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Den Boer et al.

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(54) **OUTDOOR READABLE LIQUID CRYSTAL DISPLAY DEVICE**

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(52) **U.S. Cl.**
USPC **345/102**; 345/207; 349/68; 349/69; 362/97.3

(58) **Field of Classification Search**
USPC 345/87–104, 207; 349/68–69; 362/97.1–97.4
See application file for complete search history.

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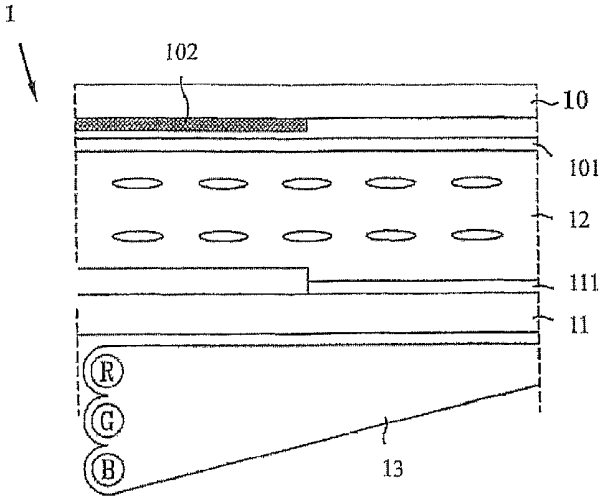
(57) **ABSTRACT**

An outdoor readable liquid crystal display device (**200**) includes a liquid crystal panel (**210**), a backlight device (**220**) and a light source control device. The backlight device (**220**) includes a plurality of red light emitting diodes (**220***r*), green light emitting diodes (**220***g*) and blue light emitting diodes (**220***b*). The light source control device is used to adjust the backlight device (**220**) based on the light intensity of ambient light. When the light intensity of ambient light is lower than a predetermined light intensity of the liquid crystal display device (**200**), the red light emitting diodes (**220***r*), the green light emitting diodes (**220***g*) and the blue light emitting diodes (**220***b*) of the backlight device (**220**) are sequentially energized to emit lights at a predetermined time lag. When the light intensity of ambient light is higher than the predetermined light intensity, the red light emitting diodes (**220***r*), the green light emitting diodes (**220***g*) and the blue light emitting diodes (**220***b*) of the backlight device (**220**) are energized to emit lights at the same time.

5 Claims, 6 Drawing Sheets



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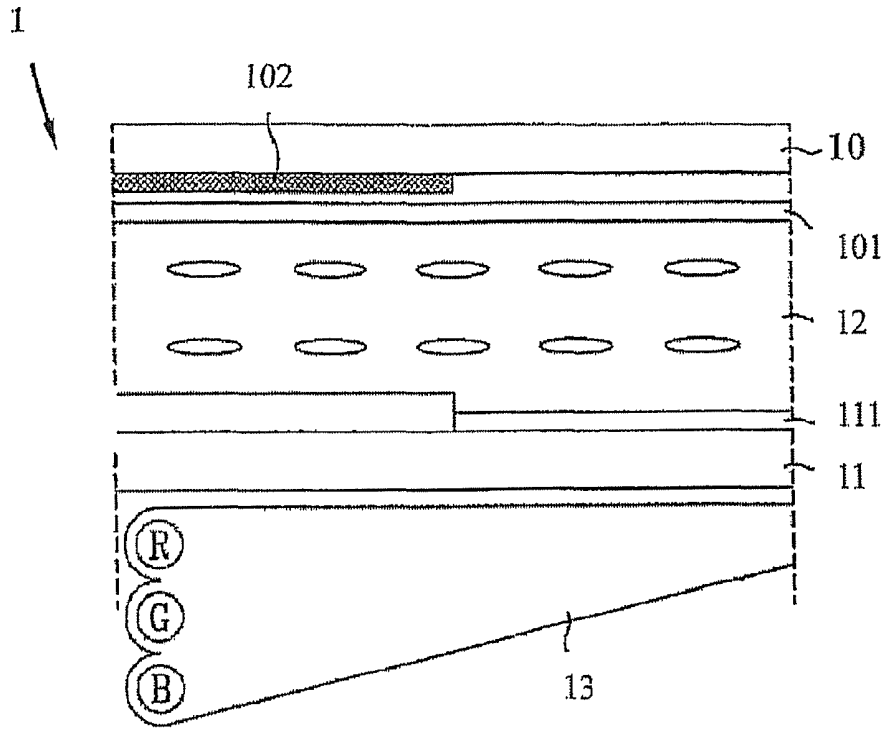


FIG. 1

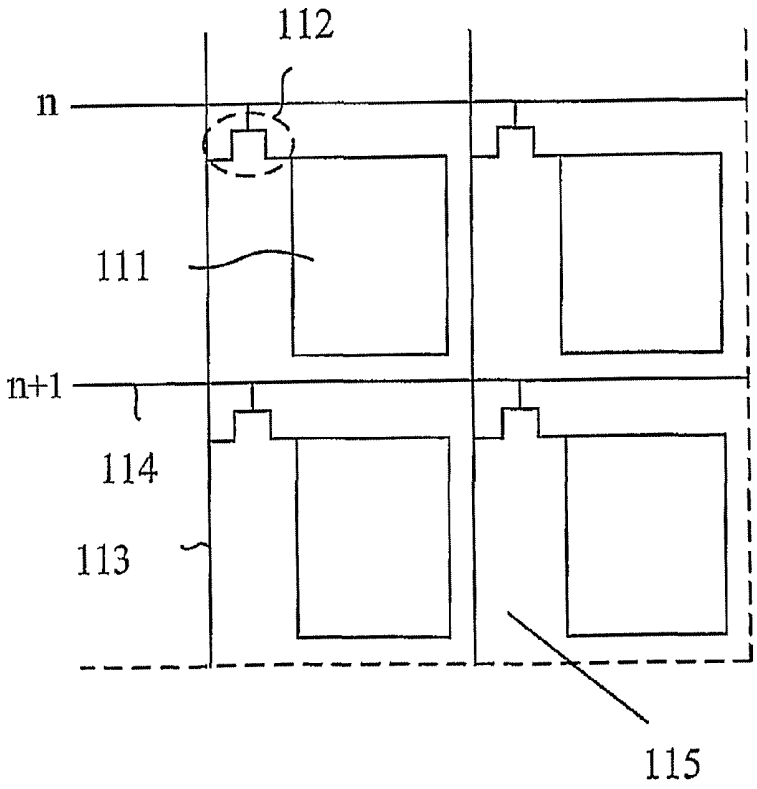


FIG. 2

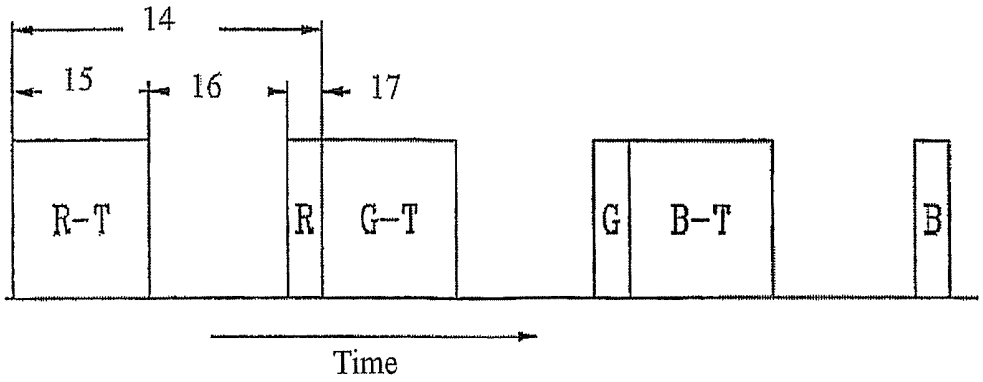


FIG. 3

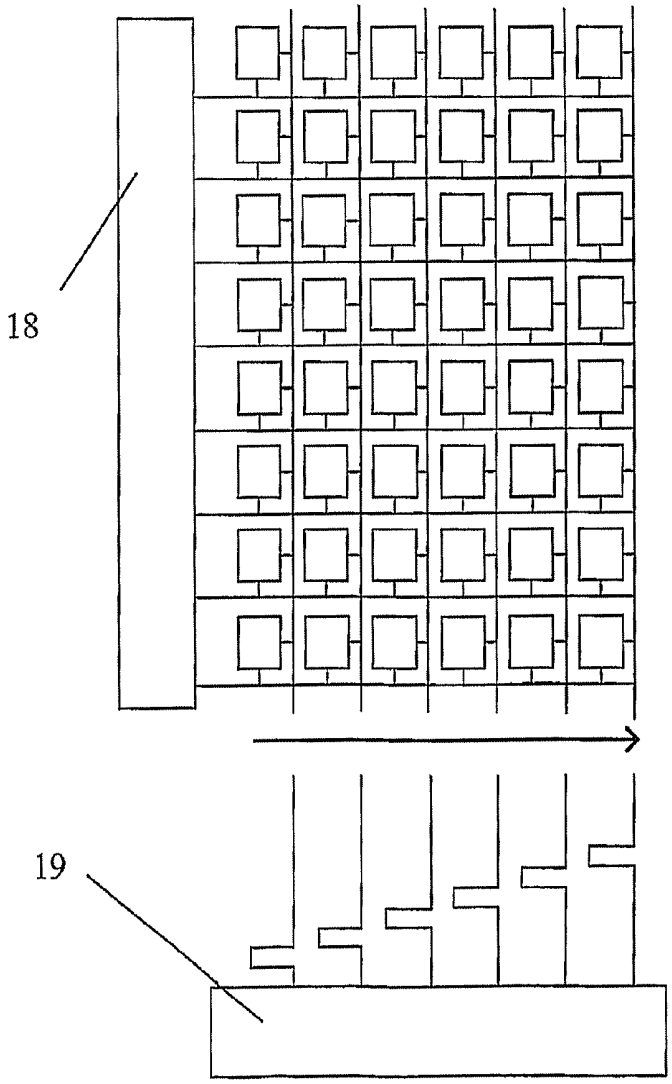


FIG. 4

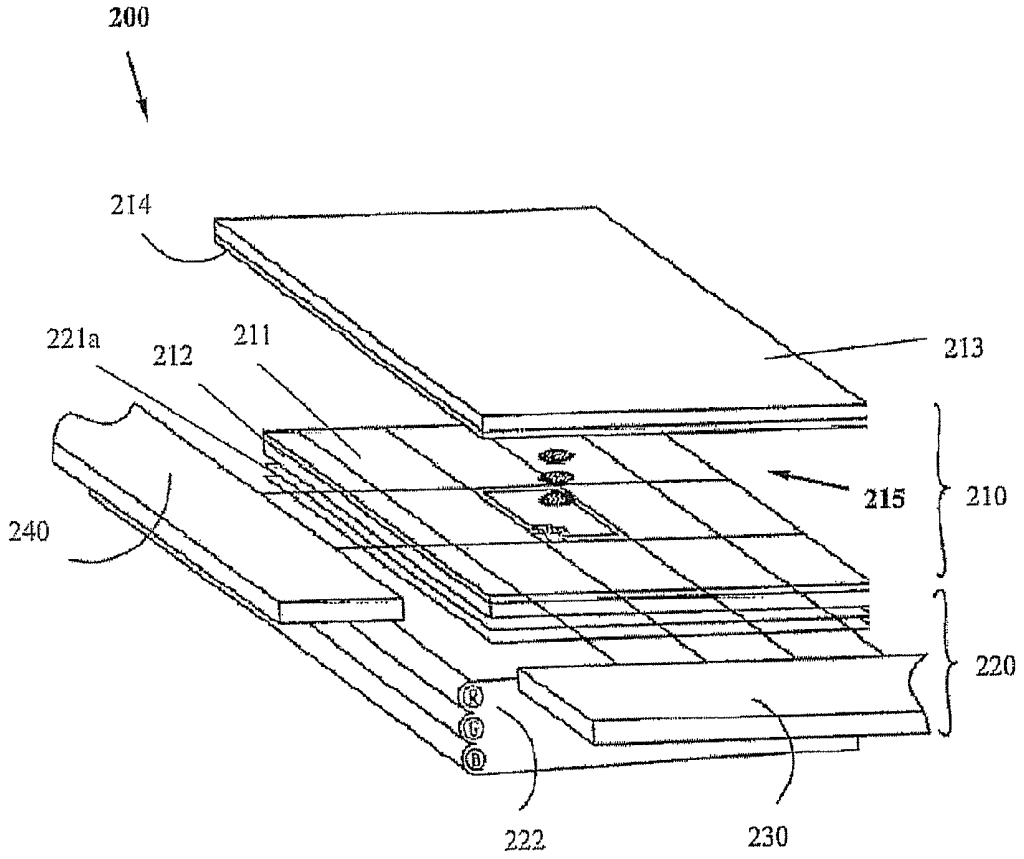
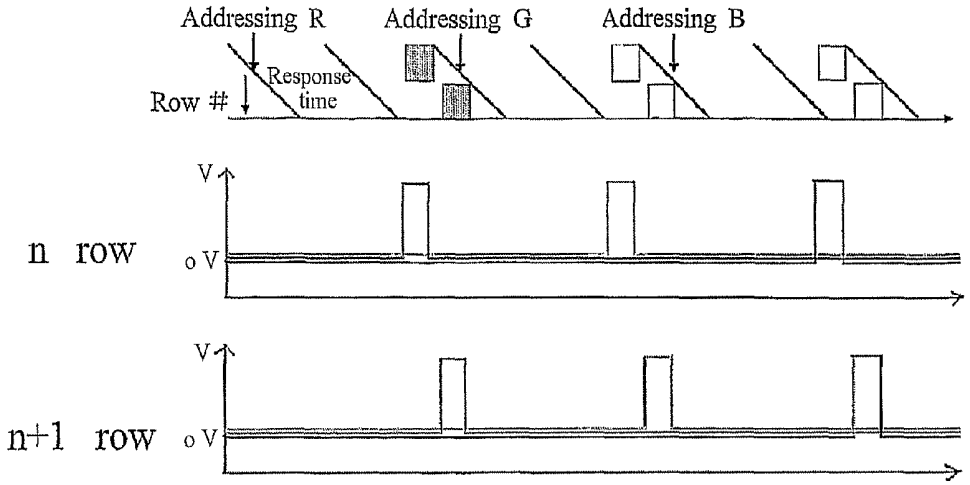
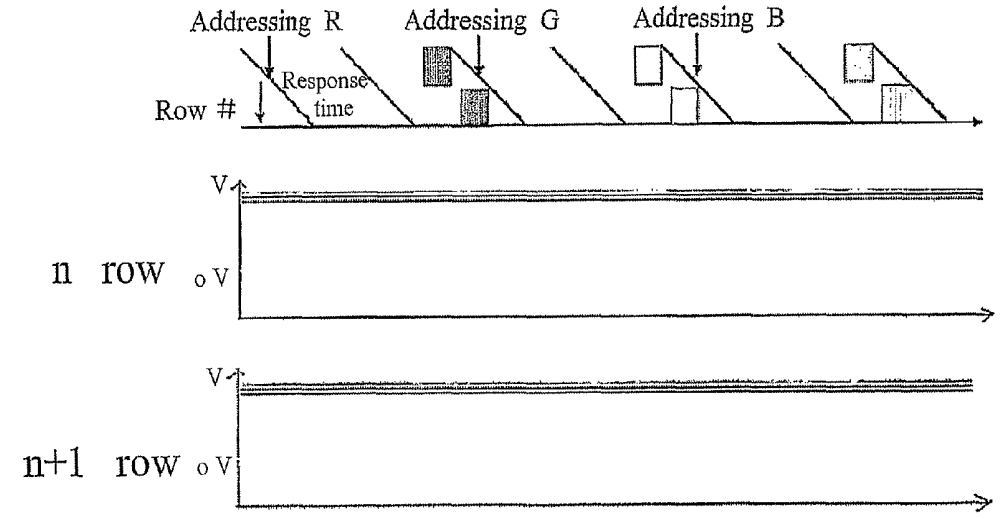


FIG. 5



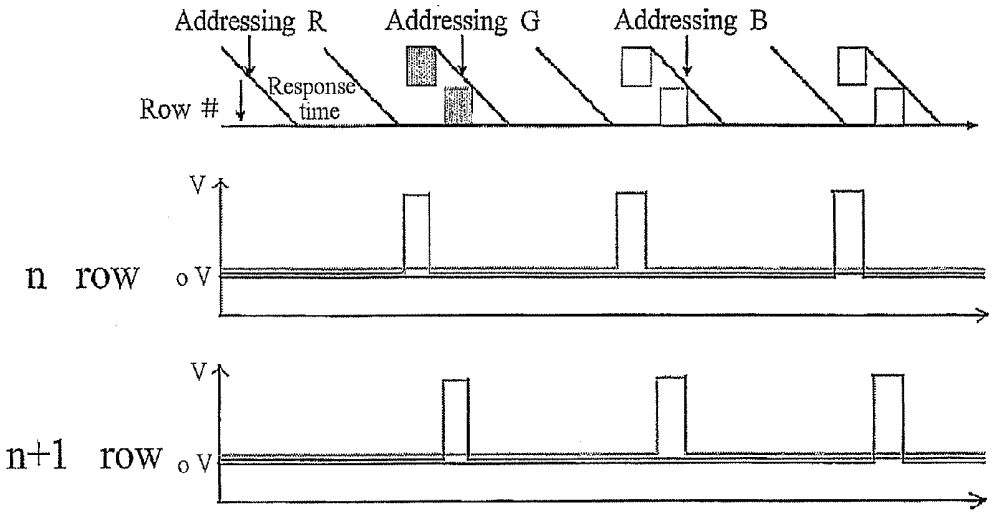
Backlight sequence with weak ambient light

FIG. 6 (a)



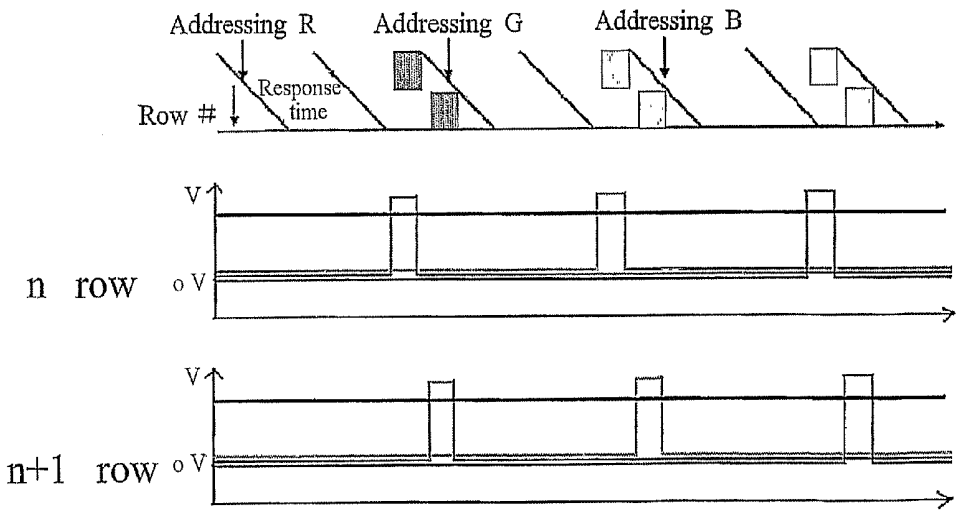
Backlight sequence with strong ambient light

FIG. 6 (b)



Backlight sequence with weak ambient light

FIG. 7 (a)



Backlight sequence with strong ambient light

FIG. 7 (b)

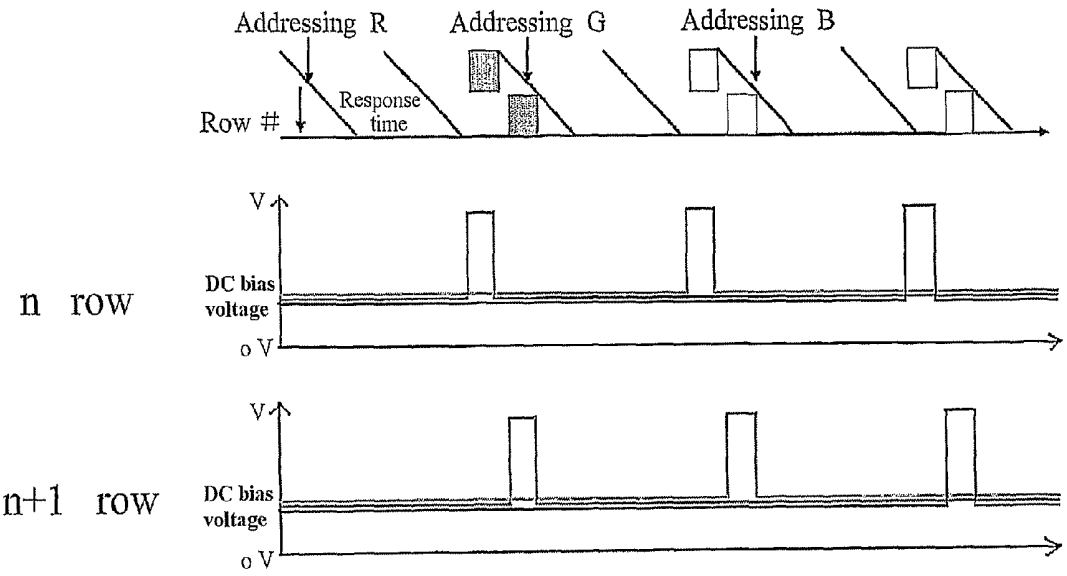

Addressing R
Addressing G
Addressing B
Row #
Response time
n row
n+1 row
V
DC bias voltage
o V

FIG. 8

OUTDOOR READABLE LIQUID CRYSTAL DISPLAY DEVICE

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a 371 U.S. National Stage of International Application No. PCT/CN2009/071111, filed Mar. 31, 2009. This application claims the benefit of Chinese Patent Application No. 200810043215.6, filed Apr. 3, 2008. The disclosures of the above applications are incorporated herein by reference.

FIELD OF THE INVENTION

The present invention relates to a liquid crystal display and in particular to an outdoor-readable liquid crystal display.

BACKGROUND OF THE INVENTION

In recent years, Liquid Crystal Displays (LCDs) have been widely used in electronics for representation of information due to their lightness, thinness, low power consumption, etc.

Conventional LCDs are broadly classified as either reflective or transmissive. Unlike Cathode Ray Tube (CRT) displays and Electroluminescent (EL) displays, LCDs are not self-emissive. A transmissive LCD is illuminated by a light source situated behind the LCD panel, and a reflective LCD is illuminated by ambient light. As a result, transmissive LCDs are less subjected to the intensity of ambient light and the contrast of the displayed image is higher, but transmissive LCDs are less power efficient due to the presence of the light source. Reflective LCDs are more power efficient because they do not need an additional light source, but the brightness and contrast of the displayed image in reflective LCDs are more subjected to the intensity of ambient light and the like. Particularly, their ability to resolve detail is notably limited in a dark environment.

A Field-Sequential Color Liquid Crystal Display (FSC-LCD) is a display with many advantageous features. The display switches on red, green and blue (R, G, B) backlights in sequence, which illuminate the display panel in sequence. That is, red, green and blue lights are applied in each pixel in sequence. Due to image sticking, the red, green and blue images are perceived by the observer as a continuous image.

Now refer to FIG. **1**, a sectional view of the structure of a conventional FSC-LCD **1**. The FSC-LCD **1** includes a first upper substrate **10**, a first lower substrate **11**, a first liquid crystal layer **12** provided between the first upper substrate **10** and the first lower substrate **11**, and a first backlight device **13** for providing the light source of the FSC-LCD **1**. The first backlight device **13** including a plurality of red Light-Emitting Diodes (LEDs) **13***r*, green LEDs **13***g* and blue LEDs **13***b*. First pixel electrodes **111** and Thin-Film Transistors (TFTs) **112** used as switches are formed on the side of the first lower substrate **11** immediately adjacent to the first liquid crystal layer **12**. The TFTs **112** are electrically connected to the first pixel electrodes **111**. A first common electrode **101** facing the first pixel electrodes **111** is formed on the side of the first upper substrate **10** immediately adjacent to the first liquid crystal layer **12**. A black base **102** is provided between the first common electrode **101** and the first upper substrate **10**, and in correspondence with the TFTs **112** of the first lower substrate **11**, for blocking light from the regions excluding the first pixel electrodes **111** of the first lower substrate **11**.

FIG. **2** is a top view of the first lower substrate **11** of the conventional FSC-LCD **1**. The TFTs **112** used as pixel switches, data lines **113** for providing signals to the first pixel electrodes **111** of the first lower substrate **11**, and gate lines **114** for providing switching signals to the TFTs **112** are provided on the first lower substrate **11**. The data lines **113** and the gate lines **114** define multiple pixel regions **115**. Each of the TFTs **112** is on the place in a pixel region **115**, where a data line **113** and a gate line **114** meet, and is electrically connected to the data line **113** and the gate line **114**.

FIG. **3** is a sequence diagram illustrating a method for driving the conventional FSC-LCD **1**. The method for driving the FSC-LCD **1** includes: scanning each of the TFTs **112** according to the first backlight device **13**, and realigning liquid crystal molecules in the first liquid crystal **12** to correspond to the lights emitted by the red LEDs **13***r*, green LEDs **13***g* and blue LEDs **13***b* of the first backlight device **13**. Specifically, scanning of all of the TFTs (tTFT) **15**, liquid crystal response (tLC) **16** and backlighting (tBL) **17** in the FSC-LCD **1** are performed in the period of a field **14**.

FIG. **4** illustrates the principle of driving the conventional FSC-LCD **1**. The FSC-LCD **1** further includes a first scanning driver **18** and a first data driver **19**. With reference to FIG. **2**, the first lower substrate **11** of the FSC-LCD **1** includes multiple pixel regions **115**, and pixels in all the pixel regions **115** form an array. The first scanning driver **18** scans pixels in the pixel regions **115** row by row in sequence, and the first data driver **19** transmits the image data to a pixel column corresponding to the pixel regions **115**.

However, for good outdoor readability of the conventional FSC-LCD **1** discussed-above, the brightness of light produced by the first backlight device **13** has to be elevated, resulting in increased power consumption.

In view of the problem in the prior art, the inventors conducted intensive studies with their vast experiences in the field, and invented the outdoor-readable LCD of the invention.

SUMMARY OF THE INVENTION

An object of the invention is to solve the drawback of the prior art, provide an outdoor-readable LCD, and realize high brightness for good outdoor readability.

To solve the problems above, the invention provides an outdoor-readable LCD, including: a liquid crystal panel including an upper substrate, a lower substrate and a liquid crystal layer provided between the upper substrate and the lower substrate; a backlight device including a plurality of red LEDs, green LEDs and blue LEDs; and a light source control device adapted to adjust the backlight device based on the intensity of ambient light. When the intensity of ambient light is lower than a predetermined light intensity of the outdoor-readable LCD, the red LEDs, the green LEDs and the blue LEDs of the backlight device are switched on in sequence to emit lights with predetermined delays; and when the intensity of ambient light is higher than the predetermined light intensity, the red LEDs, the green LEDs and the blue LEDs of the backlight device are switched on at the same time.

As discussed above, the outdoor-readable LCD applies red, green and blue (R, G, B) lights in sequence on the same pixel, for the eyes of the observer mixing the successive images into a color picture due to the image sticking, so that the invention without an expensive color filter, can realize outdoor readability, lower costs, improved resolution and lower power consumption, and increase illumination utilization of the backlight device.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings include:

FIG. **1** is a sectional view of the structure of a conventional FSC-LCD;

FIG. **2** is a top view of the first lower substrate of the conventional FSC-LCD;

FIG. **3** is a sequence diagram of the conventional FSC-LCD;

FIG. **4** illustrates the principle of driving the conventional FSC-LCD;

FIG. **5** is an exploded view of an outdoor-readable LCD according to the invention;

FIG. **6**(*a*) and FIG. **6**(*b*) are sequence diagrams for backlight in an outdoor-readable LCD according to a first embodiment of the invention;

FIG. **7**(*a*) and FIG. **7**(*b*) are sequence diagrams for backlight in an outdoor-readable LCD according to a second embodiment of the invention; and

FIG. **8** is a sequence diagram for backlight in an outdoor-readable FSC-LCD according to a third embodiment of the invention.

Numerals for the elements in the drawings are listed below:

[Prior art]

FSC-LCD	1		
First upper substrate	10	First common electrode	101
First lower substrate	11	First pixel electrode	111
TFT	112	Data line	113
Gate line	114	Pixel region	115
First liquid crystal layer	12	First backlight device	13
Period	14	Scanning of TFTs	15
Liquid crystal response	16	Backlighting	17
First scanning driver	18	First data driver	19

[The invention]

Outdoor-readable LCD	200		
Liquid crystal panel	210	Second pixel electrode	211
Second low substrate	212	Second upper substrate	213
Second common electrode	214	Second liquid crystal layer	215
Second backlight device	220	First polarizing plate	221a
Red LED	222r	Green LED	222g
Blue LED	222b	White LED	222w
Second scanning driver	230	Second data driver	240

DETAILED DESCRIPTION OF THE INVENTION

The technical solution, structural features, objects and effects of the invention are described hereinafter in connection with the embodiments and the figures.

First Embodiment

As shown in FIG. **5**, an outdoor-readable LCD **200** of the invention includes: a liquid crystal panel **210**, a second backlight device **220** adapted to illuminate the liquid crystal panel **210**, a second scanning driver **230** adapted to provide a scanning signal to the liquid crystal panel **210**, a second data driver **240** adapted to provide a data signal to the liquid crystal panel **210**, and a light source control device (not shown) adapted to adjust the brightness of the second backlight device **220**. The liquid crystal panel **210** includes: a second lower substrate **212** including second pixel electrodes **211**, a second upper substrate **213** facing to the second lower substrate **212**, a second common electrode **214** provided on the side of the second upper substrate **213** facing to the second lower substrate **212**, and a second liquid crystal layer **215** provided between the second lower substrate **212** and the second upper substrate **213**. The second backlight device **220** includes a plurality of red LEDs **220***r*, green LEDs **220***g* and blue LEDs **220***b*, and further includes a first polarizing plate **221***a* and a second polarizing plate (not shown). The first polarizing plate **221***a* is mounted on the side of the second lower substrate **212** opposite to the second pixel electrodes **211**. The second polarizing plate is mounted on the side of the second upper substrate **213** opposite to the second common electrode **214**. The red LEDs **220***r*, green LEDs **220***g* and blue LEDs **220***b* of the second backlight device **220** are provided facing to the first polarizing plate **221***a* with a certain distance between the second backlight device **220** and the first polarizing plate **221***a*. When the red LEDs **220***r*, green LEDs **220***g* and blue LEDs **220***b* of the second backlight device **220** are switched on in sequence, the red LEDs **220***r*, the green LEDs **220***g* and the blue LEDs **220***b* emit red, green and blue lights with predetermined delays; or, the red LEDs **220***r*, green LEDs **220***g* and blue LEDs **220***b* are switched on at the same time, and the red, green and blue lights emitted are superimposed, resulting in white light.

Particularly, the outdoor-readable LCD according to the invention may further include an ambient light sensor (not shown), adapted to sense the intensity of ambient light and output a sensing signal. The light source control device adjusts the second backlight device **220** based on the sensing signal.

Now refer to FIG. **6**(*a*) and FIG. **6**(*b*). When the intensity of ambient light detected by the ambient light sensor is lower than a predetermined light intensity of the outdoor-readable LCD **200**, the light source control device switches on the red LEDs **220***r*, the green LEDs **220***g* and the blue LEDs **220***b* in sequence according to the sensing signal, and the red LEDs **220***r*, the green LEDs **220***g* and the blue LEDs **220***b* emit red, green and blue lights with predetermined delays. The red, green and blue lights enter the first polarizing plate **221***a*, and pass through the second lower substrate **212**, to the second liquid crystal layer **215**. Lights arrived at the second liquid crystal layer **215** pass through the second upper substrate **213**, and leave from the second polarizing plate, to form a color image. When the intensity of ambient light detected by the ambient light sensor is higher than the predetermined light intensity of the outdoor-readable LCD **200**, the light source control device switches on the red LEDs **220***r*, the green LEDs **220***g* and the blue LEDs **220***b* of the second backlight device **220** at the same time according to the sensing signal, and the red LEDs **220***r*, the green LEDs **220***g* and the blue LEDs **220***b* of the second backlight device **220** emit red, green and blue lights correspondingly. The red, green and blue lights are superimposed into white light. The white light enters the first polarizing plate **221***a*, and passes through the second lower substrate **212**, to the second liquid crystal layer **215**. Light arrived at the second liquid crystal layer **215** passes through the second upper substrate **213**, and leaves from the second polarizing plate, to form a monochrome image with high brightness.

Second Embodiment

This embodiment differs from the first embodiment in the backlight device. Specifically, the second backlight device **220** of the outdoor-readable LCD **200** based on the first embodiment is provided with additional white LEDs **220***w* (not shown). For other arrangements regarding the outdoor-readable LCD **200**, one may refer to the first embodiment.

Now refer to FIG. **7**(*a*) and FIG. **7**(*b*). When the intensity of ambient light detected by the ambient light sensor is lower than a predetermined light intensity of the outdoor-readable LCD **200**, the light source control device switches off the white LEDs **220***w*, and switches on the red LEDs **220***r*, the green LEDs **220***g* and the blue LEDs **220***b* of the second backlight device **220** in sequence according to the sensing signal. The red LEDs **220***r*, the green LEDs **220***g* and the blue LEDs **220***b* emit red, green and blue lights with predetermined delays. The red, green and blue lights enter the first polarizing plate **221** a, and pass through the second lower substrate **212**, to the second liquid crystal layer **215**. Lights arrived at the second liquid crystal layer **215** pass through the

second upper substrate **213**, and leave from the second polarizing plate, to achieve color representation. When the detected intensity of ambient light is higher than the predetermined light intensity of the outdoor-readable LCD **200**, the white LEDs **220***w* are switched on, meanwhile, the red LEDs **220***r*, the green LEDs **220***g* and the blue LEDs **220***b* are switched on in sequence to emit red, green and blue lights. The red, green and blue lights enter the first polarizing plate **221** a, and pass through the second lower substrate **212**, to the second liquid crystal layer **215**. Lights arrived at the second liquid crystal layer **215** pass through the second upper substrate **213**, and leave from the second polarizing plate. By switching on the white LEDs **220***w*, additional white back light is provided to the outdoor-readable LCD **200**, thereby enhancing its backlight and forming a color image with high brightness.

Third Embodiment

As shown in FIG. **5**, an outdoor-readable LCD **200** of the invention includes: a liquid crystal panel **210**, a second backlight device **220** adapted to illuminate the liquid crystal panel **210**, a second scanning driver **230** adapted to provide a scanning signal to the liquid crystal panel **210**, a second data driver **240** adapted to provide a data signal to the liquid crystal panel **210**, and a light source control device (not shown) adapted to adjust the brightness of the second backlight device **220**. The liquid crystal panel **210** includes: a second lower substrate **212** including second pixel electrodes **211**, a second upper substrate **213** facing the second lower substrate **212**, a second common electrode **214** provided on the side of the second upper substrate **213** facing to the second lower substrate **212**, and a second liquid crystal layer **215** provided between the second lower substrate **212** and the second upper substrate **213**. The second backlight device **220** includes a number of red LEDs **220***r*, green LEDs **220***g* and blue LEDs **220***b*, and further includes a first polarizing plate **221***a* and a second polarizing plate. The first polarizing plate **221***a* is mounted on the side of the second lower substrate **212** facing away from the second pixel electrodes **211**. The second polarizing plate is mounted on a side of the second upper substrate **213** facing away from the second common electrode **214**. The red LEDs **220***r*, green LEDs **220***g* and blue LEDs **220***b* of the second backlight device **220** are provided facing the first polarizing plate **221***a* from a certain distance away. When the red LEDs **220***r*, green LEDs **220***g* and blue LEDs **220***b* of the second backlight device **220** are switched on in sequence, the red LEDs **220***r*, the green LEDs **220***g* and the blue LEDs **220***b* emit red, green and blue lights with predetermined delays; or, the red LEDs **220***r*, green LEDs **220***g* and blue LEDs **220***b* are switched on at the same time, and the red, green and blue lights emitted are superimposed, resulting in white light.

Particularly, the outdoor-readable LCD according to the invention may further include an ambient light sensor (not shown), adapted to sense the intensity of ambient light and output a sensing signal. The light source control device adjusts the second backlight device **220** based on the sensing signal.

Now refer to FIG. **8**. When the intensity of ambient light detected by the ambient light sensor is lower than a predetermined light intensity of the outdoor-readable LCD **200**, the light source control device adjusts a bias voltage V of the red LEDs **220***r*, the green LEDs **220***g* and the blue LEDs **220***b* of the second backlight device **220** to be zero according to the sensing signal, and the red LEDs **220***r*, the green LEDs **220***g* and the blue LEDs **220***b* are switched on in sequence to emit red, green and blue lights with predetermined delays. The red, green and blue lights enter the first polarizing plate **221***a*, and pass through the second lower substrate **212**, to the second liquid crystal layer **215**. Lights arrived at the second liquid crystal layer **215** pass through the second upper substrate **213**, and leave from the second polarizing plate. When the intensity of ambient light detected by the ambient light sensor is higher than the predetermined light intensity of the outdoor-readable LCD **200**, the light source control device adjusts the bias voltage V of the red LEDs **220***r*, the green LEDs **220***g* and the blue LEDs **220***b* of the second backlight device **220** according to the sensing signal, by setting the bias voltage V to a predetermined value according to the intensity of ambient light. Thereby the brightness of backlight provided by the second backlight device **220** are elevated, and the red LEDs **220***r*, the green LEDs **220***g* and the blue LEDs **220***b* are switched on in sequence to emit red, green and blue lights with predetermined delays. The red, green and blue lights enter the first polarizing plate **221***a*, and pass through the second lower substrate **212**, to the second liquid crystal layer **215**. Lights arrived at the second liquid crystal layer **215** pass through the second upper substrate **213**, and leave from the second polarizing plate, to form a color image with high brightness.

To sum up, the outdoor-readable LCD **200** applies red, green and blue (R, G, B) lights in sequence on the same pixel. The eyes of the observer mix the successive images into a color picture due to image sticking. The invention without an expensive color filter, can realize outdoor readability, lower costs, lower power consumption and improved resolution, and increase illumination utilization of the backlight device.

Those skilled in the art shall understand that various modifications and alternations of the invention can be made without deviation from the scope of the invention. Accordingly, the invention shall include those modifications and alternations within the scope defined by the appended claims.

The invention claimed is:

1. An outdoor-readable Liquid Crystal Display (LCD), comprising:

a liquid crystal panel, the liquid crystal panel comprising an upper substrate, a lower substrate and a liquid crystal layer provided between the upper substrate and the lower substrate;

a backlight device, comprising a plurality of red Light-Emitting Diodes (LEDs), green LEDs and blue LEDs; and

a light source control device, adapted to adjust the backlight device based on the intensity of ambient light, wherein, when the intensity of ambient light is lower than a predetermined light intensity of the outdoor-readable LCD, a bias voltage of the red LEDs, the green LEDs and the blue LEDs of the backlight device is set to zero, and the red LEDs, the green LEDs and the blue LEDs are switched on in sequence to emit lights with predetermined delays; and when the intensity of ambient light is higher than the predetermined light intensity, the bias voltage of the red LEDs, the green LEDs and the blue LEDs of the backlight device is elevated, and the red LEDs, the green LEDs and the blue LEDs are switched on in sequence to emit lights with predetermined delays.

2. The outdoor-readable LCD according to claim **1**, wherein the outdoor-readable LCD further comprises an ambient light sensor adapted to detect the intensity of ambient light and output a sensing signal; and wherein the light source control device is adapted to adjust the backlight device based on the sensing signal.

3. The outdoor-readable LCD according to claim **1**, wherein when the intensity of ambient light is higher than the predetermined light intensity, the increment of the bias volt-

age of the red LEDs, the green LEDs and the blue LEDs of the backlight device increases as the intensity of ambient light increases.

4. The outdoor-readable LCD according to claim **3**, wherein the outdoor-readable LCD further comprises an ambient light sensor adapted to detect the intensity of ambient light and output a sensing signal; and wherein the light source control device is adapted to adjust the backlight device based on the sensing signal.

5. A method for driving an outdoor-readable Liquid Crystal Display (LCD), wherein the outdoor-readable LCD comprises:

a liquid crystal panel, the liquid crystal panel comprising an upper substrate, a lower substrate and a liquid crystal layer provided between the upper substrate and the lower substrate;

a backlight device, comprising a plurality of red Light-Emitting Diodes (LEDs), green LEDs and blue LEDs; and

a light source control device, adapted to adjust the backlight device based on the intensity of ambient light, and

wherein the method for driving the outdoor-readable LCD comprises: when the intensity of ambient light is lower than a predetermined light intensity of the outdoor-readable LCD, setting a bias voltage of the red LEDs, the green LEDs and the blue LEDs of the backlight device to zero, and switching on the red LEDs, the green LEDs and the blue LEDs in sequence to emit lights with predetermined delays; and when the intensity of ambient light is higher than the predetermined light intensity, elevating the bias voltage of the red LEDs, the green LEDs and the blue LEDs of the backlight device, and switching on the red LEDs, the green LEDs and the blue LEDs in sequence to emit lights with predetermined delays.

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UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 8,624,826 B2
APPLICATION NO. : 12/935487
DATED : January 7, 2014
INVENTOR(S) : Willem Den Boer et al.

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

Title Page, Item (86), Column 1, Line 1 (PCT. No.); Delete "PCT/CN2009/711111" and insert --PCT/CN2009/71111--

Signed and Sealed this
Twenty-sixth Day of August, 2014

Michelle K. Lee

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Deputy Director of the United States Patent and Trademark Office

专利名称(译)	户外可读液晶显示装置		
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申请(专利权)人(译)	上海天马微电子有限公司.		
当前申请(专利权)人(译)	上海天马微电子有限公司.		
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优先权	200810043215.6 2008-04-03 CN		
其他公开文献	US20110018856A1		
外部链接	Espacenet USPTO		

摘要(译)

室外可读液晶显示装置（200）包括液晶面板（210），背光装置（220）和光源控制装置。背光装置（220）包括多个红色发光二极管（220r），绿色发光二极管（220g）和蓝色发光二极管（220b）。光源控制装置用于基于环境光的光强度调节背光装置（220）。当环境光的光强度低于液晶显示装置（200）的预定光强度时，红色发光二极管（220r），绿色发光二极管（220g）和蓝色发光二极管（220b）背光装置（220）依次通电以在预定的时间滞后发光。当环境光的光强度高于预定光强度时，背光装置（220）的红色发光二极管（220r），绿色发光二极管（220g）和蓝色发光二极管（220b）通电同时发光。