

PATENT SPECIFICATION

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(54) IMPROVEMENTS IN AND RELATING TO CONTROLLABLE LIQUID-CRYSTAL DISPLAY DEVICE

(71) We, BBC BROWN, BOVERI & COMPANY, LIMITED, a Corporation organised under the laws of the Confederation of Switzerland of, Baden, Switzerland, 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:—

The invention concerns a controllable liquid-crystal display device comprising a liquid crystal contained between transparent electrodes located on two plane surfaces, between a first transparent support plate and a second support plate and between a first linear polarizer and a second linear polarizer combined with a reflector.

Such controllable liquid-crystal display devices are already known from Patent Specification No. 1,382,868.

Here the incident light must pass twice through the polarizers, the support plates and the liquid crystal. In the bright position, therefore, (transmitting directions of both polarizers perpendicular to each other when using a nematic liquid crystal with a 90° helical structure) the intensity of the outgoing light is considerably weaker than the incoming, non-polarized light. With the usual linear polarizers, however, an arbitrarily high transmissivity cannot be achieved, because even in the ideal case only light oscillating in a certain direction is transmitted, while the polarizer absorbs the light oscillating in other directions. In the case of commercially available polarizers, polarizers with the greatest transmissivity show the lowest opacity ratio, whereby opacity ratio is meant the relationship of the intensity of light passing through a pair of polarizers with parallel axes to that passing through a polarizer pair with crossed axes. Under unfavourable lighting conditions, therefore, the ease of reading a

liquid-crystal display device operating by reflection can be severely impaired.

The commercial polarizer sold under the Trade Mark "Polaroid" as Polaroid HN 42, for example, has for non-polarized incident light a transmissivity of 42%, a transmissivity of 35% for two polarizers in the bright position, and a maximum attainable opacity ratio of 1:70. In the case of a display with a bright background, therefore, the brightness of the background is equivalent to less than 35% of the incident light because the reflector is often made slightly diffusive to avoid undesired reflection of the light source, and the light when reflected back has to pass through the display again. For this reason, the display is difficult to read under conditions of low ambient lighting level, even when the contrast between the electrically energized characters and the background is adequate. An improvement in legibility by brightening the background can be achieved with a pair of thin-film polarizers sold under the Trade Mark "Polaroid" as Polaroid HN 55, but contrast is then much poorer.

The object of the invention, therefore, is to create a liquid-crystal display device which exhibits both good contrast between background and displayed characters, and also a sufficiently bright background or image.

This object is achieved in that the polarizers are of such a kind that the first polarizer in conjunction with another polarizer of the same type exhibits a high opacity ratio as herein defined and the second polarizer in conjunction with another polarizer of the same type exhibits a comparatively low opacity ratio and the reflector scatters little or no light.

Other details of the invention are to be found from the example described below with reference to the drawing, in which:—

The drawing shows a section through a liquid-crystal display device.

In the drawing the reference number 1

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denotes a nematic liquid crystal, the molecule groups 2 of which are orientated in a 90° structure through suitable surface treatment of the support plates 5, 6 and of the transparent electrodes 3, 4 located on the plates. Two polarizers 7, 8 rotated through 90° with respect to each other, and a reflector 9, complete the liquid-crystal display device, which is connected to a voltage source 10. 11 represents a light source from which light 12 falls on the display assembly, and 13 is an observer which perceives the light 14 reflected from the display device. $\epsilon_{\parallel}$ is the dielectric constant along the longitudinal axis of the molecule groups 2, and $\epsilon_{\perp}$ is the dielectric constant perpendicular to this axis.

In a manner similar to the liquid crystal display described in Patent Specification No. 1,382,868 the 90° helical structure of the liquid-crystal layer 1 has the effect of turning through 90° the plane of oscillation of the linearly polarized light passing through the front polarizer 7, and therefore causes the rear polarizer 8, acting as an analyser, to transmit the maximum light intensity when in the position shown in Figure 1, i.e. when the polarizers 7 and 8 are crossed with respect to each other. The light reflected by reflector 9 then passes in the reverse direction through polarizer 8, support plate 6, electrode coating 4, liquid crystal 1, electrode coating 3, support plate 5 and polarizer 7 to the observer 13, who perceives maximum brightness on the display device.

If the liquid-crystal molecule groups 2 exhibit positive anisotropy of the dielectric constant, i.e. if $\epsilon_{\parallel}$ is greater than $\epsilon_{\perp}$, the electric field built up between the electrodes 3, 4 by applying a sufficiently high electric voltage, as indicated by the broken lines in the drawing, has the effect of largely aligning the liquid-crystal molecule groups 2 in the field direction E, whereupon the optical activity of liquid-crystal layer 1 is largely eliminated, and in this state the brightness of the display is perceived by the observer to be much less than in the state with no voltage. Therefore, if voltage is applied only to certain portions of electrodes 3, 4, e.g. in the shape of numerals, the observer will perceive dark numerals on a bright ground, their legibility being substantially improved by the invention through the use of suitable polarizers 7, 8 and reflectors 9.

The first and second polarizers 7, 8 can of course also have the same orientation, in which case bright, energized characters can be displayed on a dark background.

The reflector 9 of Figure 1 consists, for example, of an aluminium foil which is slightly roughened on the display side and thus scatters light in some degree. A

reflector 9 of this kind can be obtained by brushing and then anodizing one side of a bright aluminium foil. Its only slightly roughened surface reflects collimated incident light chiefly within a narrow range of angles symmetrically distributed about the angle of reflection as defined for ideal mirrors. The criterion for the amount of roughening is that the reflector surface should be roughened only to such an extent that the light source 11 is just no longer reflected as from a specular mirror.

In another configuration according to the invention, a bright specular aluminium foil is used in conjunction with polarizer 7 roughened on the viewing side. The first polarizer 7 is, for example, a commercial polarizer of the Polaroid HN 42 type with a transmissivity of 35% in the bright position (axes parallel) and of 0.5% in the dark position (axes crossed), thus allowing a maximum contrast of 1:70 in the transmitted light mode. The second polarizer 8 is a commercial polarizer of the Polaroid HN 55 type with a transmissivity for unpolarized light of 45% in the bright position and 22% in the dark position for a pair of polarizers, thus allowing a maximum contrast of 1:2 in the transmitted light mode.

With this arrangement of the polarizers 7, 8 in the display device one obtains a background or image which is much brighter than that obtained with two identical polarizers of type Polaroid HN 42, and a contrast which is visually scarcely distinguishable from that achieved with two polarizers of type Polaroid HN 55.

A similar effect can also be achieved with other types of polarizer, such as Polaroid HN 48 instead of Polaroid HN 42.

Surprisingly, this brightening of the background while retaining almost the same contrast is achieved only with the arrangement of the invention. If the polarizers 7 and 8 are interchanged, the same background brightness is obtained but there is a serious loss of contrast owing to brightening of the energized electrode areas in the shape of numerals, for example.

The effect of the invention can thus be achieved only if the non-polarized incident light 12 is sufficiently strongly polarized by the first polarizer 7. The second polarizer does not have to meet the same exacting requirements as regards polarizing capacity because reflector 9 scatters light only slightly and therefore the degree of polarization of the reflected light largely corresponds to the degree of polarization of the incident light.

Since the requirements demanded of the second polarizer 8 are less than for the first polarizer 7, the liquid-crystal display device can be built partly by employing thin-film

techniques. Possible sequences of the films are then liquid-crystal layer 1, electrode 4, polarizer 8, support plate 6, reflector 9, or liquid-crystal layer 1, electrode 4, polarizer 8, reflector 9, support plate 6, or liquid-crystal layer 1, polarizer 8, electrode 4, reflector 9, support plate 6. In the third of these arrangements the polarizer 8 must have a sufficiently high electrical capacitance (small film thickness and high dielectric constant) to be able to energize liquid-crystal layer 1 by alternating voltage (capacitive voltage divider). Furthermore, in this case the reflector 9 must not influence the electrical functioning of the electrodes 4, which may be segmented. For example the reflector 9 may be either suitably segmented so as to act simultaneously as an electrode, or an insulating intermediate coating (e.g. silicon oxide) is evaporated on to the reflecting metal layer before the transparent electrode is applied. The second and third arrangements mentioned above have the advantage that parallax phenomena are largely eliminated.

A linearly dichroic polyvinyl alcohol (PVA) film produced by photographic means can be used as a thin-film polarizer 8. When making a film of this kind, a PVA film is first made light-sensitive with a suitable aqueous solution of cupric chloride and ammonium dichromate. A pattern of parallel lines then serves as a photomask for selectively illuminating the photosensitive layer. After developing, dichroic pigment molecules of the kind used for conventional polarizers become incorporated only along the thin, unexposed strips, resulting in a film with dichroic pigment molecules orientated largely in parallel.

WHAT WE CLAIM IS:—

1. A controllable liquid-crystal display device comprising a liquid crystal contained between transparent electrodes located on two plane surfaces, between a first transparent support plate and a second support plate and between a first linear polarizer and a second linear polarizer combined with a reflector, in which the polarizers are of such a kind that the first polarizer in conjunction with another polarizer of the same type exhibits a high opacity ratio as herein defined and the

second polarizer in conjunction with another polarizer of the same type exhibits a comparatively low opacity ratio and the reflector scatters little or no light.

2. A controllable liquid-crystal display device as claimed in Claim 1, in which the transmissivity for non-polarized light of the first polarizer is less than that of the second polarizer.

3. A controllable liquid-crystal display device as claimed in Claim 1 or 2, in which the first polarizer is a thin-film polarizer with a transmissivity of 42% for non-polarized light.

4. A controllable liquid-crystal display device as claimed in Claim 1, 2 or 3, in which the reflector is a slightly roughened and anodized aluminium foil.

5. A controllable liquid-crystal display device as claimed in any one of the preceding claims, in which the second polarizer is such that a pair of such polarizers would have a transmissivity for unpolarized light of 45% in the bright position and 22% in the dark position.

6. A controllable liquid-crystal display device as claimed in any one of the preceding claims, in which the second polarizer and the reflector are located between the liquid crystal and the second support plate.

7. A controllable liquid-crystal display device as claimed in Claim 6, in which the construction of the liquid-crystal display device embodies thin-films.

8. A controllable liquid-crystal display device as claimed in Claim 6 or 7, in which the second polarizer is a film having dichroic pigment molecules uniformly orientated by photographic means.

9. A controllable liquid-crystal display device substantially as hereinbefore described with reference to the accompanying drawing.

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Reference has been directed in pursuance of Section 9, Subsection (1) of the Patents Act 1949, to Specification No. 1,436,085.



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A linearly dichroic polyvinyl alcohol (PVA) film produced by photographic means can be used as a thin-film polarizer 8. When making a film of this kind, a PVA film is first made light-sensitive with a suitable aqueous solution of cupric chloride and ammonium dichromate. A pattern of parallel lines then serves as a photomask for selectively illuminating the photosensitive layer. After developing, dichroic pigment molecules of the kind used for conventional polarizers become incorporated only along the thin, unexposed strips, resulting in a film with dichroic pigment molecules orientated largely in parallel.

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