

PATENT SPECIFICATION

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(54) LIQUID CRYSTAL DISPLAY DEVICE /

(71) We, KABUSHIKI KAISHA SUWA SEIKOSHA, a Japanese body corporate, of 3-4, 4-chome, Ginza, Chuo-ku, Tokyo, Japan, do hereby declare the invention for which we pray that a patent may be granted to us, and the method by which it is to be performed to be particularly described in and by the following statement:—

10 This invention relates to liquid crystal display devices.

One conventional solid wrist watch has a quartz vibrator, a COS-MOS electronic driving circuit and a liquid crystal display device. Such a conventional wrist watch has a relatively high degree of accuracy, a relatively low power consumption, and is of relatively small size. However, such conventional wrist watches are not, as yet, in commercial production.

One conventional liquid crystal display device uses nematic liquid crystal material, the liquid crystal material being disposed between a pair of plates having electrodes thereon. Light scattering by the liquid crystal material is determined by either applying or not applying an electric field to the liquid crystal material. Such a conventional liquid crystal display device has the disadvantage that the contrast of the display is indistinct and it is difficult to see the display in the dark because it utilises incident light and so the visibility of the display depends upon the light conditions of the environment surrounding the liquid crystal display device.

The present invention seeks to provide a more practical liquid crystal display device which does not suffer from the above defects.

According to one aspect of the present invention there is provided a liquid crystal display device comprising: a transparent first plate; a transparent second plate

spaced apart from the first plate; liquid crystal material between first surfaces of the first and second plates; an analyser disposed on a second surface of the first plate opposite to the first surface thereof, a polariser disposed on the second surface of the second plate opposite to the first surface thereof; luminescent material disposed on the polariser; transparent first conductive means on said first surface of the first plate; and second conductive means on said first surface of the second plate.

Preferably the analyser and polariser are arranged with their planes of polarisation at right angles.

The liquid crystal material may be of the type which is optically active when an electric field is not applied thereto and is optically inactive when an electric field is applied thereto.

According to a still further aspect of the present invention there is provided a watch comprising a quartz vibrator, a COS-MOS electronic driving circuit and a liquid crystal display device as recited above.

The invention is illustrated, merely by way of example, in the accompanying drawings, in which:

Figure 1 is a cross-section of a conventional liquid crystal display device;

Figures 2 and 3 illustrate the principle of operation of a liquid crystal display device according to the present invention; and

Figure 4 is a cross-section of a liquid crystal display device according to the present invention.

Referring to Figure 1 there is shown, in cross-section, a conventional liquid crystal display device. The conventional liquid crystal display device has a transparent upper plate 1, a transparent lower plate 2 and liquid crystal material 3 therebetween.

The upper plate 1 has a pair of transparent conductive films 5, 6 on the surface which is in contact with the liquid crystal

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material, and the lower plate 2 has a pair of transparent conductive films 7, 8 on the surface which is in contact with the liquid crystal material. On the surface of the base plate opposite to the surface carrying the conductive films 7, 8 there is a further plate 4 with a reflecting film 9 thereon. The two pairs of conductive films 5, 7 and 6, 8 are so shaped that when an electric field is applied therebetween the liquid crystal material is stimulated so that, for example, the numerals "2" and "3" are visible from the upper plate 1. The numerals are visible because incident light is reflected by the stimulated liquid crystal material, and for this reason contrast is poor since it depends upon the light conditions of the environment surrounding the liquid crystal display device. In addition, the numerals are difficult to see in the dark because of the reduction in the intensity of the incident light.

Figures 2 and 3 illustrate the principle of operation of a liquid crystal display device according to the present invention. The liquid crystal display device comprises a polariser 11, an analyser 12 and liquid crystal material 13 therebetween. The polariser 11 and the analyser 12 are disposed so that their planes of polarisation are at right angles to one another. Thus linearly polarised light which passes from the polariser 11 is rotated by 90° as it passes through the liquid crystal material 13 when an electric field is not applied thereto, as shown in Figure 2. Accordingly, the plane of polarisation of the light after it has passed through the liquid crystal material 13 is the same as the plane of polarisation of the analyser 12. Thus light passes through the analyser 12 to an observer and the analyser will appear light in colour, as shown in plan view in Figure 2.

Figure 3 illustrates the case when an electric field is applied to the liquid crystal material. The linearly polarised light which passes through the polariser 11 is, in this case, not rotated by the liquid crystal material 13. This is because the liquid crystal material is of the nematic type which is optically inactive when an electric field is applied thereto.

Accordingly, the light after it has passed through the liquid crystal material 13 does not pass through the analyser 12 because its plane of polarisation is different from the plane of polarisation of the analyser. Thus, to an observer, the analyser 12 would appear black or almost black as shown in plan view in Figure 3. Therefore, viewing the analyser 12, incident light on the polariser is shut out or is visible depending upon whether or not an electric field is applied to the liquid crystal material 13. It will be appreciated that in

such a liquid crystal display device a greater contrast can be obtained compared with the conventional liquid crystal display device.

The same effect will be achieved by viewing the polariser 11 if a reflector (not shown) is disposed on the surface of the analyser 12 opposite to the surface in contact with the liquid crystal material.

The contrast is superior to that of the conventional liquid crystal display device because it does not depend upon the light conditions of the environment surrounding the liquid crystal display device. Moreover, the contrast is reasonable even when the intensity of the incident light is poor. Furthermore, the liquid crystal display device can be used in a relatively dark environment because luminescent or fluorescent material is used, whereas fluorescent material cannot be used in conjunction with the conventional liquid crystal display device.

Figure 4 shows, in cross-section, a liquid crystal display device according to the present invention. A transparent upper plate 14 and a transparent lower plate 15 holds liquid crystal material 16 therebetween. The upper plate 14 and the lower plate 15 have transparent conductive films 21, 22 and 23, 24 respectively on the surfaces which are in contact with the liquid crystal material 16. An analyser 17 is disposed in front of the upper plate 14, that is to say on the surface opposite to the surface in contact with the liquid crystal material and a polariser 18 is disposed on the back of the lower plate 15, that is to say on the surface opposite to the surface in contact with the liquid crystal material. The analyser 17 and the polariser 18 are arranged to form a polariscope, and have their planes of polarisation at right angles to one another. The liquid crystal material 16 is such that when an electric field is not applied thereto it is optically active to rotate the plane of polarisation of light incident thereon through 90°, and when an electric field is applied it becomes optically inactive. On the back of the polariser 18 is disposed a transparent base plate 19 having a coating 20 of luminescent fluorescent or phosphorescent material thereon.

When a voltage is applied between the films 21, 23 and the films 22, 24 the numerals "2" and "3", for example, are visible from the analyser 17 as shown in plan view in Figure 4. The background to the numerals appears light in colour. The contrast is good even in relatively dark environments because it does not depend solely upon the light conditions of the environment surrounding the liquid crystal display device. Furthermore, in extremely dark environments, the light emit-

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Any conventional luminescent, or fluorescent or phosphorescent material may be used for the coating 20 which can, if desired, be applied directly to the analyser.

The liquid crystal display device of Figure 4 is such that the planes of polarisation of the polariser and analyser are at right angles to one another. However, the analyser and polariser may be arranged so that their planes of polarisation are parallel to one another. In such a case the display would be light numerals upon a black background.

As an alternative in the above embodiment the conductive films 23, 24 may be reflective and a suitably shaped transparent insulating film (not shown) may be placed over the reflective conductive film and in contact with the liquid crystal material. The conductive films 23, 24 may be constituted by a single conductive film. The transparent insulating film is shaped to enable alphanumeric characters etc. to be displayed.

The liquid crystal display device shown in Figure 4 may be used in conjunction with a wrist watch including a quartz vibrator and a COS-MOS electronic driving circuit, neither of which are shown in the drawings.

A liquid crystal display device having the above features is also described and claimed in our copending application No. 1989/74 (Serial No. 1386715).

WHAT WE CLAIM IS:—

1. A liquid crystal display device comprising:

a transparent first plate; a transparent second plate spaced apart from the first plate; liquid crystal material between first surfaces of the first and second plates; an analyser disposed on a second surface of the first plate opposite to the first surface thereof; a polariser disposed on the second surface of the second plate opposite to the first surface thereof; luminescent material disposed on the polariser; transparent first conductive means on said first surface of the first plate; and second conductive means on said first surface of the second plate.

2. A liquid crystal display device as claimed in claim 1 in which the analyser and polariser are arranged with their planes of polarisation at right angles.

3. A liquid crystal display device as claimed in claim 1 or 2 in which the liquid crystal material is of the type which is optically active when an electric field is not applied thereto and is optically inactive when an electric field is applied thereto.

4. A liquid crystal display device as claimed in claim 1 and substantially as herein described with reference to and as shown in Figure 4 of the accompanying drawings.

5. A watch comprising a quartz vibrator, a COS-MOS electronic driving circuit and a liquid crystal display device as claimed in claim 1.

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