

SPECIFICATION

Liquid crystal display device

- 5 The present invention relates to a liquid crystal display device, and particularly to a liquid crystal display device which includes a plurality of liquid crystal layers lying in piles, and in which special attention is paid to the generation of a white on black pattern based upon an overlap of patterns formed respectively in the liquid crystal layers, that is, the generation of the above-mentioned white pattern is prevented.
- 10 According to one aspect of the present invention, a liquid crystal display device is proposed in which the generation of white on black patterns is prevented.
- In an electronic device having a display part such as a wrist watch, a small-sized clock, or an electronic desk calculator, a liquid crystal display device has been widely used as the above display part in recent years. Further, there has been developed a watch or clock in which, as shown in Fig. 1 of the accompanying drawings, a display part 1 is divided into an analog display region 5 having short, long and second hands 2, 3 and 4 and a digital display region 6 for indicating the time by numerals. The display part 1 may be fabricated in such a manner that the analog and digital display regions 5 and 6 are formed of liquid crystal layers 7 and 8 respectively, as shown in Fig. 2. In more detail, the upper and lower liquid crystal layers 7 and 8 include therein analog and digital display patterns respectively. Further, upper and lower polarizers 9 and 10 are arranged above and below the liquid crystal layers 7 and 8 respectively, and a reflecting plate 11 is arranged below the lower polarizer 10. The polarizers 9 and 10 are equal in direction of transmission axis to each other.
- In such a two-layer structure, when a portion (or a segment) of the upper liquid crystal layer 7 and a portion (or a segment) of the lower liquid crystal layer 8 overlap each other and moreover are simultaneously applied with a voltage, an overlapping portion of the segments forms a white on black pattern on a display surface. For this reason, the display part 1 is so designed that respective patterns in the liquid crystal layers 7 and 8 are prevented from overlapping each other. That is, the display part 1 is obliged to become large, and therefore it is impossible to provide a small-sized electronic device.
- Now, explanation will be made in detail on the phenomenon that, in a case where respective segments of upper and lower liquid crystal layers overlap each other and are simultaneously applied with a voltage, an overlapping portion of the segments forms a white on black portion on a display surface and cannot be observed clearly, by reference to Figs. 3a

- and 3b. Fig. 3a is an exploded, explanatory view for showing a display part including liquid crystal layers and polarizers. Referring to Fig. 3a, an upper polarizer 12, a glass plate 13, an upper liquid crystal layer 14, a glass plate 15, a glass plate 16, a lower liquid crystal layer 17, a glass plate 18 and a lower polarizer 19 are arranged in the order described in the direction from top to bottom. In Fig. 3a, reference characters *a*, *b*, *c* and *d* designate points where light passes through the display part. In more detail, light passes through the upper polarizer 12, the upper liquid crystal layer 14, the lower liquid crystal layer 17 and the lower polarizer 19 at the points *a*, *b*, *c* and *d* respectively. Further, reference numerals ①, ② and ③ designate paths of light travelling in a direction from top to bottom, and ①', ②' and ③' those of light travelling in a direction from bottom to top (usually, the paths of light reflected back from a reflecting plate). Referring to Fig. 3a, on the paths ① and ①', there is provided no electrode for the liquid crystal layers 14 and 17.
- On the paths ② and ②', there are provided a pair of electrodes 20 which are formed on the glass plates 13 and 15 for sealing up the upper liquid crystal layer 14 therebetween. On the paths ③ and ③', there are provided upper electrodes 20 for the upper liquid crystal layer 14 and lower electrodes 20 for the lower liquid crystal layer 17. That is, the upper electrodes 20 and the lower electrodes 20 overlap each other.
- Fig. 3b shows the polarization direction of light at a time immediately after light has passed through the members 12, 14, 17 and 19. In Fig. 3b, reference symbols ⊕ and ⊙ designate polarization directions of polarized light, and ⊗ shows that light has been absorbed and therefore a pattern becomes black on a display surface. The polarization direction of light is not changed when the light passes through that portion (or segment) of a liquid crystal layer which is applied with a voltage, but is changed by an angle of 90° when the light passes through a segment which is not applied with any voltage. Accordingly, in a case where light travels along the paths ① and ①', on which the upper and lower liquid crystal layers 14 and 17 are not applied with any voltage, light passes through the upper polarizer 12, the liquid crystal layers 14 and 17 and the lower polarizer 19, and therefore no pattern appears on the display surface. In a case where light travels along the paths ② and ②', on which only the upper liquid crystal layer 14 is applied with a voltage, the light travelling in the direction of the path ② cannot pass through the lower polarizer 19 and therefore a black pattern is formed on the display surface, and the light travelling in the direction of the path ②' cannot pass through the upper polarizer 12 and therefore a black pattern appears on

the display surface.

In a case where light travels along the paths ③ and ③', on which each of the upper and lower liquid crystal layers 14 and 17 is provided with a pair of electrodes 20, and where a voltage is applied across the layer 14 and across the layer 17 simultaneously, light passes through the members 12, 13, 14, 15, 16, 17, 18 and 19 and therefore forms a light region on the display surface. In other words, an overlapping portion of the electrode pair 20 for the layer 14 and that for the layer 17 forms a white on black region on the display surface when these electrode pairs are simultaneously applied with a voltage.

Accordingly, an object of the present invention is to provide a liquid crystal display device in which a plurality of liquid crystal layers are stacked to display several kinds of patterns on a display surface, and in which the generation of a white on black region based upon an overlap of the patterns is prevented to reduce the area of the display surface.

According to the present invention, there is provided a liquid crystal display device comprising: a plurality of liquid crystal layers each for displaying a pattern, said liquid crystal layers being arranged as a stacked pile; a pair of polarizers arranged one above the uppermost liquid crystal layer and the other below the lowermost liquid crystal layer; electrode patterns provided for said liquid crystal layers and having predetermined shapes respectively; and at least one additional polarizer arranged between liquid crystal layers in the stack in such a manner that a transmission axis of the or each said additional polarizer is perpendicular to a transmission axis of each of the two polarizers adjacent to said additional polarizer, so that said electrode patterns on different liquid crystal layers may be viewed in a darkened state at the same time without light areas being viewed where said electrode patterns overlap.

The present invention will become further apparent from the following description taken in conjunction with the accompanying drawings, in which:

Figure 1 is a plan view showing a display part of a conventional watch including two liquid crystal layers;

Figure 2 is an exploded, explanatory view for showing an arrangement of liquid crystal layers and the like in the display part shown in Fig. 1;

Figure 3a is an exploded, explanatory view for showing that a light beam passes through various regions of the display part shown in Figs. 1 and 2, and Fig. 3b shows polarization directions of light;

Figure 4a is an exploded, explanatory view for showing that a light beam passes through various regions of an embodiment of a liquid crystal device according to the present inven-

tion, and Fig. 4b shows polarization directions of light;

Figure 5a is an exploded, explanatory view for showing that a light beam passes through various regions of an embodiment of a liquid crystal display device including three liquid crystal layers according to the first aspect of the present invention, and Fig. 5b shows polarization directions of light; and

Figure 6 is a plan view showing a display part of a watch according to the present invention.

Fig. 4a is an exploded, explanatory view for showing an embodiment of a liquid crystal display device (including two liquid crystal layers) according to the first aspect of the present invention, and Fig. 4b shows polarization directions of light passing through the embodiment shown in Fig. 4a. In the device shown in Fig. 4a, an upper polarizer 21, a glass plate 22, an upper liquid crystal layer 23, a glass plate 24, an intermediate polarizer 25, a glass plate 26, a lower liquid crystal layer 27, a glass plate 28, and a lower polarizer 29 are arranged in the order described in the direction from top to bottom. Light passes through the device in the direction from top to bottom, and is then reflected back from a reflecting plate (not shown) to pass through the device in the direction from bottom to top. In Fig. 4a, reference numerals ①, ②, ③ and ④ designates paths of light in a case when light travels in the direction from top to bottom, and ①', ②', ③' and ④' paths of light in a case when the reflected light travels in the direction from bottom to top. On the paths ④ and ④', there are provided a pair of electrodes 30 for each of the liquid crystal layers 23 and 27. On the paths ③ and ③', there are provided a pair of electrodes 30, which are formed on facing surfaces of the glass plates 26 and 28 for sealing up the lower liquid crystal layer 27 therebetween. On the paths ② and ②', there are provided a pair of electrodes 30, which are formed in facing surfaces of the glass plates 22 and 24 for sealing up the upper liquid crystal layer 23 therebetween. On the paths ① and ①' is provided no electrode. In Fig. 4a, reference characters a, b, c, d and e designate points where light passes through the device. In more detail, light passes through the upper polarizer 21, the upper liquid crystal layer 23, the intermediate polarizer 25, the lower liquid crystal layer 27 and the lower polarizer 29 at the points a, b, c, d, and e respectively. Further, reference symbols ⊕ and ⊖ designates polarization directions of polarized light, and ⊗ shows that light has been absorbed and therefore a pattern becomes black on a display surface.

In such a structure, when the electrodes for the upper liquid crystal layer 23 and the electrodes for the lower liquid crystal layer 27, which overlap each other on the paths ④

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and ④', are simultaneously applied with a voltage, an overlapping portion of the electrodes forms a black pattern on the display surface as shown on the paths ④ and ④' in

5 Fig. 4b, and thus the generation of a white on black region in a conventional device can be prevented. In more detail, the light travelling on the path ④ passes through the upper polarizer 21 and an upper liquid crystal part

10 (made up of the upper liquid crystal layer 23, the glass plates 22 and 24, and so on) while keeping the polarization direction thereof (namely, of light) unchanged since the upper liquid crystal layer 23 is applied with the

15 voltage. The light having passed through the upper liquid crystal part is absorbed by the intermediate polarizer 25 since the direction of transmission axis of the polarizer 25 is different from the polarization direction of

20 light incident upon the polarizer 25, so that a region of the display surface corresponding to the region of the upper liquid crystal layer 23 applied with the voltage becomes black. Further, the light travelling on the path ④'

25 passes through the lower polarizer 29 and a lower liquid crystal part (made up of the lower liquid crystal layer 27, the glass plates 26 and 28, and so on) without changing the polarization direction, and is then absorbed by the

30 intermediate polarizer 25. Thus, the region of the lower liquid crystal layer 27 applied with the voltage forms a black pattern on the display surface. Accordingly, an overlapping portion of those regions of the upper and

35 lower liquid crystal layers 23 and 27 which are simultaneously applied with the voltage, can also form a black pattern on the display surface. In a case where only one of the liquid crystal layers 23 and 27 is applied with the

40 voltage, as shown by the paths ②, ②', ③ and ③' in Fig. 4a, a black pattern is formed on the display surface as shown by the paths ②, ②', ③ and ③' in Fig. 4b. In a case

45 where neither of the liquid crystal layers 23 and 27 are applied with the voltage as shown by the paths ① and ①' in Fig. 4a, light can pass through all of the members 21 to 29, and therefore exhibits no pattern on the display surface.

50 Fig. 5a is an exploded, explanatory view for showing another embodiment of a liquid crystal display device (including three liquid crystal layers) according to the present invention, and Fig. 5b shows the polarization direction of light passing through the embodiment shown in Fig. 5a. Like numerals designate like parts in Fig. 4a, 4b, 5a and 5b. In Fig. 5a,

55 reference numerals 31 and 33 designates glass plates, 32 a liquid crystal layer, and 34 a polarizer. Referring to Figs. 5a and 5b, an overlapping portion of those regions of at least two layers of the liquid crystal layers 23, 27 and 32 which are simultaneously applied

60 with a voltage, can form a black pattern on a display surface, as shown on the paths ③,

③', ④ and ④' in Fig. 5b. That is, the overlapping portion does not form a white on black pattern. It is to be noted that the polarizers 21 and 34 are different in direction

70 of transmission axis from each other, the polarizers 21 and 25 are also different in direction of transmission axis from each other, and further the polarizers 29 and 34 are different in direction of transmission axis from

75 each other.

In the above description, explanation has been made on the embodiments including two and three liquid crystal layers. However, the present invention is not limited to such embodiments, but four or more liquid crystal layers can be included in a device according to the present invention. In this case, it is required that polarizers are provided above an uppermost liquid crystal layer, below a lowermost liquid crystal layers, and between adjacent liquid crystal layers, and adjacent polarizers are different in direction of transmission axis from each other.

80 As explained previously, in a liquid crystal display device (including a plurality of liquid crystal layers) according to the present invention, an overlapping portion of patterns formed by the liquid crystal layers appears as a part of these patterns. Accordingly, a pattern formed by a liquid crystal layer and another pattern formed by another liquid crystal layer may overlap each other, as in a display part of a watch shown in Fig. 6. That is, the area of the display part can be reduced. In other words, an electronic device having such a display part can be made small-sized.

100 Further, since it is possible to overlap various patterns, a fashionable display pattern can be formed.

CLAIMS

1. A liquid crystal display device comprising: a plurality of liquid crystal layers each for displaying a pattern, said liquid crystal layers being arranged as a stacked pile; a pair of polarizers arranged one above the uppermost liquid crystal layer and the other below the lowermost liquid crystal layer; electrode patterns provided for said liquid crystal layers and having predetermined shapes respectively; and at least one additional polarizer arranged between liquid crystal layers in the stack in such a manner that a transmission axis of the or each said additional polarizer is perpendicular to a transmission axis of each of the two polarizers adjacent to said additional polarizer, so that said electrode patterns on different liquid crystal layers may be viewed in a darkened state at the same time without light areas being viewed where said electrode patterns overlap.

2. A liquid crystal display device according to claim 1, wherein each of said liquid crystal layers rotates the axis of polarization of



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and ④', are simultaneously applied with a voltage, an overlapping portion of the electrodes forms a black pattern on the display surface as shown on the paths ④ and ④' in Fig. 4b, and thus the generation of a white on black region in a conventional device can be prevented. In more detail, the light travelling on the path ④ passes through the upper polarizer 21 and an upper liquid crystal part (made up of the upper liquid crystal layer 23, the glass plates 22 and 24, and so on) while keeping the polarization direction thereof (namely, of light) unchanged since the upper liquid crystal layer 23 is applied with the voltage. The light having passed through the upper liquid crystal part is absorbed by the intermediate polarizer 25 since the direction of transmission axis of the polarizer 25 is different from the polarization direction of light incident upon the polarizer 25, so that a region of the display surface corresponding to the region of the upper liquid crystal layer 23 applied with the voltage becomes black. Further, the light travelling on the path ④' passes through the lower polarizer 29 and a lower liquid crystal part (made up of the lower liquid crystal layer 27, the glass plates 26 and 28, and so on) without changing the polarization direction, and is then absorbed by the intermediate polarizer 25. Thus, the region of the lower liquid crystal layer 27 applied with the voltage forms a black pattern on the display surface. Accordingly, an overlapping portion of those regions of the upper and lower liquid crystal layers 23 and 27 which are simultaneously applied with the voltage, can also form a black pattern on the display surface. In a case where only one of the liquid crystal layers 23 and 27 is applied with the voltage, as shown by the paths ②, ②', ③ and ③' in Fig. 4a, a black pattern is formed on the display surface as shown by the paths ②, ②', ③ and ③' in Fig. 4b. In a case where neither of the liquid crystal layers 23 and 27 are applied with the voltage as shown by the paths ① and ①' in Fig. 4a, light can pass through all of the members 21 to 29, and therefore exhibits no pattern on the display surface.

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③', ④ and ④' in Fig. 5b. That is, the overlapping portion does not form a white on black pattern. It is to be noted that the polarizers 21 and 34 are different in direction of transmission axis from each other, the polarizers 21 and 25 are also different in direction of transmission axis from each other, and further the polarizers 29 and 34 are different in direction of transmission axis from each other.

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2. A liquid crystal display device according to claim 1, wherein each of said liquid crystal layers rotates the axis of polarization of

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incident light substantially by 90 degrees in the absence of an applied voltage and keeps the axis of polarization of incident light in the presence of an applied voltage.

- 5 3. A light crystal display device according to claim 1 or 2, wherein the number of liquid crystal layers is at least three.

- 10 4. A liquid crystal display device according to any preceding claim, wherein said at least one polarizer is disposed between each pair of adjacent liquid crystal layers.

5. A liquid crystal display device substantially as hereinbefore described with reference to and as shown by Figs. 4 to 6 of the accompanying drawings.

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