

Liquid Crystal Display Unit

Field of the invention

This invention relates to a liquid crystal display unit, particularly a reflection type liquid crystal display unit.

Description of the prior art

5 Figure 1 is a perspective view of a typical prior art liquid crystal display unit shown disassembled. Referring to Figure 1, a reflection type liquid crystal display unit is shown. This liquid crystal display unit includes a liquid crystal display element 2. The liquid crystal display
10 element 2 includes a first glass sheet 4 and a second glass sheet 6. A spacer 8 made, eg of Mylar material (Mylar is a registered Trade Mark) is interposed between the first and second glass sheets 4 and 6. As a result, a thin clearance of about 10 microns is defined between the first and second
15 glass sheets 4 and 6. The clearance is filled with a liquid crystal 10. One surface of the first glass sheet 4, namely the surface opposed to the second glass sheet 6 is formed with transparent segment electrodes 12 in a desired pattern. Each electrode 12 has a lead wire 14 connected thereto and
20 extending to a terminal 16. One surface of the second glass sheet 6, namely the surface opposed to the first glass sheet 4 is formed with a common

electrode 18. The common electrode 18 also has a lead wire connected thereto and extending to a terminal, though not shown. In addition, the electrodes 12 and 18 are made of a material which has good adhesion to glass sheets and high light transmissibility. For example, they are formed of a film of tin oxide.

The liquid crystal display unit shown in Fig. 1 is intended to be a liquid crystal display unit wherein twisted nematic liquid crystal molecules are used in a field effect mode. Fig. 2 diagrammatically shows the cross-sectional construction of such liquid crystal display unit wherein twisted nematic liquid crystal molecules are used in a field effect mode (such unit being hereinafter referred to as TN-FEM liquid crystal display unit). Referring to Figs. 1 and 2, the liquid crystal display element 2 is sandwiched between two polarizing sheets 20 and 22. Each of the polarizing sheets 20 and 22 is in the form of a triacetate sheet formed with a film having polarizing characteristics. In Figs. 1 and 2, the lower surface of the lower polarizing sheet 22 has a reflecting sheet 24 bonded thereto. That is, the liquid crystal display unit shown in these figures is of the reflection type. As for the reflecting sheet 24, e.g., an aluminum foil is used.

Fig. 2 illustrates the various elements on a nonactual scale to give a better understanding of the operation of the

TN-FEM liquid crystal display unit. For example, the thickness of the clearance filled with the liquid crystal 10 is shown in an exaggerated manner. In liquid crystal display units of the TN-FEM type, the liquid crystal molecules 26 are
5 disposed in a twisted state. In this state, if voltage is applied between a pair of opposed electrodes 12 and 18, the liquid crystal molecules are lined up in the direction of the electrostatic field, losing their optical activity. Fig. 2 shows voltage being applied between a pair of electrodes
10 12 and 18. When the electrostatic field disappears, the liquid crystal molecules 26 return to the twisted state.

Referring to Fig. 2, the principle of operation of the reflection type TN-FEM liquid crystal display unit will now be described. In addition, it is assumed that the respective
15 polarization axes of the polarizing sheets 20 and 22 are at right angles to each other. Unpolarized, external light falls from top of Fig. 20 upon the polarizing sheet 20, where it is polarized in a first direction. Therefore, the light incident upon the liquid crystal 10 has been polarized
20 in the first direction. If voltage has been applied between a pair of electrodes 12 and 18, then the liquid crystal molecules 26 in the corresponding region are in the illustrated state. Therefore, the light incident upon this portion passes through the liquid crystal 10 and falls upon the
25 lower polarizing sheet 22. The lower polarizing sheet 22

has an axis of polarization extending in a second direction which is at right angles to the first direction. As a result, the light which has been transmitted from the upper polarizing sheet 20 through the liquid crystal 10 is completely cut. Therefore, no light reaches the reflecting sheet 24 and no reflected light is obtained from the latter. Therefore, it looks dark. On the other hand, the light which falls upon other regions than that described above is gradually polarized by the corresponding liquid crystal molecules 26 which have optical activity, with the result that when passing through the crystal liquid 10, the light has been polarized through 90 degrees as compared with the incident light. Thus, the light incident upon the lower polarizing sheet 22 has been polarized in the second direction and passes through the polarizing sheet 22. Therefore, this light reaches the reflecting sheet 24, whereat it is reflected. The reflected light passes through the polarizing sheet 22 and in the liquid crystal 10 its direction of polarization is restored to the first direction. Therefore, the light passes through the upper polarizing sheet 20. Thus, it looks bright. On such principle of operation of the display unit, voltage-applied regions look dark, while those having no voltage applied thereto look bright, and the contrast between the dark and bright regions makes desired display possible.

Attention is invited to the cross-section of the liquid crystal display unit shown in Fig. 2. On the side of the liquid crystal display unit nearer to the viewer, the substantially light transmissible polarizing sheet 20 overlies the first glass sheet 4 which is a flat glass sheet. The surface conditions of the upper surface of the first glass sheet 4 and the lower surface of the polarizing sheet 20 will now be considered. The surfaces of the two sheets must be truly smooth and flat, for, if not, a problem illustrated in Fig. 3 would be caused.

Fig. 3 is an engineering model diagram for explanation of a problem with conventional liquid crystal display units. Referring to Fig. 3, the laminated state of a first glass sheet 4 and a polarizing sheet 20 is depicted. In such state, if the upper surface of the first glass sheet 1 and the lower surface of the polarizing sheet 20 do not form true planes, a clearance 28 is formed. It will be understood that the presence of such clearance 28 produces interference fringes known as Newton's rings. Such interference fringes are caused by the fact that an incident light ray 30 to be reflected by the lower surface of the polarizing sheet 20 and another incident light ray 32 to pass through the polarizing sheet 20 and be reflected by the upper surface of the first glass sheet 4 interfere with each other when so reflected. The formation of such interference fringes makes it difficult

for the viewer to see the display. Particularly in a display unit adapted to be viewed by help of general light coming from outside without using a particular light source as in a reflection type liquid crystal display unit, occurrence of interference fringes which hinder viewing must be prevented.

In order to prevent the formation of the clearance 28 shown in Fig. 3, the upper surface of the first glass sheet 4 and the lower surface of the polarizing sheet 20 must be truly flat. In this case, making the upper surface of the first glass sheet 4 is a machining problem and is not impossible if surface grinding is performed with the greatest care. Making the lower surface of the polarizing sheet 20 truly flat, however, involves not only a machining problem. That is, it is also related to the material of the polarizing sheet 20. For example, if the polarizing sheet 20 contains such a resin as triacetate, other problems than a machining one are liable to occur. Triacetate is hygroscopic and expands and contracts to a degree, so that it is liable to warp. Therefore, no matter how truly a flat surface may be formed in the machining step, it will eventually be deformed into a curved surface.

Fig. 4 shows the cross-sectional construction of a prior art liquid crystal display unit which is of interest to the present invention. In order to prevent occurrence of interference fringes described above, the polarizing sheet

20 may be spaced apart from the first glass sheet 4 sufficiently to preclude Newton's rings. Referring to Fig. 4, the polarizing sheet 20 is disposed on the first glass sheet 4 through a spacer 36. The spacer 36 is formed, e.g., by punching a plastic film about 0.5 mm thick in a picture frame fashion. This spacer 36 prevents contact between the polarizing sheet 20 and the first glass sheet 4. Therefore, the formation of interference fringes due to Newton's rings is advantageously prevented. In addition, the liquid crystal display unit shown in Fig. 4 is the same as the one shown in Figs. 1 and 2 except for the arrangement described above. Therefore, like parts are given like reference numerals and a description thereof will be omitted.

The construction shown in Fig. 4 has drawbacks. For example, if such display unit has a small or elongated display face, the spacer 36 can be advantageously used. More particularly, even a spacer having a thickness of only about 0.5 mm is effective to prevent contact between the polarizing sheet 20 and the first glass sheet 4 over the entire area regardless of a possible warp of the polarizing sheet 20. In the case of the display unit having a large display face, however, it is impossible for a spacer about 0.5 mm thick to prevent contact between the polarizing sheet 20 and the first glass sheet 4. Such display unit having a large display face is used, e.g., in a game device shown in

Fig. 5.

Referring to Fig. 5, a display face 40 is provided on top of the housing 38 of the game device. The size of the display face 40 could be inferred from the housing 38 measuring e.g., 5 cm long by 9 cm broad. Thus, it will be understood that the display face 40 shown therein is greater than the display face of at least a wristwatch, a portable small electronic computer or the like. If a liquid crystal display unit having a construction such as shown in Fig. 4 is used to form such display face 40, it is necessary to increase the thickness of the spacer 36 to provide a sufficient clearance between the polarizing sheet 20 and the first glass sheet 4 to ensure that the polarizing sheet 20 will not contact the first glass sheet 4 when warping. However, such increase in the thickness of the spacer 36 is not desirable since it increases the overall thickness of the liquid crystal display unit. It might be also contemplated to increase the thickness of the polarizing sheet 20, but this has the same drawback as described above. Therefore, it is desired to provide a liquid crystal display unit wherein contact between the polarizing sheet 20 and the first glass sheet 4 can be prevented irrespective of the size of the display face.

In addition, it has been understood that interference fringes which must be eliminated are caused by contact

between the polarizing sheet and the first glass plate, but their occurrences are not limited to the described particular combination. Generally, interference fringes can occur when two light transmissible sheets are combined. Therefore, any light transmissible sheet placed on a liquid crystal display element involves a similar problem of interference fringes.

Summary of the invention

According to the present invention, there is provided means for preventing contact between light transmissible sheets in the upper region of a liquid crystal display element with the object of preventing the occurrence of interference fringes in order to improve display quality, even in units with relatively large display areas.

The present invention thus provides a liquid crystal display unit comprising:

a liquid crystal display element comprising a first transparent sheet, a second transparent sheet opposed to said first transparent sheet and having a surface opposed to one surface of said first transparent sheet, a first electrode formed on one surface of said first transparent sheet, a second electrode formed on one surface of said second transparent sheet and opposed to said first electrode, and a liquid crystal placed in a space defined between said two transparent sheets;

a reflecting sheet disposed relative to the other side of said second transparent sheet;

at least one light transmissible sheet having substantial light transmissibility and disposed on the other side of said first transparent sheet; and

first means for forming a clearance between said first transparent sheet and said light transmissible sheet, said means having a predetermined height and being in the form of an array distributed over substantially the entire interface
5 between said light transmissible sheet and the first transparent sheet.

In a preferred embodiment of the invention, the light transmissible sheet is a polarizing sheet. This polarizing sheet preferably comprises a transparent resin sheet, and the
10 clearance forming means is in the form of projections formed on said resin sheet by embossing the latter. The formation of projections by directly embossing the polarizing sheet in this manner, though not readily foreseeable, provides an increased yield in the production of polarizing sheets. The
15 reason is as follows.

It has been considered that even slight scratches on polarizing sheets have delicate influences on the polarizing characteristics, and only flawless polarizing sheets have been passed as acceptable parts. However, it has been very difficult
20 to produce such polarizing sheets in a flawless condition and then produce liquid crystal display units without scratching such flawless sheets. As a result, the yield has been poor, resulting in increased manufacturing costs of acceptable parts. With such background, it would be impossible for a
25 plan suggest itself of embossing a polarizing sheet. However, geometrically distributed projections formed on a polarizing sheet by embossing are not clumsy since they are in orderly arrangement. Moreover, such arrangement rather gives an impression that the quality of the display section has been improved.
30 oved.

According to another preferred embodiment of the invention, said at least one light transmissible sheet comprises first and second light transmissible sheets to be successively placed on the liquid crystal display element. Preferably, 5 the first light transmissible sheet is formed of a transparent sheet which does not disturb polarized light (eg a cast film), while the second light transmissible sheet is formed of a polarizing sheet. The first light transmissible sheet, which is a usual transparent sheet, is formed on each 10 surface thereof with a plurality of geometrically distributed projections. As a result, a clearance is advantageously formed between the first light transmissible sheet and the liquid crystal display element and between the latter and the second light transmissible sheet. According to this embodi- 15 ment, since the polarizing sheet which constitutes the first light transmissible sheet is not subjected to any treatment, there is no danger of detracting from the polarizing characteristics of the polarizing sheet.

In another embodiment of the invention, the clearance forming 20 means is in the form of a mesh sheet. With this arrangement, it is possible to form a clearance in accordance with the thickness of the mesh sheet without detracting light transmissibility.

The invention will be further described by way of example, with reference to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS:

Fig. 1 is a perspective view of a typical liquid crystal
5 display unit shown disassembled;

Fig. 2 is a diagrammatic view of the cross-sectional construction of a TN-FEM liquid crystal display unit;

Fig. 3 is an optical model view for explanation of problems with conventional liquid crystal display units;

10 Fig. 4 is a cross-sectional view of a prior art liquid crystal display unit which is of interest to the present invention;

Fig. 5 is a perspective view showing the outline of a game device in which a liquid crystal display unit of the
15 present invention can be advantageously used;

Fig. 6 is a view of the cross-sectional construction of an embodiment of the invention shown disassembled;

Fig. 7 is a diagrammatic view of a device for embossing a polarizing sheet used in Fig. 6;

20 Fig. 8 is an enlarged plan view of a polarizing sheet embossed by the device shown in Fig. 7;

Fig. 9 is an enlarged section of a polarizing sheet embossed by the device shown in Fig. 7;

Fig. 10 is a view of the cross-sectional construction of another embodiment of the invention shown disassembled;

5 and

Fig. 11 is an exploded perspective view of a further embodiment of the invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS:

According to the invention, there is advantageously
10 provided a liquid crystal display unit having a relatively large display face such as the display face 40 of a game device shown in Fig. 5.

Referring to Fig. 6, the construction shown therein is substantially the same as the one shown in Fig. 4 except
15 that the polarizing sheet 20 and spacer 36 shown in Fig. 4 are replaced by a polarizing sheet 42. Like parts are given like reference numerals, and a description thereof will be omitted.

The polarizing sheet 42 is obtained, e.g., by forming a
20 polarizing film on a triacetate sheet. The polarizing sheet 42 is embossed, whereby at least one surface (in this example, the surface opposed to the first glass sheet 4) is formed with a plurality of projections 44.

Referring to Figs. 7 through 9, the polarizing sheet 42
25 is passed between a pair of rollers 46 and 48. One roller

46 is an embossing roller whose outer surface is formed with a plurality of relatively small quadrangular pyramidal projections geometrically distributed in an orderly arrangement. The roller 48 has its outer surface formed of relatively elastic paper. The rotative shaft of the paper roller 48 is at a fixed position, while the rotative shaft of the embossing roller 46 is supported in a lever 54 pivoted at a fulcrum 52. The lever 54 has a weight 56 suspended from the other end thereof. Thus, the embossing roller 46 exerts on the paper roller 48 a pressure correlated with the heaviness of the weight 56.

The embossing roller 46 and the paper roller 48 are synchronously driven for rotation in the direction of arrow. The polarizing sheet 42 is moved as held between the rollers 46 and 48. Preferably, the polarizing sheet 42 is heated immediately before it is inserted between the rollers 46 and 48. The heating temperature is, e.g., between 60°C and 100°C. Such heating has the advantage of increasing the embossing rate.

The polarizing sheet having passed between the rollers 46 and 48 has formed thereon quadrangular pyramidal projections 44 shown in Fig. 8. The projections 44 are orderly distributed in connection with a geometrical pattern. Further, the projections 44 are uniform in height. If, therefore, the polarizing sheet 42 thus obtained is disposed with its

projections 44 opposed to the first glass sheet 4, as shown in Fig. 6, then it is possible to form a clearance of uniform thickness between the polarizing sheet 42 and the first glass sheet 4. Preferably, the positions of the projections 44 on the polarizing sheet will be so selected as not to interfere with identification of a display pattern provided by the liquid crystal display element 2.

As best shown in Fig. 9, it often occurs that said embossing operation produces projections 58 also on the surface opposite to the one formed with the projections 44. This is believed to result from a reaction to the projections 50 on the embossing roller 46 being pressed against the polarizing sheet 42. There is a tendency that the projections 58 project the more, the more the height of the projections 50 on the embossing roller 46 exceeds the thickness of the polarizing sheet 42. If, therefore, suitable embossing conditions are selected, it is possible to form the projections 44 and 58 on the opposite surfaces of the polarizing sheet as the same time. This has an important meaning in an embodiment shown in Fig. 10 to be presently described.

Referring to Fig. 10, a liquid crystal display element 2, a polarizing sheet 22 and a reflecting sheet 24 are of the same construction as those shown in Fig. 6. Therefore, a description thereof will be omitted, and dissimilar arrangements alone will be described. Successively placed on the first

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glass sheet 4 of the liquid crystal element 32 are a transparent protective sheet 60 and a polarizing sheet 62. The protective sheet 60 is made of transparent resin or the like. The polarizing sheet 62 is of the same arrangement as the conventional polarizing sheet 20 (Figs. 1 through 4).

The protective sheet 60 is embossed in the manner described with reference to Figs. 7 through 9. The first glass sheet 4, which is a light transmissible sheet, and the polarizing sheet 62 are disposed on the opposite sides of the protective sheet 60. Therefore, there is a possibility of causing interference fringes between the protective sheet 60 and the polarizing sheet 62 and between the protective sheet 60 and the first glass sheet 4. Accordingly, clearances must be formed in these two interfaces to avoid interference fringes. To achieve this, it is preferable to provide projections distributed on the opposite surfaces of the protective sheet 60, whereby said two clearances can be formed at a time. The formation of such projections on the opposite surfaces of the protective sheet 60 can be achieved in a single process by the method described with reference to Fig. 9. Instead of this method, the one shown in Fig. 7 may be applied to the opposite surfaces of the protective sheets. According to such embodiment shown in Fig. 10, since no treatment is applied to the polarizing sheet 62, which is optically delicate, it is possible to expect the

ent effects of the invention without deteriorating the polarizing
a characteristics.

ion, Fig. 11 is an exploded perspective view of a further
embodiment of the invention. In this embodiment, a net 64
5 is used in lieu of the protective sheet 60 shown in Fig. 10.
The net 64 may be formed by weaving fine metal wire or
filaments of any other suitable material. Such net 64
uniformly defines a clearance correlated with the thickness
of the net 64 between the polarizing sheet 62 and the first
10 glass sheet 4. In addition, such net 64 may be bonded to
the lower surface of the polarizing sheet 62 before it is
combined with the liquid crystal display element 2.

The liquid crystal display unit of the invention described
so far can be advantageously applied to display devices
15 requiring a relatively large display face. For example, it
is possible to advantageously provide the display face 40 of
the game device shown in Fig. 5. In addition, the game
device shown in Fig. 5 is disclosed in "TIMEPIECE APPARATUS
HAVING GAME FUNCTION" by Gunpei Yokoi and one other filed
20 June , 1980 in the United States of America.

While the invention has been fully described with
reference to preferred embodiments thereof in connection
with the accompanying drawings, it will be possible for
those skilled in the art to modify the same without departing
25 from the spirit of the invention. It must be understood

that the invention is limited only by the attached claims.

For example, the way the projections disclosed as means for forming a clearance is not limited to the illustration and instead other geometrical distribution may be employed.

- 5 Further, the liquid crystal display element is not limited to the TN-FEM type and instead it may be of the dynamic scattering type.



Claims

1. A liquid crystal display unit comprising:

a liquid crystal display element comprising a first transparent sheet, a second transparent sheet opposed to said first transparent sheet and having a surface opposed to one surface of said first transparent sheet, a first electrode formed on one surface of said first transparent sheet, a second electrode formed on one surface of said second transparent sheet and opposed to said first electrode, and a liquid crystal placed in a space defined between said two transparent sheets;

a reflecting sheet disposed relative to the other side of said second transparent sheet;

at least one light transmissible sheet having substantial light transmissibility and disposed on the other side of said first transparent sheet; and

first means for forming a clearance between said first transparent sheet and said light transmissible sheet, said means having a predetermined height and being in the form of an array distributed over substantially the entire interface between said light transmissible sheet and the first transparent sheet.

2. A liquid crystal display unit as set forth in claim 1, wherein said at least one light transmissible sheet comprises a polarizing sheet.



3. A liquid crystal display unit as set forth in claim 2, wherein said first clearance forming means is in the form of a plurality of projections distributed on the surface of said polarizing sheet opposed to said first transparent sheet.
- 5 4. A liquid crystal display unit as set forth in claim 3, wherein said projections are formed by embossing said resin sheet.
5. A liquid crystal display unit as set forth in claim 2, 3 or 4, wherein said polarizing sheet comprises a transparent
10 resin sheet.
6. A liquid crystal display unit as set forth in claim 1, wherein said at least one light transmissible sheet includes first and second light transmissible sheets successively placed on said first transparent sheet.
- 15 7. A liquid crystal display unit as set forth in claim 6, which further comprises second means for forming a clearance between said first and second light transmissible sheets, said means having a predetermined height and being in the form of an array over substantially the entire interface
20 between said first and second light transmissible sheets.
8. A liquid crystal display unit as set forth in claim 7, wherein said first and second clearance forming means are in the form of a plurality of projections distributed on each surface of said first light transmissible sheet.



9. A liquid crystal display unit as set forth in claim 8, wherein said projections are formed by embossing said first light transmissible sheet.
10. A liquid crystal display unit as set forth in any one
5 of claims 6 to 9, wherein said first light transmissible sheet comprises a transparent resin sheet.
11. A liquid crystal display unit as set forth in any one of claims 6 to 10, wherein said first light transmissible
10 sheet is a transparent sheet for protecting said liquid crystal display element, and said second light transmissible sheet is a polarizing sheet.
12. A liquid crystal display unit as set forth in claim 1, wherein said first clearance forming means is in the form of a mesh sheet.
- 15 13. A liquid crystal display unit as set forth in any one of the preceding claims, which further comprises a polarizing sheet between said second transparent sheet and said reflecting sheet.
14. A liquid crystal display unit as set forth in any one
20 of the preceding claims, wherein said first and second transparent sheets are glass sheets.
15. A liquid crystal display unit as set forth in any one of the preceding claims, wherein said liquid crystal display element is one used for a display unit for a game device.



16. A liquid crystal display unit constructed and arranged as herein described with reference to the accompanying drawings.
17. A game device comprising a liquid crystal display unit 5 in accordance with any one of the preceding claims.

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