....	350/150

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### [57]

### ABSTRACT

An electronic wristwatch display device comprises a polarizing plate, a transparent ferroelectric ceramic and a reflector. The intensity of the display is enhanced by the use of a light-gathering positive lens, a reflector and a viewing area of a size which is small relative to that of the light-gathering lens.

**8 Claims, 10 Drawing Figures**

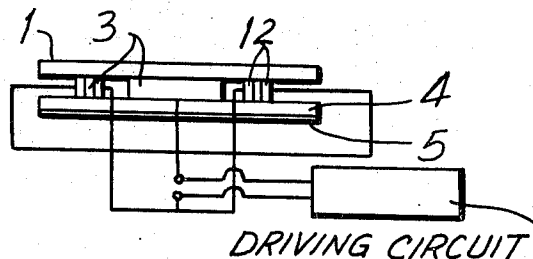


FIG. 1

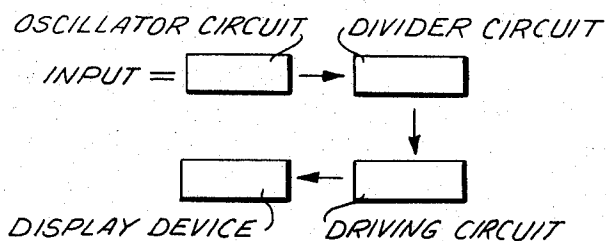


FIG. 2

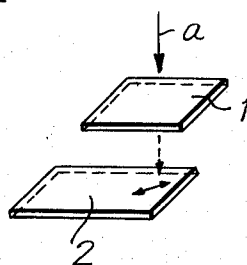


FIG. 3

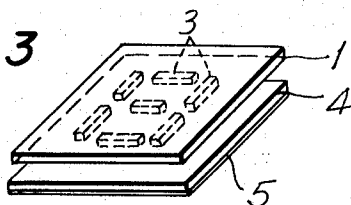


FIG. 4

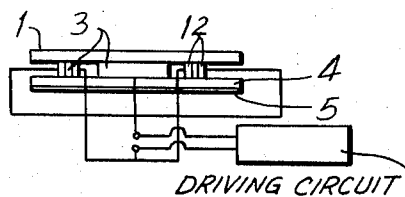


FIG. 5

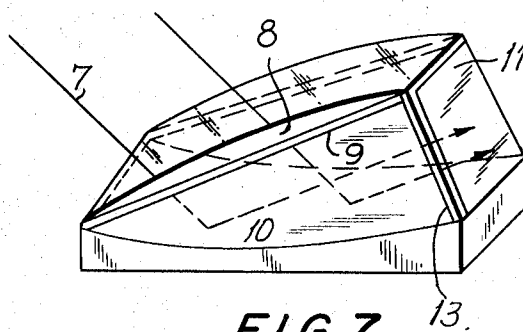
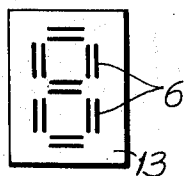


FIG. 6

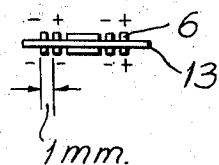


FIG. 7

FIG. 8

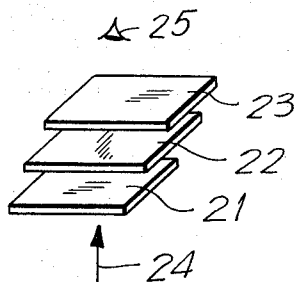


FIG. 9

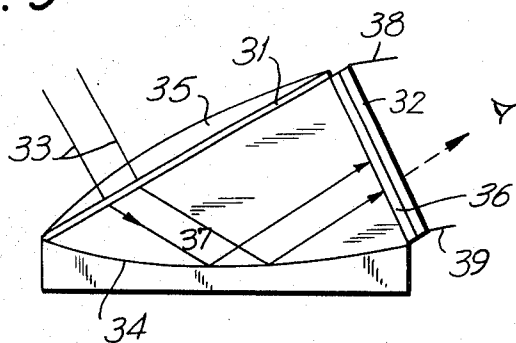
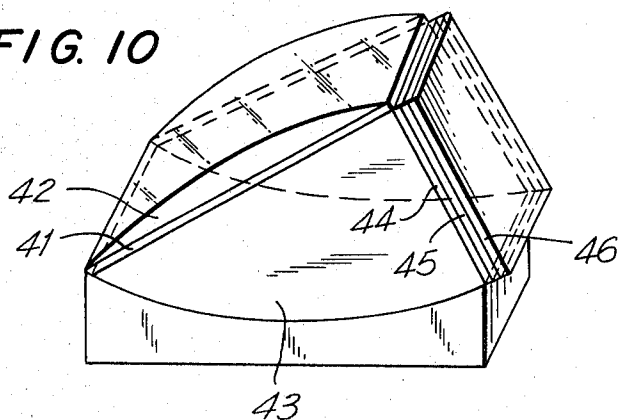


FIG. 10



## ELECTRONIC WRIST WATCH DISPLAY

## BACKGROUND OF THE INVENTION

In electronic display devices for showing the time as measured by a battery driven wristwatch, liquid crystals between opposed transparent electrically conducting plates and light-emitting diodes have been used. The liquid crystal device suffers from the disadvantage that the liquid crystals themselves are subject to deterioration from the effects of sunlight, heat and the presence of impurities such as moisture or traces of solvent. With respect to light-emitting diodes, these use substantial amounts of current so that the period during which a wristwatch can function without replacement of the battery unit is seriously limited. Further, both the liquid crystal display system and the light-emitting diodes are relatively expensive.

## SUMMARY OF THE INVENTION

The display device of the present invention for showing the time is based on the change of polarization of a light beam by a variety of means including transparent ferroelectric materials which ordinarily are passive but which become active with respect to change in the polarization of light passing therethrough when a voltage is impressed thereon. Further, segments of such materials are arranged so that when activated selectively, numerics become visible. The visibility of the display is enhanced by the use of a light-gathering lens which transmits light to a reflector and then to the display system, where the light-gathering lens is substantially larger in area than the viewing area.

Accordingly, an object of the present invention is to provide an improved electronic display for electrically driven wristwatches.

Another object of the present invention is to provide an improved electronic display for an electrically driven time-piece where the visibility of the display is enhanced by the use of a large light-gathering lens and a reflector.

A further object of the invention is to provide an improved electronic display for an electrically driven wristwatch using polarized light.

An important object of the present invention is to provide an improved electronic display for an electrically driven wristwatch using transparent ferroelectric materials which affect polarization in a light beam when activated by an imposed voltage.

Still other objects and advantages of the invention will in part be obvious and will in part be apparent from the specification.

The invention accordingly comprises the features of construction, combinations of elements, and arrangement of parts which will be exemplified in the constructions hereinafter set forth, and the scope of the invention will be indicated in the claims.

## BRIEF DESCRIPTION OF THE DRAWING

For a fuller understanding of the invention, reference is had to the following description taken in connection with the accompanying drawings in which:

FIG. 1 shows diagrammatically the circuit elements involved in the display device of the present invention;

FIG. 2 is a view in perspective of a combination of a circularly polarizing plate and a reflector plate showing how reflected light is extinguished;

FIG. 3 is a perspective view of a pair of plates similar to those shown in FIG. 2 containing between them segments of a transparent ferroelectric material activatable to change the degree of polarization;

FIG. 4 is an edge view in partial section of a display device using ferroelectric ceramic;

FIG. 5 is a plan view of a monolithic PLZT;

FIG. 6 is an end view of the device of FIG. 5 indicating polarity of the segments;

FIG. 7 is a perspective view of a permeation-type display device for an electronic wristwatch;

FIG. 8 shows two polarizing plates with crossed axes and a plate having double refraction therebetween;

FIG. 9 is a side view of a device suitable for use with a wristwatch employing plates similar to those of FIG. 8; and

FIG. 10 is a perspective view of a display device similar to that of FIG. 9 but using GMO  $[\text{Gd}_2(\text{MoO}_4)_3]$  single crystals.

## DESCRIPTION OF THE PREFERRED EMBODIMENT

The circuitry involved in displaying time as measured by an electronic wristwatch is shown in FIG. 1 where "input" represents a power source such as a battery. The oscillatory circuit provides a high frequency signal to the divider circuit. The latter divides the high frequency into low frequency timing signals which are supplied in turn to the driving circuit which activates the display device. Such display devices using 7-segment arrays as shown in FIG. 3 are well known in the art and are shown and described in U.S. Pats. as follows:

Patent No.	Inventor	Issue Date	Figure
3,613,351	R. S. Walton	Oct. 19, 1971	1
3,505,804	S. R. Hofstein	April 14, 1970	4
3,691,755	P. Girard	Sept. 19, 1972	1

As a means of displaying indicia it is not sufficient to use a circular polarizing plate and a reflector alone. Such a combination is shown in FIG. 2 where light beam *a* passes through circular polarizing plate 1 and is reflected by reflector plate 2. The sense of the circular polarization is reversed by reflection as the result of which no reflected light can return through plate 1. In consequence, plate 1 when viewed from above appears dark even though light beam *a* is falling on and passing therethrough.

To make use of such a combination of plates, a transparent ferroelectric material is mounted between the circular polarizing plate and the reflector. A voltage is imposed upon the ferroelectric and when the direction of polarization is properly combined with the polarization of the light passing through plate 1, the polarization or residual retardation can be suitably altered up to a maximum of  $\lambda/2$  where  $\lambda$  is the wavelength of the incident light. The extent of retardation or polarization change depends upon the applied voltage. The optical system is brightest at the point where the retardation is  $\lambda/2$ . The system goes from on to off by cutting off the voltage. Since the ambient light incident on said combination is generally white, the fact that the system is brightest at the point where the retardation is  $\lambda/2$  means that the color of the light transmitted through

the combination of plates will depend on the applied voltage.

The transparent ferroelectric ceramic as shown in perspective in FIG. 3 and edgewise in FIG. 4 is a PLZT which is set by the hybrid method. The display is of the standard 7-segment type which can display any of the digits from 0 to 9 by selective activation of the segments. Glass plate 4 has a reflective evaporated aluminum film 5 on the lower surface thereof. Plate 1 is a circular polarizer.

The necessary change in light intensity, i.e., contrast, requires the application of about 300 V. The distance between electrodes 12 is about 1 mm, the area of each electrode is about 3 mm<sup>2</sup> and the thickness of the ceramic is about 60 m  $\mu$ .

In another embodiment, the PLZT display is set by the monolithic method rather than the hybrid method. Suitable arrangements are shown in FIGS. 5 and 6 which illustrate the placement of the segments. Transparent electrode film 6 is attached to both faces of PLZT 3, and the segments are formed by an etching technique as is made clear by FIG. 6. The distance between electrode segments is about 1 mm and a PLZT thickness of about 50 m  $\mu$  is suitable. Here again, adequate contrast between light and dark areas suitable for a wristwatch display is achieved by using voltages of about 300 V.

Transparent ferroelectric ceramics can also be used in a permeation-type display device suitable for an electronic wristwatch, the device being shown in FIG. 7. Incident light 7 falls on condensing lens 8 and passes through polarizing plate 9. The incident light after polarization then strikes concave mirror 10 from which it is directed to polarizing plate 11. The direction of polarization of analyzer plate 11 is at 90° to the plane of polarization of the light reflected from mirror 10. The light from mirror 10 strikes analyzer 11 at an angle close to 90° in order to obtain maximum transmission. In the absence of activatable PLZT segments, virtually no light traverses analyzer 11. However, incorporation of a plate 13 fitted with segments as shown in FIGS. 5 and 6 and suitably connected to a driving circuit makes it possible to present a numerical display by means of the device 7. It should be noted that the area of condensing lens 8 is substantially greater than the viewing area constituted by the analyzer plate 11. As a result, the light intensity and the contrast of the display viewed on the analyzer plate 11 are much greater than would otherwise be the case. Also, this intensification compensates for the loss of light involved in polarization of same. The polarizers may be nicol prisms or Polaroid.

Polarized light can be used in other ways to achieve the desired display. A basic assembly is shown in exploded view in FIG. 8 where light beam 24 passes through polarizing plate 21 and analyzer plate 23 oriented so that their directions of polarization are at 90° to each other. Between plates 21 and 23 is disposed plate 22 which is of a material exhibiting double refraction. In the absence of plate 22, virtually no light reaches the eye at position 25. However, by inserting plate 22 between polarizing plates 21 and 23, retardation ensues and the plane of polarization of the light passing therethrough is changed so that some of the light transmitted through plate 21 reaches the eye through plate 23. However, in such an arrangement, it is difficult to obtain satisfactory contrast due to the loss

in light in passing through the two polarizing plates. To increase the amount of light reaching the eye a device such as is shown in FIG. 9 is employed, this device resembling that of FIG. 7 externally. In the side view of FIG. 9, light beam 33 is condensed by positive lens 35, is reflected by mirror 34 through PLZT plate 36 to the viewing area constituted by analyzer plate 32. As with the device of FIG. 7, the illumination is increased through the use of condensing lens 33 in this arrangement. It is advantageous to prevent access of stray light to the viewing area and visors 38 and 39 are positioned at the edge of the viewing area for this purpose.

The device of FIG. 10 resembles those of FIG. 7 and FIG. 9 with respect to the increase in light intensity achieved in the viewing area by means of use of a positive lens 42. Condensor 42 is contiguous with first polarizing plate 41; the light leaving polarizing plate 41 is reflected and focused by concave mirror 43 and next passes through GMO ( $Gd_2(MoO_4)_3$ ) single crystals shown as plate 44, then through sensitive colored plate 45 and the crossed analyzer plate 46 which constitutes the viewing area. The sensitive colored plate 45 transmits light at 570 m $\mu$  and when voltage is applied to GMO segments along the Z axis, the segments assume a yellow color as a result of retardation by the GMO crystals in combination with the colored plate. When the voltage is inverted, the color of the segments is altered to a bright blue.

The thickness of the GMO plate 44 should be about 100  $\mu$ , the necessary voltage is about 70 V and the sensitive colored plate, as aforementioned, transmits at 570 m $\mu$ . In the device of FIG. 10 as well as those of FIGS. 7 and 9, the reflector is preferably a top surface reflector using evaporated aluminum (not shown) as the reflecting surface.

The importance of the various embodiments described is due to the fact that with the advent of MOS type integrated circuits, it has become possible to reduce the size of the circuitry and simultaneous reduce the power necessary for driving a wristwatch electrically. The devices as described above are activated only when connected to a source of voltage and the actual current passed is extremely low. Consequently, the drain on the battery used for powering the watch is negligible so that the useful life of the battery is not seriously curtailed.

It will thus be seen that the objects set forth above, among those made apparent from the preceding description, are efficiently attained and, since certain changes may be made in the above constructions without departing from the spirit and scope of the invention, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

It is also to be understood that the following claims are intended to cover all of the generic and specific features of the invention herein described, and all statements of the scope of the invention which, as a matter of language, might be said to fall therebetween.

What is claimed is:

1. A timepiece display device for digital display of the time comprising a polarizer plate for circularly polarizing light incident thereon and passing therethrough, a reflector plate opposed to said polarizer plate and means intermediate said opposed plates for controllably retarding said light passing between said opposed

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polarizer and reflector plates, said means being activatable for controlling the retardation of said light by selective impositions of a suitable voltage to at least a portion of said means, substantially no light reflected from said reflector plate being transmitted through said polarizer plate in the absence of a voltage applied to said means.

2. A timepiece display device as defined in claim 1, wherein said means is a transparent ferroelectric ceramic of PLZT.

3. A timepiece display device as defined in claim 2, wherein said PLZT is segmented for forming any numeral from 0 to 9 by selective application of a suitable voltage to groups of said segments.

4. A timepiece display device as defined in claim 2, wherein said device further comprises electrodes for applying a voltage to said ceramic, the distance between opposed electrodes is about 1 mm, the area of said electrodes is about 3 mm<sup>2</sup>, said ceramic is about 60μ thick, and a suitable voltage is about 300 V.

5. A timepiece display device as defined in claim 2, wherein said PLZT is in plate form, and said device further comprises transparent electrode films on each face of said PLZT, said films being segmented to present

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any numeral from 0 to 9 by selective application of a suitable voltage to groups of said segments.

6. A timepiece display device as defined in claim 5, wherein the distance between electrodes is about 1 mm, the thickness of said PLZT is about 50μ, and a suitable voltage is about 300 V.

7. A timepiece display device as defined in claim 2, wherein said voltage introduces a retardation of up to λ/2, this value giving maximum contrast.

8. A digital time display device comprising a polarizer plate for circularly polarizing light incident thereon and passing therethrough, a reflector plate opposed to said polarizer plate and means intermediate said plates for controllably retarding said light passing between said opposed plates, said means being transparent ferroelectric ceramic of PLZT which can control the retardation of said light by selective impositions of a suitable voltage, substantially no reflected light being transmitted through said polarizer plate in the absence of a voltage applied to said means, being segmented for forming any numeral from 0 to 9 by selective application of a suitable voltage to groups of said segments.

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