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(54) **LIQUID CRYSTAL DISPLAY**
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Description

Technical Field

[0001] The present invention relates to liquid crystal displays, and more particularly to segmented-pixel liquid crystal displays.

Background Art

[0002] Liquid crystal displays are flat displays that boast of high resolution, slimness, lightweight, low electric power consumption, and other advantages. In recent years, liquid crystal displays have seen improvement of display performance, improvement of fabrication capacity, and price competitiveness against other types of display, and accordingly they have been enjoying a rapidly growing market.

[0003] More recently, as the display quality of liquid crystal displays has been further improved, a problem in viewing angle characteristics has become apparent: the gamma characteristic varies between in orthogonal viewing and in oblique viewing; in other words, the gamma characteristic depends on the viewing angle. Here, the gamma characteristic denotes the dependence of display brightness on halftone levels. Thus, the fact that the gamma characteristic varies between in orthogonal viewing and in oblique viewing means that the way different halftone levels are displayed varies with the direction of viewing. This is annoying especially during the display of photograph images or of TV broadcasts, among others.

[0004] This problem of the viewing-angle dependence of the gamma characteristic is more remarkable in the multi-domain vertical alignment mode (MVA mode, as disclosed in JP-A-H11-242225) and in the axisymmetric aligned mode (ASM mode, as disclosed in JP-A-H10-186330) than in the in-plane switching mode (IPS mode, as disclosed in JP-B-S63-021907). On the other hand, with the IPS mode, it is more difficult, than with the MVA or ASM mode, to fabricate liquid crystal panels that offer high contrast in orthogonal viewing with satisfactory productivity. Hence, improvements addressing the viewing-angle dependence of the gamma characteristic are sought especially eagerly in MVA and ASM mode liquid crystal displays.

[0005] Under this background, the applicant of the present invention once proposed a technology whereby each pixel is segmented into two sub-pixels to which different voltages are applied to mitigate the viewing-angle dependence of the gamma characteristic (for example, in Patent Document 1 listed below).

Patent Document 1: JP-A-2004-078157, Claims
Patent Document 2: JP-A-H6-332009, Claims
Patent Document 3: JP-A-2004-062146, Embodiments

Disclosure of the Invention

Problems to be Solved by the Invention

[0006] Incidentally, the human eye tends to recognize pixels and borders by being attracted by light spots and areas. On the other hand, the recent trend toward increasingly large-screen liquid crystal displays has resulted in their having larger pixels than they have conventionally had. Under these circumstances, segmenting each pixel into two sub-pixels causes an inconvenience: as a result of the human eye recognizing pixels by tracing the lighter sub-pixel of each pixel, when an image with a straight border is displayed, the line of sight moves in a zigzag along the border, from one pixel with one halftone level to another having a different halftone level, often causing the viewer to perceive unsmoothness or unnatural hues. To be sure, in conventional liquid crystal displays, certain improvements have been made to address the viewing-angle dependence of the gamma characteristic; these improvements, however, are not quite satisfactory.

[0007] An object of the present invention is to provide a segmented-pixel liquid crystal display that does not produce unnaturalness even when displaying an image with a straight border and that offers a further improved gamma characteristic.

EP 0 669 549 discloses a liquid crystal display device, in which each pixel electrode of a liquid crystal display device is divided into a plurality of sub-pixel electrodes, which arc separated by a gap from each other, and a control capacitor electrode is provided opposite at least one of the sub-pixel electrode through a first insulating film. The control capacitor electrode has a region extending the entire length of the gap so that a drive voltage can be applied to liquid crystal in the gap. The control capacitor electrode forms a control capacitor connected in series to a liquid crystal capacitor formed by the above-said at least one sub-pixel electrode between it and a common electrode corresponding thereto. An additional capacitor electrode, which is opposite the said at least one sub-pixel electrode through a second insulating film, is formed, by which is formed an additional capacitor equivalently in parallel to the liquid crystal capacitor. In one embodiment the control capacitor electrode is disposed at the centre of the pixel region and a sub-pixel electrode is formed around the electrode overlapping its marginal portion.

Means for Solving the Problem

[0008] achieve the above object, according to the invention, there is provided a liquid crystal display according to claim 1.
[0009] From the viewpoint of further improving the gamma characteristic of the liquid crystal display, preferably, the ratio of an area of the bright sub-pixel electrode to an area of the dim sub-pixel electrode is in the range from 1 : 1 to 1 : 4.
[0010] From the viewpoint of preventing disturbed alignment in the liquid crystal layer and improving display quality, preferably, a metal layer is formed under a first contact hole via which a conductor electrode via which a display signal voltage is supplied connects to the bright sub-pixel electrode and under a second contact hole via which a conductor electrode via which a display signal voltage is supplied connects to the dim sub-pixel electrode, with an insulating layer (21b) interposed between the metal layer and the contact holes.
From the viewpoint of improving the aperture ratio, in the described embodiment the display includes a scanning line running between pixels in said other direction, a signal line running between pixels in said one direction and two auxiliary capacitance conductors running parallel to the scanning line between the bright sub-pixel electrode and each of said two parts of the dim sub-pixel electrode.
Preferably, there are provided scanning lines extending in the said other direction, signal lines extending in said one direction; and, for each pixel, at least two switching devices, one to supply a display signal voltage from the common signal line for the bright sub-pixel electrode, and another to supply a display signal voltage from the common signal line for the dim sub-pixel.

Brief Description of Drawings

[0011]

[Fig. 1] A plan view schematically showing the pixel structure in a liquid crystal display according to a background example.
[Fig. 2] A cross-sectional view along line A-A shown in Fig. 1.
[Fig. 3] A cross-sectional view along line B-B shown in Fig. 1.
[Fig. 4] A graph showing the viewing-angle dependence of the gamma characteristic in relation to the ratio of the aperture area of the middle sub-pixel to the ratio of the total aperture area of the side sub-pixels.
[Fig. 5] An enlarged plan view of the TFTs shown in Fig. 1
[Fig. 6] A circuit diagram electrically equivalent to the pixel structure in the liquid crystal display shown in Fig. 1.
[Fig. 7] A diagram schematically showing an example of the voltage waveforms with which the liquid crystal display according to the invention is driven.
[Fig. 8] A plan view schematically showing the pixel structure in a liquid crystal display according to another background example.
[Fig. 9] A plan view schematically showing the sub-Pixel electrodes used in an embodiment of the invention.

List of Reference Symbols

[0012]

10a, 10b, 10c sub-pixels
11a, 11b, 11c, 11d sub-pixel electrodes
12 scanning lines
13 signal lines
14O, 14E auxiliary capacitance conductors
15a, 15b, 15c TFTs (switching devices)
16a, 16b, 16c, 16d, 16e, 16a’, 16b’ extensions from drain electrodes
17a, 17b auxiliary capacitance electrodes
18a, 18b, 18c contact holes
19 metal layer
21 common electrode
141, 142, 141’, 142’ auxiliary capacitance common electrode
SC semiconductor layer
ClcO, $ClcE_1$, $ClcE_2$ liquid crystal capacitances

CcsO, CcsE auxiliarycapacitances

Best Mode for Carrying Out the Invention

[0013] Hereinafter, liquid crystal displays will be described with reference to the accompanying drawings. It should be understood that the embodiment is not meant to limit in any way how the invention is implemented.

[0014] Fig. 1 is a plan view schematically showing the pixel structure on the active matrix substrate of a liquid crystal display according to a background example, focusing on the pixel at line *n,* column *m*. Figs. 2 and 3 are cross-sectional view along lines A-A and B-B, respectively, shown in Fig. 1. Sub-pixel electrodes 11a-11 c are arranged next to one another in the column direction. A scanning line 12(*n*) is laid between pixels to run laterally as seen in Fig. 1; a signal line 13(*m*) is laid between pixels to run longitudinally as seen in Fig. 1. Two auxiliary capacitance conductors 140 and 14E are laid parallel to the scanning line 12(*n*), between the sub-pixel electrodes 11a, 11b, and 11c. As switching devices, TFTs 15a-15c are provided at the intersection between the scanning line 12(*n*) and the signal line 13(*m*).

[0015] A drain electrode extension 16a from the TFT 15a runs over the auxiliary capacitance conductor 14E to reach above the auxiliary capacitance conductor 140, where a portion of the drain electrode extension 16a faces, across an insulating layer (unillustrated), an auxiliary capacitance common electrode 141 formed integrally with the auxiliary capacitance conductor 140 to function as an auxiliary capacitance electrode 17a. In this auxiliary capacitance electrode 17a, a contact hole 18a is capacitance electrodes and the auxiliary capacitance common electrodes of the middle and side sub-pixels are disposed in reversed patterns. This allows the center sub-pixel to have the highest brightness.

[0016] Preferably, the scanning lines are laid between mutually adjacent pixels, and, in each pixel, the two auxiliary capacitance conductors are laid parallel to the scanning lines and between the sub-pixels. This helps improve the aperture ratio. Moreover, preferably, the conductor electrode via which the display signal voltage is supplied to the sub-pixel electrode of the middle sub-pixel is so formed as to cross the two auxiliary capacitance conductors. This helps cancel out the two parasitic capacitances formed where the conductor electrode crosses the auxiliary capacitance conductors, and thus helps improve image quality.

[0017] Preferably, a metal layer is formed under a contact hole via which the conductor electrode via which the display signal voltage is supplied connects to the sub-pixel electrode. This helps shield disturbed alignment in the liquid crystal layer, and thus helps improve image quality.

Brief Description of Drawings

[0018]

[Fig. 1] A plan view schematically showing the pixel structure in a liquid crystal display according to the invention.
[Fig. 2] A cross-sectional view along line A-A shown in Fig. 1.
[Fig. 3] A cross-sectional view along line B-B shown in Fig. 1.
[Fig. 4] A graph showing the viewing-angle dependence of the gamma characteristic in relation to the ratio of the aperture area of the middle sub-pixel to the ratio of the total aperture area of the side sub-pixels.
[Fig. 5] An enlarged plan view of the TFTs shown in Fig. 1.
[Fig. 6] A circuit diagram electrically equivalent to the pixel structure in the liquid crystal display shown in Fig. 1.
[Fig. 7] A diagram schematically showing an example of the voltage waveforms with which the liquid crystal display according to the invention is driven.
[Fig. 8] A plan view schematically showing the pixel structure in another liquid crystal display according to the invention.
[Fig. 9] A plan view schematically showing another example of the sub-pixel electrodes usable in the invention.

List of Reference Symbols

[0019]

10a, 10b, 10c sub-pixels
11a, 11b, 11c, 11d sub-pixel electrodes
12 scanning lines
13 signal lines
14O, 14E auxiliary capacitance conductors
15a, 15b, 15c TFTs (switching devices)
16a, 16b, 16c, 16d, 16e, 16a', 16b' extensions from drain electrodes
17a, 17b auxiliary capacitance electrodes

18a, 18b, 18c contact holes
19 metal layer
21 common electrode
141, 142, 141', 142' auxiliary capacitance common electrode
SC semiconductor layer
ClcO, $ClcE_1$, $ClcE_2$ liquid crystal capacitances
CcsO, CcsE auxiliary capacitances

Best Mode for Carrying Out the Invention

[0020] Hereinafter, liquid crystal displays embodying the present invention will be described with reference to the accompanying drawings. It should be understood that these embodiments are not meant to limit in any way how the invention is implemented.

[0021] Fig. 1 is a plan view schematically showing the pixel structure on the active matrix substrate of a liquid crystal display according to the invention, focusing on the pixel at line n, column m. Figs. 2 and 3 are cross-sectional view along lines A-A and B-B, respectively, shown in Fig. 1. Sub-pixel electrodes 11a-11c are arranged next to one another in the column direction. A scanning line 12(*n*) is laid between pixels to run laterally as seen in Fig. 1; a signal line 13(*m*) is laid between pixels to run longitudinally as seen in Fig. 1. Two auxiliary capacitance conductors 14O and 14E are laid parallel to the scanning line 12(*n*), between the sub-pixel electrodes 11a, 11b, and 11c. As switching devices, TFTs 15a-15c are provided at the intersection between the scanning line 12(*n*) and the signal line 13(*m*).

[0022] A drain electrode extension 16a from the TFT 15a runs over the auxiliary capacitance conductor 14E to reach above the auxiliary capacitance conductor 14O, where a portion of the drain electrode extension 16a faces, across an insulating layer (unillustrated), an auxiliary capacitance common electrode 141 formed integrally with the auxiliary capacitance conductor 14O to function as an auxiliary capacitance electrode 17a. In this auxiliary capacitance electrode 17a, a contact hole 18a is formed to connect the drain electrode extension 16a to the sub-pixel electrode 11 a. Likewise, drain electrode extensions 16b and 16c merge together on the way to reach above the auxiliary capacitance conductor 14E, where a portion of the drain electrodes extension 16b and 16c faces, across an insulating layer (unillustrated), an auxiliary capacitance common electrode 142 formed integrally with the auxiliary capacitance conductor 14E to function as an auxiliary capacitance electrode 17b. In this auxiliary capacitance electrode 17b, a contact hole 18b is formed to connect the drain electrodes extension 16b and 16c to the sub-pixel electrode 11b (see Fig 2). From the auxiliary capacitance electrode 17b, a drain electrode extension 16d further extends to run over the auxiliary capacitance conductor 14O to reach above the sub-pixel electrode 11c, where the drain electrode extension 16d connects via a contact hole 18c to the sub-pixel electrode 11c (see Fig. 3).

[0023] As shown in Figs. 2 and 3, under the contact hole 18b, the auxiliary capacitance conductor 14E is formed with an insulating layer 21a interposed in between; under the contact hole 18c, a metal layer 19 forming an island is formed with an insulating layer 21b interposed in between. This helps shield disturbed alignment in the liquid crystal layer, and thus helps improve image quality. The insulating layer 21a, which forms an auxiliary capacitance, and the insulating layer 21b under the contact hole 18c are each, for example, the gate insulating layer of a TFT.

[0024] With this structure, an equal effective voltage is applied to the sub-pixel electrodes 11b and 11c. Moreover, as will be described later, by supplying different auxiliary capacitance common voltages to the two auxiliary capacitance conductors 14O and 14E, it is possible to make the effective voltage at the sub-pixel electrode 11 a higher than the effective voltage at the sub-pixel electrodes 11b and 11c. Thus, it is possible to make the brightness level of a sub-pixel 10a higher than the brightness level of sub-pixels 10b and 10c. This helps eliminate unnaturalness as is conventionally produced when an image with a straight border is displayed, and also helps further mitigate the viewing-angle dependence of the gamma characteristic.

[0025] Through experiments, the applicant has come to know that an effective way to mitigate the viewing-angle dependence of the gamma characteristic is to reduce the proportion of the aperture area of the sub-pixel 10a that has a higher brightness level. In Fig. 4 is a graph showing the viewing-angle dependence in relation to the ratio of the aperture area of the higher-brightness sub-pixel 10a (indicated as "high" in the graph) to the total aperture area of the lower-brightness sub-pixels 10b and 10c (indicated as "low" in the graph). In Fig. 4, the horizontal axis represents the halftone level observed in orthogonal viewing, and the vertical axis represents the viewing-angle dependence of the gamma characteristic observed at different aperture area ratios, namely "with no pixel segmentation", "at a high-to-low ratio of 1:1 ", "at a high-to-low ratio of 1:3", and "at a high-to-low ratio of 1:4", by using the halftone level observed in oblique viewing from 45 degrees upward, downward, leftward, and rightward. This graph shows the following. As the proportion of the "high" brightness aperture area decreases, the gamma characteristic becomes increasingly close to the ideal straight line, becoming closest to it when the high-to-low ratio is 1 : 3; as the "high" brightness aperture area further decreases (to 1:4), the gamma characteristic then becomes increasingly less close to the ideal straight line. Hence, the ratio of the aperture area of the higher brightness sub-pixel 10a to the total aperture area of the lower sub-pixels 10b and 10c is preferably in the range between 1 : 1 to 1 : 4, and further preferably in the range between 1 : 2.5 to 1 : 3.5. Incidentally, the relationship between, on one hand, the just mentioned viewing-angle dependence of the gamma characteristic in relation to the aperture area ratio and, on the other hand, transmissivity is explained in JP-A-2004-062146, a prior application by the same applicant.

[0026] Moreover, the ratio between the aperture areas of the sub-pixels 10b and 10c is preferably in the range from 1 : 1 to 1 : 4, and further preferably in the range from 1 : 1 to 1 : 2. With the higher-brightness sub-pixel located in a deviated position, an evaluation of the display quality of an image of a person revealed an unintended change in color at the border of a skin-color area, like where a skin-color area, such as representing the chin of a person, overlaps a single-color background, such as clothes. This phenomenon was alleviated when the higher-brightness sub-pixel was located closer to the center.

[0027] In the arrangement under discussion, TFTs (thin-film transistors) are used as switching devices. Fig. 5 is an enlarged view of the TFTs in the liquid crystal display shown in Fig. 1. On top of a gate electrode G formed as part of the scanning line 12(*n*), a gate insulating film (unillustrated) is formed, and, further on top, a semiconductor layer SC is formed. On top of this semiconductor layer SC, a source electrode S and three drain electrodes D_1, D_2, and D_3 are formed. From the source electrode S, a plurality of extensions extend substantially in the shape of a comb. The drain electrodes D_1, D_2, and D_3 are formed between these extensions, with a predetermined distance secured from them.

[0028] Forming the three TFTs 15a to 15c on a single semiconductor layer SC in this way helps give the pixel a larger aperture ratio than when they are formed separately. Moreover, by varying the width W and length L of the channel regions formed between the extensions of the source electrode S and the drain electrodes D_1, D_2, and D_3, it is possible to supply the desired current that suits the capacity of the pixel.

[0029] There are no particular restrictions on the shapes of the source electrode S, the drain electrodes D_1, D_2, and D_3, and the semiconductor layer SC; these may be given any shapes so long as no current leakage occurs. As switching devices, any conventionally known switching devices other than TFTs may instead be used, such as MIMs (metal insulator metals).

[0030] Fig. 6 is a schematic diagram showing a circuit equivalent to the liquid crystal display shown in Fig. 1. In this diagram, the liquid crystal capacitance corresponding to the sub-pixel 10a is indicated as ClcO, and the liquid crystal capacitances corresponding to the sub-pixels 10b and 10c is indicated as $ClcE_1$ and $ClcE_2$. The liquid crystal capacitances ClcO, $ClcE_1$, and $ClcE_2$ of the sub-pixels 10a, 10b, and 10c are formed by the sub-pixel electrodes 11 a to 11 c, a common electrode 21, and the liquid crystal layer lying in between. The sub-pixel electrodes 11a to 11c are connected via the TFTs 15a to 15c to the signal line 13(*m*), and the gate electrode G (shown in Fig. 5) of the TFTs is connected to the scanning line 12(*n*)

[0031] A first auxiliary capacitance provided for the sub-pixel 10a and a second auxiliary capacitance provided for the sub-pixels 10b and 10c are indicated as CcsO and CscE in Fig. 6. The auxiliary capacitance electrode 17a of the first auxiliary capacitance CcsO is connected via the drain electrode extension 16a to the drain of the TFT 15a. The auxiliary capacitance electrode 17b of the second auxiliary capacitance CcsE is connected via the drain electrode extensions 16b and 16c to the drains of the TFTs 15b and 15c. The auxiliary capacitance electrodes 17a and 17b may be connected in any manner other than specifically illustrated, so long as they are electrically so connected as to receive voltages equal to those applied to the corresponding sub-pixel electrodes, namely the sub-pixel electrode 11a and the sub-pixel electrodes 11b and 11c, respectively; that is, the sub-pixel electrode 11a and the sub-pixel electrodes 11b and 11c have simply to be electrically connected, either directly or indirectly, to the corresponding auxiliary capacitance electrodes 17a and 17b, respectively.

[0032] The auxiliary capacitance common electrode 141 of the first auxiliary capacitance CcsO is connected to the auxiliary capacitance conductor 14O, and the auxiliary capacitance common electrode 142 of the second auxiliary capacitance CcsE is connected to the auxiliary capacitance conductor 14E. With this structure, it is possible to apply different auxiliary capacitance common voltages to the auxiliary capacitance common electrodes 141 and 142 of the first and second auxiliary capacitance CcsO and CcsE, respectively. As will be described later, how the auxiliary capacitance common electrodes 141 and 142 are connected to the first and second auxiliary capacitances CcsO and CcsE is selected to suit the driving method adopted (for example, dot-inversion driving).

[0033] Next, a description will be given of the mechanism by which different voltages are applied, on one hand, to the sub-pixel electrode 11 a and, on the other hand, to the sub-pixel electrodes 11b and 11 c.

[0034] Fig. 7 shows the voltage waveforms of the signals fed to the pixel (n, m) shown in Fig. 6; that is, it shows how those signals change their voltage levels over time. In Fig. 7, at (a) is shown the waveform of the display signal voltage (halftone signal voltage) Vs supplied to a signal line 13; at (b) is shown the waveform of the scanning signal voltage Vg supplied to a scanning line 12; at (c) and (d) are shown the waveforms of the auxiliary capacitance common voltages VcsO and Vcse supplied to the auxiliary capacitance conductors 14O and 14E, respectively; at (e) and (f) are shown the waveforms of the voltages VlcO and VlcE applied to the liquid crystal capacitances $ClcE_1$ and $ClcE_2$ of the sub-pixel 10a and of the sub-pixels 10b and 10c, respectively.

[0035] The driving method shown in Fig. 7 is adopted when the invention is applied to a liquid crystal display that operates on a "1H dot inversion plus frame inversion" basis.

[0036] The display signal voltage Vs applied to a signal line 13 inverts its polarity every time a scanning line is selected (every 1H); in addition, between every two mutually adjacent signal lines, the display signal voltages applied thereto have opposite polarities (1H inversion). Moreover, the display signal voltages Vs on all the signal lines 13 invert their polarities every frame (frame inversion).

[0037] In the example under discussion, the cycle at which the auxiliary capacitance common voltages VcsO and Vcse invert their polarities is 2H; moreover, the auxiliary capacitance common voltages VcsO and Vcse have waveforms such that they have an equal amplitude and are 180 degrees out of phase with each other. The cycle at which the auxiliary capacitance common voltages VcsO and Vcse invert their polarities may be longer than 2H.

[0038] Now, with reference to Fig. 7, a description will be given of why the voltages VlcO and VlcE applied to the liquid crystal capacitance ClcO and to the liquid crystal capacitances $ClcE_1$ and $ClcE_2$ change their voltage levels as shown in Fig. 7.

[0039] At time T_1, the scanning signal voltage Vg turns from low (VgL) to high (VgH), and thereby brings the TFTs 15a to 15c into a conducting state, allowing the display signal voltage Vs on the signal line 13 to be applied to the sub-pixel electrodes 10a to 10c. The voltages applied across the liquid crystal capacitance ClcO and across the liquid crystal capacitances $ClcE_1$ and $ClcE_2$ are the differences between the voltages at the sub-pixel electrodes 11 a to 11c and the voltage (Vcom) at the common electrode 21. That is, $VlcO = VlcE_1 = VlcE_2 = Vs - Vcom$.

[0040] At time T_2, the scanning signal voltage Vg turns from high (VgH) to low (VgL, < Vs), and thereby brings the TFTs 15a to 15c into a non-conducting state (off state), electrically insulating all the sub-pixels and the auxiliary capacitances from the signal line 13. At this point, under the influence of the parasitic capacitances etc. of the TFTs 15a to 15c, the voltages at the sub-pixel electrodes 11 a to 11c momentarily fall by ΔVd, a phenomenon called "pulling".

[0041] At time T_3, the voltage VlcO at the liquid crystal capacitance ClcO changes under the influence of the voltage VcsO at the auxiliary capacitance common electrode 141 of the auxiliary capacitance CcsO, which electrode is electrically connected to the sub-pixel electrode 11 a of the liquid crystal capacitance ClcO. Moreover, the voltage VlcE at the liquid crystal capacitances $ClcE_1$ and $ClcE_2$ changes under the influence of the voltage VcsE at the auxiliary capacitance common electrode 142 of the second auxiliary capacitance CcsE, which electrode is electrically connected to the sub-pixel electrodes 11b and 11c of the liquid crystal capacitances $ClcE_1$ and $ClcE_2$.

[0042] Here, suppose that, at time T_3, the auxiliary capacitance common voltage VcsO increases by VcsOp > 0 and the auxiliary capacitance common voltage VcsE decreases by VcsEp > 0. That is, let the whole amplitude Vp - p of the auxiliary capacitance common voltage VcsO be VcsOp, and let the whole amplitude of the auxiliary capacitance common voltage VcsE be VceEp.

[0043] Moreover, let the total capacitance of the liquid crystal capacitance ClcO and the auxiliary capacitance CcsO be $C_{pix}O$, and let the total capacitance of the liquid crystal capacitances $ClcE_1$ and $ClcE_2$ and the auxiliary capacitance CcsE be $C_{pix}E$. Then,

$$VlcO = Vs - \Delta Vd + VcsOp\,(CcsO / C_{pix}O) - Vcom,$$

and

$$VlcE = Vs - \Delta Vd + VcsEp\,(CcsE / C_{pix}E) - Vcom.$$

[0044] Next, at time T_4, likewise under the influence of the voltages VcsO and VceE at the auxiliary capacitance common electrodes, the voltages VlcO and VlcE restore their voltages at time T_2.

$$VlcO = Vs - \Delta Vd - Vcom,$$

and

$$VlcE = Vs - \Delta Vd - Vcom.$$

[0045] These changes in voltage are repeated until the voltage Vg(n) turns to VgH in the next frame. As a result, the voltages VlcO and VlcE come to have different effective values. Specifically, let the effective value of the voltage VlcO be $VlcO_{rms}$, and let the effective value of the voltage VlcE be $VlcE_{rms}$, then

$$VlcO_{rms} = Vs - \Delta Vd + (1 / 2)\ VcsOp\ (CcsO / C_{pix}O) - Vcom,$$

and

$$VlcE_{rms} = Vs - \Delta Vd - (1 / 2)\ VcsEp\ (CcsE / C_{pix}E) - Vcom$$

$$(\text{provided that } (Vs - \Delta Vd - Vcom) >> VcsOp\ (CcsO / C_{pix}O),$$

and

$$(Vs - \Delta Vd - Vcom) >> VcsEp\ (CcsE / C_{pix}E)).$$

Hence, let the differences between these effective values be $\Delta Vlc = VlcO_{rms} - VlcE_{rms}$, then

$$\Delta Vlc = [VcsOp\ (CcsO / C_{pix}O) + VcsEp\ (CcsE / C_{pix}E)]\ /2.$$

In this way, by controlling the voltages applied to the auxiliary capacitance common electrodes 141 and 142 of the auxiliary capacitances CcsO and CcsE connected to the sub-pixel electrodes 11a to 11c, it is possible to apply different voltages to the sub-pixel electrode 11a and to the sub-pixel electrodes 11b and 11c.

[0046] By interchanging the voltages VcsO and VcsE, it is possible to give the voltage VlcO a smaller effective value and the voltage VlcE a greater effective value. Alternatively, also by reversing the combination of the auxiliary capacitance conductors 14O and 14E connected to the auxiliary capacitance common electrodes 141 and 142 of the auxiliary capacitances CcsO and CcsE, it is possible to give the voltage VlcO a smaller effective value and the voltage VlcE a greater effective value.

[0047] Here, since the driving method adopted involves frame inversion, in the next frame, the polarity of the voltage Vs is inverted, so that Vlc < 0. Even then, the same results as described above can be obtained by inverting the polarities of VcsO and VcsE in synchronism with frame inversion.

[0048] Moreover, here, since the driving method adopted involves dot inversion, between every two mutually adjacent signal lines 13 (*m*) and 13(*m*+1), the display signal voltages supplied thereto have opposite polarities. Thus, to make the effective voltage applied to the sub-pixel electrode 11a' always higher than the effective voltage applied to the sub-pixel electrodes 11b' and 11c' even in the pixel (*n*, *m*+1) in the next frame, as shown in Fig. 8, it is necessary that the auxiliary capacitance electrode 17a' of the sub-pixel electrode 11a' face the auxiliary capacitance common electrode 142' of the auxiliary capacitance conductor 14E and that the auxiliary capacitance electrode 17b' of the sub-pixel electrodes 11b' and 11c' face the auxiliary capacitance common electrode 141' of the auxiliary capacitance conductor 14O.

[0049] Here, in the pixel (*n, m*), since the drain electrode extension 16a of the sub-pixel electrode11 a crosses the two auxiliary capacitance conductors 140 and 14E, and the voltages applied to the auxiliary capacitance conductors

14O and 14E are 180 degrees out of phase with each other, the parasitic capacitances attributable to the drain electrode extension 16a and attributable to the auxiliary capacitance conductors 14O and 14E cancel out. On the other hand, in the pixel (*n*, *m*+1), although the drain electrode extension 16a' of the sub-pixel electrode 11a' does not need to cross the auxiliary capacitance conductor 14O, if the drain electrode extension 16a' of the sub-pixel electrode 11a' crosses only the auxiliary capacitance conductor 14E, the above-mentioned parasitic capacitances do not cancel out, and cause uneven display between the sub-pixel electrodes 11a and 11a'. To overcome this inconvenience, it is recommended that a drain electrode extension 16e be formed to extend further from the auxiliary capacitance electrode 17a' of the sub-pixel electrode 11a' to reach above the auxiliary capacitance conductor 14O so that together the drain electrode extensions cross the two auxiliary capacitance conductors 14O and 14E.

[0050] In the liquid crystal display described above, the sub-pixel electrodes 11 a to 11 c of the sub-pixels10a to 1 0c are formed separately from one another (see Fig. 1); it is however also possible, according to the present invention, to form the sub-pixel electrodes 11b and 11c as a single sub-pixel electrode 11d as shown in Fig. 9. Even in that case, just as described previously, by controlling the voltages applied to the auxiliary capacitance common electrodes 141 and 142 connected to the sub-pixel electrodes 11 a and 11d, it is possible to apply different voltages to the sub-pixel electrodes 11a and 11d. In the liquid crystal display described above, the sub-pixels are arranged next to one another in the column direction; needless to say, it is also possible to arrange them in the row direction instead.

[0051] The embodiment described above demonstrates that the present invention contributes to improving the gamma characteristic in normally black mode liquid crystal displays, in particular MVA mode liquid crystal displays. It should however be understood that the present invention finds application in any other type of liquid crystal display, among others, IPS liquid crystal displays.

Industrial Applicability

[0052] Liquid crystal displays according to the invention offer an improved gamma characteristic with less viewing angle dependence than ever, and do not produce unsmoothness or unnatural hues along a border even when an image with a straight border is displayed. This makes liquid crystal displays according to the invention suitable for use in, for example, television monitors with large screens.

Claims

1. A liquid crystal display having a plurality of pixels arrayed in a matrix, each pixel having a plurality of electrodes (11a, 11d) for applying an electric field to a liquid crystal layer,
wherein each pixel has two sub-pixels (10a, 10b/10c), the two sub-pixels having different brightness levels when the pixel as a whole is in a given middle halftone state, and
when, of said two sub-pixels, one having a higher brightness level is called a bright sub-pixel and one having a lower brightness level is called a dim sub-pixel,
the bright sub-pixel has a bright sub-pixel electrode (11a) and the dim sub-pixel has a dim sub-pixel electrode (11d), **characterized in that**
the dim sub-pixel electrode is formed of two parts located next to the bright sub-pixel electrode on opposite sides thereof in a first one of a column direction and a row direction, and a third part located next to the bright sub-pixel electrode on one side thereof in the other of said column direction and said row direction, and **in that**
the liquid crystal display includes a scanning line (12n) running between pixels in said other direction, a signal line (13m) running between pixels in said one direction and two auxiliary capacitance conductors (14O, 14E) running parallel to the scanning line between the bright sub-pixel electrode (11a) and each of said two parts of the dim sub-pixel electrode.

2. The liquid crystal display according to claim 1,
wherein a ratio of an area of the bright sub-pixel electrode to an area of the dim sub-pixel electrode is in a range from 1 : 1 to 1 : 4.

3. The liquid crystal display according to claim 1 or claim 2,
wherein a metal layer (14E, 140, 19) is formed under a first contact hole via which a conductor electrode via which a display signal voltage is supplied connects to the bright sub-pixel electrode and under a second contact hole via which a conductor electrode via which a display signal voltage is supplied connects to the dim sub-pixel electrode, with an insulating layer (21b) interposed between the metal layer and the contact holes.

4. A liquid crystal display according to claim 1, including scanning lines extending in the said other direction, signal lines extending in said one direction, and, for each pixel, at least two switching devices, one to supply a display signal voltage from the common signal line for the bright sub-pixel electrode, and another to supply a display signal voltage from the common signal line for the dim sub-pixel.

Patentansprüche

1. Flüssigkristallanzeige mit einer Mehrzahl von Pixeln, die in einer Matrix angeorcinet sind,
wobei jedes Pixel eine Mehrzahl von Elektroden (11a, 11d) zum Anlegen eines elektrischen Feldes an eine Flüssigkristallschicht aufweist,
wobei jedes Pixel zwei Teilpixel (10a, 10b/10c) aufweist, wobei die zwei Tellpixel unterschledliche Helllgkeitsstufen besitzen, wenn das Pixel als Ganzes sich in einem festgelegten mittleren Halbtonzustand befindet und
wenn von den zwei Tell pixeln eines mit einer höheren Helligkeilsstufe helles Teilpixel genannt wird und eines mit einer niedrigeren Helligkeitsstufe dunkles Teilpixel genannt wird,
das helle Teilpixel eine Elektrode (11a) für das helle Teilpixel und das dunkle Teilpixel eine Elektrode (11d) für das dunkle Teilpixel aufweist,
daduzch gekennzeichnet,
dass die Elektrode für das dunkle Teilpixel von zwei Teilen gebildet wird, die nahe zur Elektrode für das helle Teilpixel an gegenüberliegenden Seiten davon in einer ersten einer Spaltenrichtung und einer Zeilenrichtung angeordnet sind und von einem dritten Teil, der nahe der Elektrode für das helle Teilpixel an, einer Seite davon in der anderen der Spaltenrichtung und der Zeilenrichtung angeordnet ist, und
dass die Flüssigkristallanzeige eine Abtastleitung (12n), die zwischen Pixeln in der anderen Richtung verläuft, eine Signalleitung (13m), die zwischen Pixeln in der einen Richtung verläuft und zwei Hilfskapazltätsleiter (140. 14E) aufweist, die parallel zur Abtastleitung zwischen der Elektrode (11a) für das helle Teilpixel und jedem der beiden Teile der Elektrode für das dunkle Teilpixel verlaufen.

2. Flüssigkristallanzeige nach Anspruch 1,
wobei ein Verhältnis einer Fläche der Elektrode des hellen Teilpixels zu einer Fläche der Elektrode des dunklen Teilpixels im Bereich von 1:1 zu 1:4 liegt.

3. Flüssigkristallanzeige nach Anspruch 1 oder Anspruch 2.
wobei eine Metallschicht (14E, 14O, 19) unter einem ersten Kontaktloch ausgebildet ist, über welches eine Leiterelektrode, über welche eine Anzeigesigaxalspannung zugeführt wird, mit der Elektrode des hellen Teilpixels verbindet, sowie unter einem zweiten Kontaktloch, über welches eine Leiterelektrode, über welche eine Anzelgesignalspannung zugeführt wird, mit der Elektrode des dunklen Teilpixels verbindet, wobei eine Isolationsschicht (21b) zwischen der Metallschicht und den Kontaktlöchern vorgesehen ist.

4. Flüssigkristallanzeige nach Anspruch 1,
mit Abtastleitungen, die sich in der anderen Richtung erstrecken. Signalleitungen, die sich in der einen Richtung erstrecken, und für jedes Pixel mindestens zwei Schalteinrichtungen, eine zum Zuführen einer Anzelgesignalspannung von einer gemeinsamen Signalleitung für die Elektrode des hellen Teilpixels und eine andere zum Zuführen einer Anzeigesignalspannung von der gemeinsamen Signalleitung für das dunkle Teilpixel.

Revendications

1. Écran à cristaux liquides possédant plusieurs pixels organisés sous la forme d'une matrice, chaque pixel possédant plusieurs électrodes (11a, 11d) pour appliquer un champ électrique à une couche de cristaux liquides,
chaque pixel possédant deux sous-pixels (10a, 10b/10C), les deux sous-pixels possédant différents niveaux de luminosité lorsque le pixel, considéré dans son entier, se trouve dans un état de nuance médiane donné, et
dans lequel, concernant lesdits deux sous-pixels, l'un, possédant un niveau de luminosité supérieur, est baptisé sous-pixel lumineux, et l'autre, possédant un niveau de luminosité inférieur, est baptisé sous-pixel sombre,
le sous-pixel lumineux possède une électrode de sous-pixel lumineux (11a) et le sous-pixel sombre possède une électrode de pixel sombre (11d),
caractérisé en ce que
l'électrode de sous-pixel sombre est constituée de deux parties, situées à proximité de l'électrode de sous-pixel lumineux, sur ses côtés opposés, dans une première direction constituée d'une direction de colonne et d'une direction de rangée, et d'une troisième partie, située à proximité de l'électrode de sous-pixel lumineux, sur un côté de celle-

ci, dans l'autre direction constituée de ladite direction de colonne et de ladite direction de rangée, et **en, ce que** l'écran à cristaux liquides comporte une ligne de balayage (12n) reliant les pixels orientés selon ladite autre direction, une ligne de signal (13m) reliant les pixels orientés selon ladite direction et deux conducteurs de capacité auxiliaire (14O, 14E) reliant, en parallèle de la ligne de balayage, l'électrode de sous-pixel lumineux (11a) et chacune des deux parties de l'électrode de sous-pixel sombre.

2. Écran à cristaux liquides selon la revendication 1, dans lequel un rapport d'une surface de l'électrode de sous-pixel lumineux à une surface de l'électrode de sous-pixel sombre appartient à un intervalle compris entre 1 pour 1 et 1 pour 4.

3. Écran à cristaux liquides selon la revendication 1 ou la revendication 2,
dans lequel une couche de métal (14E, 14O, 19) est réalisée sous un premier trou de contact au travers duquel une électrode de conducteur, au travers de laquelle une tension de signal d'affichage est fournie, est reliée à l'électrode de sous-pixel lumineux, et sous un deuxième trou de contact au travers duquel une électrode de conducteurs, au travers de laquelle une tension de signal d'affichage est fournie, est reliée à l'électrode de sous-pixel sombre, une couche d'isolation (21b) étant interposée entre la couche de métal et les trous de contact.

4. Écran à cristaux liquides selon la revendication 1, comportant des lignes de balayage se prolongeant dans ladite autre direction, les lignes de signal se prolongeant dans ladite une direction, et, pour chaque pixels, au moins deux dispositifs de commutation, l'un pour fournir une tension de signal d'affichage à partir de la ligne de signal commune pour l'électrode de sous-pixel lumineux, et un autre pour fournir une tension de signal d'affichage à partir de la ligne de signal commune pour le sous-pixel sombre.

FIG.1

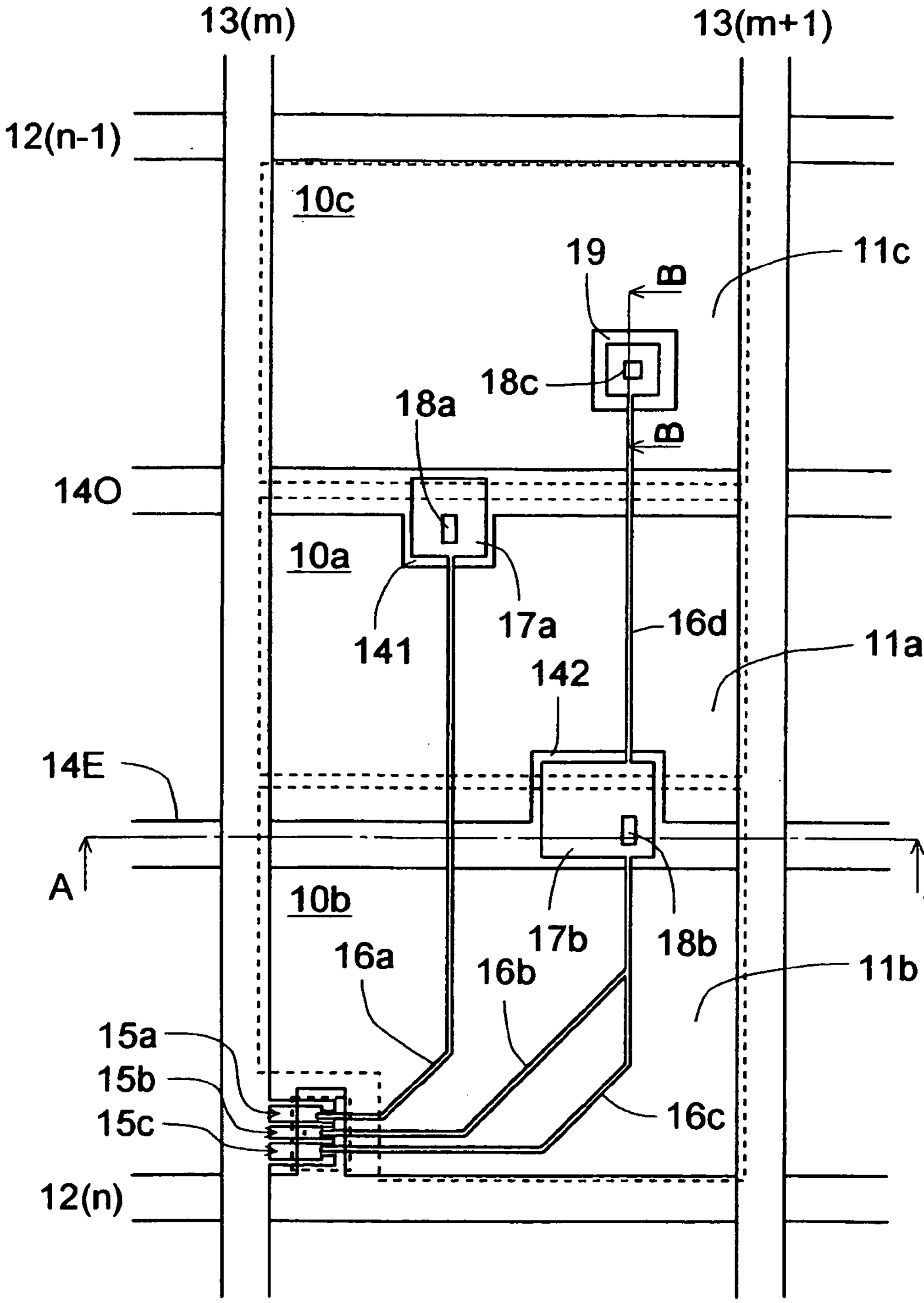

13(m)
13(m+1)
12(n-1)
10c
19
11c
B
18c
18a
B
14O
10a
141
17a
16d
11a
141
142
14E
A
A
10b
17b
18b
16a
16b
11b
15a
15b
15c
16c
12(n)

FIG.2

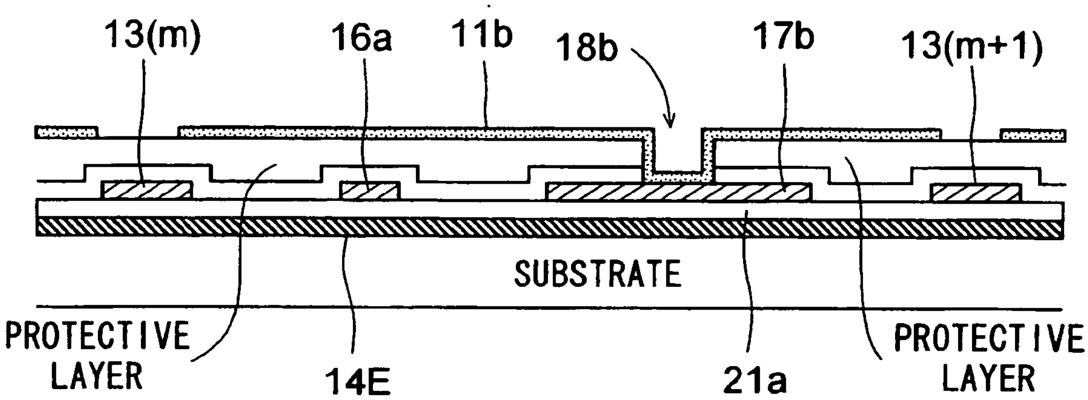


FIG.3

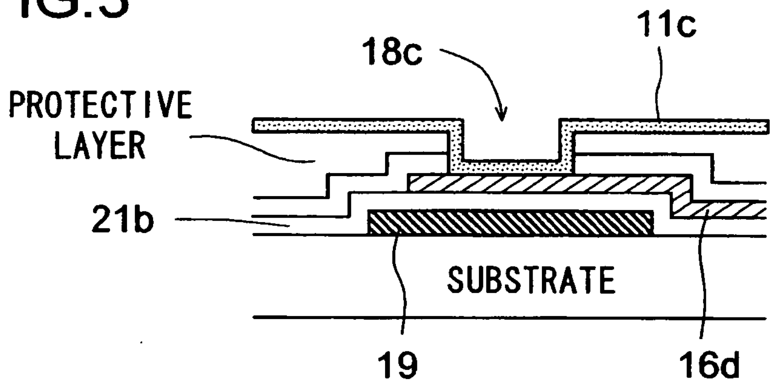


FIG.4

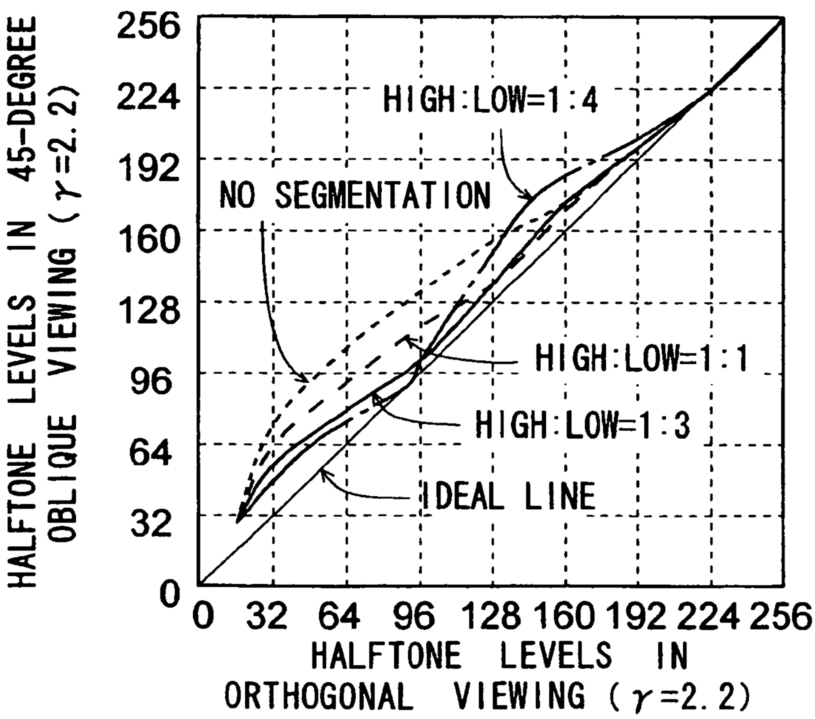


FIG.5

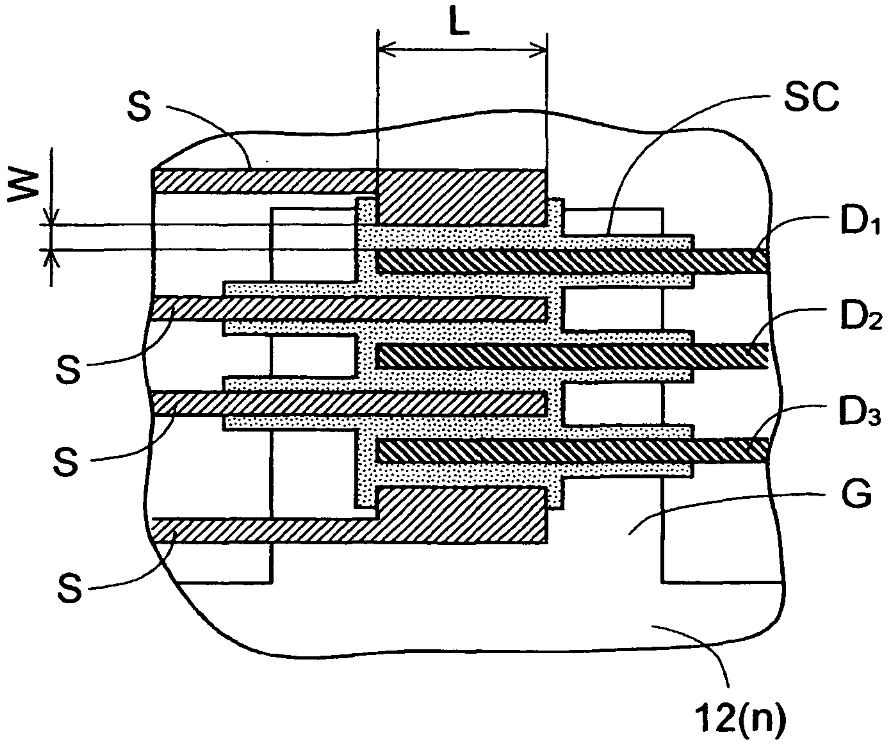


FIG.6

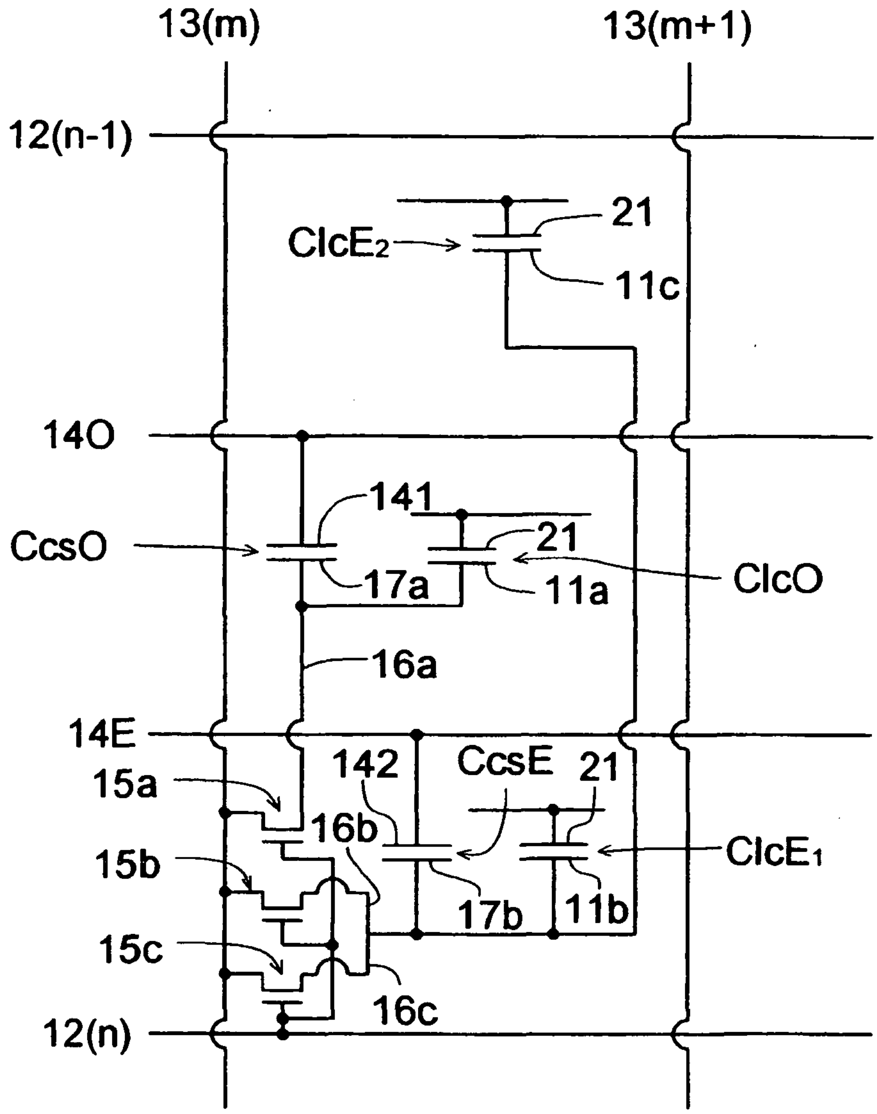

13(m)
13(m+1)
12(n-1)
ClcE2
21
11c
14O
141
CcsO
21
ClcO
17a
11a
16a
14E
15a
142
CcsE
21
16b
ClcE1
15b
17b
11b
15c
16c
12(n)

FIG.7

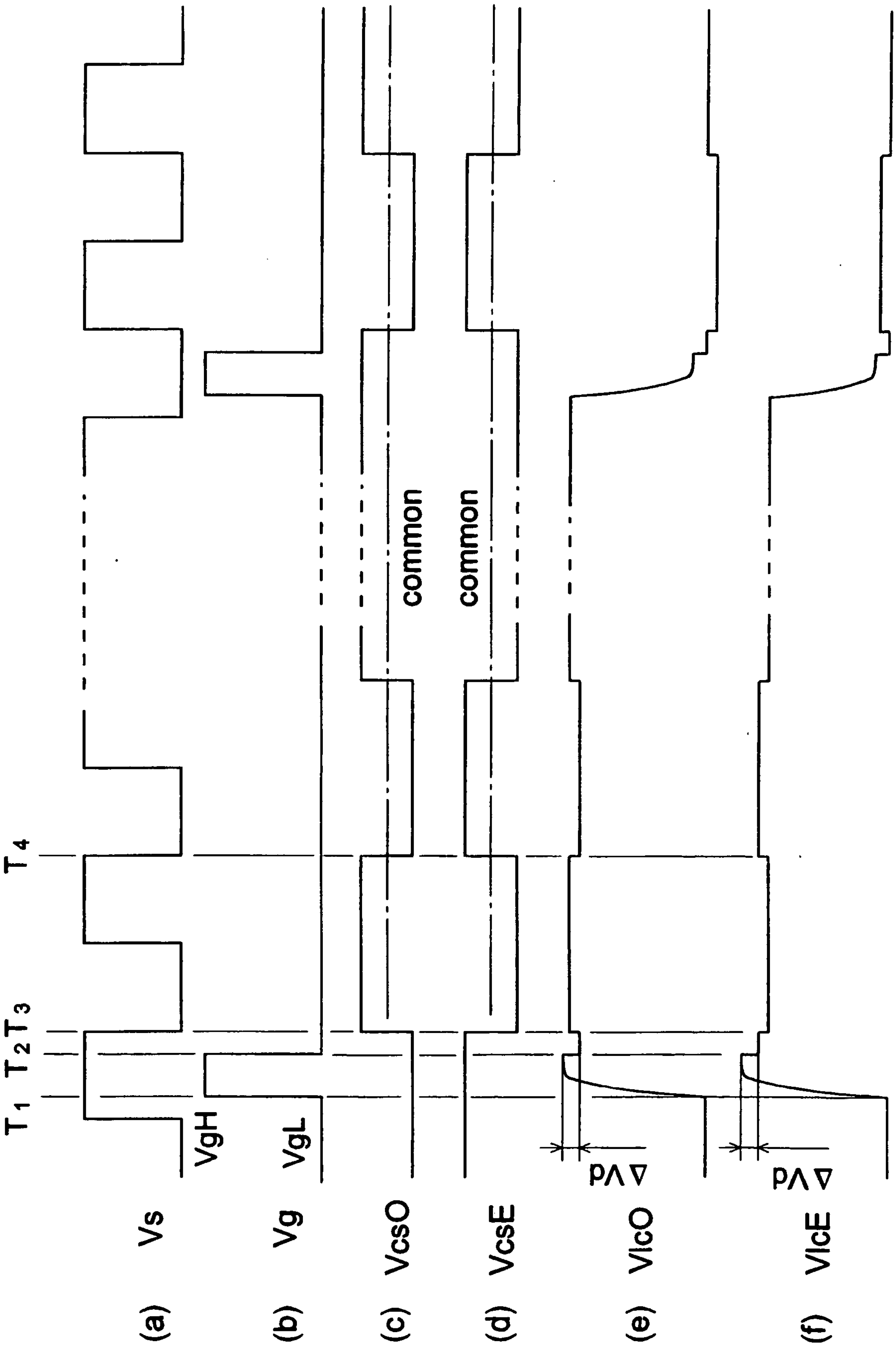

T1
T2
T3
T4
(a) Vs
(b) Vg
(c) VcsO
(d) VcsE
(e) VlcO
(f) VlcE
VgH
VgL
common
common
ΔVd
ΔVd

FIG.8

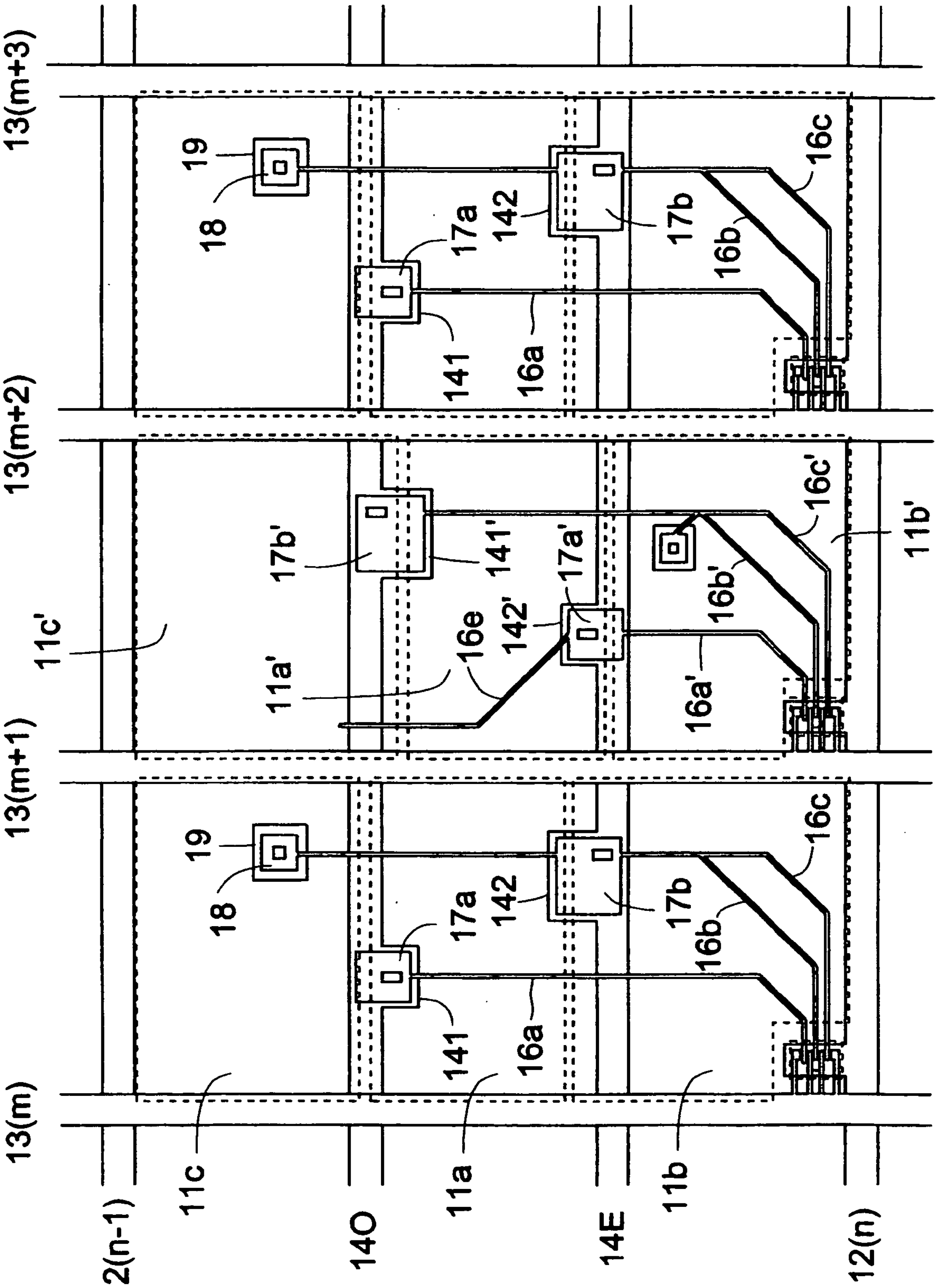
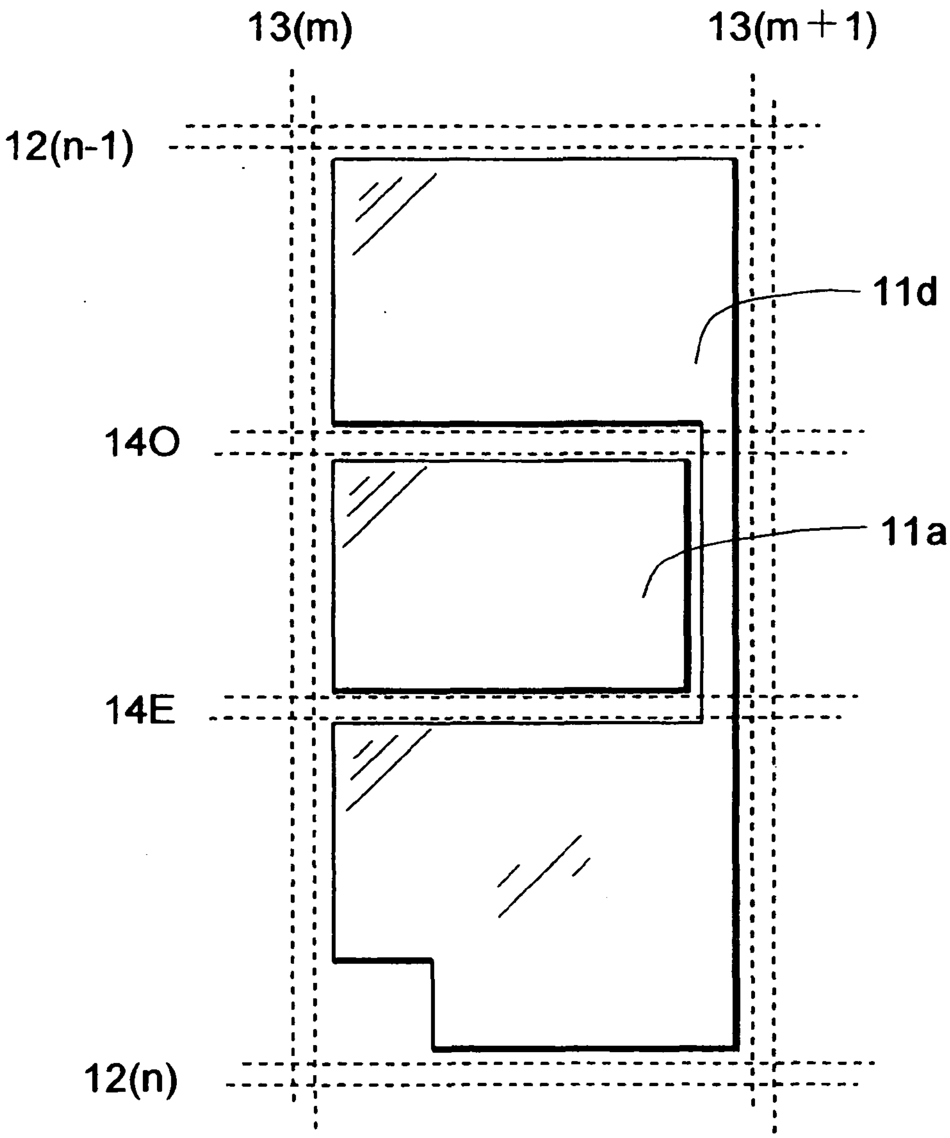

13(m)
13(m+1)
13(m+2)
13(m+3)
12(n-1)
11c
14O
11a
14E
11b
12(n)
18
19
17a
142
17b
141
16a
16b
16c
11c'
11a'
16e
142'
17a'
17b'
141'
16a'
16b'
16c'
11b'

FIG.9



REFERENCES CITED IN THE DESCRIPTION

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- JP H6332009 A **[0005]**
- JP 2004062146 A **[0005] [0025]**
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专利名称(译)	液晶显示器		
公开(公告)号	EP1798591B1	公开(公告)日	2013-07-24
申请号	EP2005790494	申请日	2005-10-04
[标]申请(专利权)人(译)	夏普株式会社		
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发明人	TAKEUCHI, MASANORI OHTSUBO, TOMOKAZU TSUBATA, TOSHIHIDE		
IPC分类号	G02F1/1343 G02F1/1362 G09F9/35 G09G3/20 G09G3/36		
CPC分类号	G02F1/13624 G02F1/134336 G02F1/136213 G02F2001/134345 G09G3/3648 G09G2300/0443 G09G2300/0447 G09G2300/0876 G09G2320/0276		
优先权	2004293218 2004-10-06 JP		
其他公开文献	EP1798591A1 EP1798591A4		
外部链接	Espacenet		

摘要(译)

分段像素液晶显示器具有多个像素，每个像素具有三个子像素10a-10c，即一个中间和两个侧子像素，在列方向或行方向上彼此相邻排列。当像素整体处于给定的中间半色调状态时，子像素10a-10c具有不同的亮度等级，并且中间子像素10a具有最高的亮度等级。这消除了当显示具有直边界的图像时传统上产生的不自然，并且进一步改善了伽玛特性。

$$Vlc0 = Vs - \Delta Vd + Vcs0p\,(Cs0 / C_{pix}0) - Vcom,$$