pixel) is adjusted so as to reduce the viewing angle dependence of the color reproducibility of a human skin color (hereinafter, "skin color").

CITATION LIST

PATENT LITERATURE

[0010]

Patent Document 1: Japanese Laid-Open Patent Publication No. 2004-62146 (Specification of U.S. Patent No. 6,958,791)

Patent Document 2: WO 2007/034876 (Specification of U.S. Patent No. 8,159,432)

SUMMARY OF INVENTION

TECHNICAL PROBLEM

[0011] However, the liquid crystal display device disclosed in Patent Document 2 has such a problem that the colors of which the viewing angle dependence of the color reproducibility can be improved are limited or the driving method becomes complicated.

[0012] ~~An object~~Embodiments of the present invention ~~is to~~ provide a liquid crystal display device having a multi-pixel configuration which is capable of reducing the viewing angle dependence of the color reproducibility.

SOLUTION TO PROBLEM

[0013] ~~A liquid crystal display device according to an embodiment of the present invention is a liquid crystal display device including: a plurality of pixels arranged in a matrix of rows and columns; and a control circuit configured to receive an input display signal that is indicative of a grayscale level which is to be exhibited by the plurality of pixels and supply a display signal voltage to each of the plurality of pixels, wherein the plurality of pixels form a plurality of color display pixels, each of the plurality of color display pixels including three or more pixels which exhibit different colors, each of the plurality of pixels includes a first sub-pixel electrically connected to a first source bus line via a first TFT and a second sub-pixel electrically connected to a second source bus line via a second TFT, and the control circuit is configured to generate a first display signal voltage and a second display signal voltage that are to be supplied to the first sub-pixel and the second sub-pixel of an arbitrary one of the plurality of pixels based on a grayscale level to be exhibited by the arbitrary pixel and grayscale levels to be exhibited by two or more remaining pixels included in a color display pixel to which the arbitrary pixel belongs that are indicated by the input display signal, and output the generated first and second display signal voltages to the first source bus line and the second source bus line, respectively.~~

According to an aspect, there is provided a liquid crystal display device, comprising: a plurality of pixels arranged in a matrix of rows and columns; and a control circuit configured to receive an input display signal that is indicative of a grayscale level which is to be exhibited by the plurality of pixels and supply a display signal voltage to

each of the plurality of pixels, wherein the plurality of pixels form a plurality of color display pixels, each of the plurality of color display pixels including three or more pixels which exhibit different colors, each of the plurality of pixels includes a first sub-pixel electrically connected to a first source bus line via a first TFT and a second sub-pixel electrically connected to a second source bus line via a second TFT, and the control circuit is configured to generate a first display signal voltage and a second display signal voltage that are to be supplied to the first sub-pixel and the second sub-pixel of an arbitrary one of the plurality of pixels based on a grayscale level to be exhibited by the arbitrary pixel and grayscale levels to be exhibited by two or more remaining pixels included in a color display pixel to which the arbitrary pixel belongs that are indicated by the input display signal, and output the generated first and second display signal voltages to the first source bus line and the second source bus line, respectively, wherein the plurality of color display pixels each include m pixels, from a 1st pixel to a mth pixel, where m is an integer which is not less than 3, grayscale levels which are to be exhibited by the 1st pixel to the mth pixel are 1st grayscale level GL1 to m^{th} grayscale level GLm, wherein luminances at a front viewing angle of the 1st pixel to the mth pixel achieved when the 1st pixel to the mth pixel exhibit the 1st grayscale level GL1 to the mth grayscale level GLm, which are normalized on the assumption that a luminance at the front viewing angle achieved when a highest grayscale level is exhibited is 1, are 1st frontal normalized luminance NL1 to m^{th} frontal normalized luminance NLm, respectively, wherein luminances at an oblique 60° viewing angle of the 1st pixel to the mth pixel which are normal-

ized on the assumption that a luminance at the oblique 60° viewing angle achieved when a highest grayscale level is exhibited is 1 are 1st oblique viewing angle normalized luminance IL1 to mth oblique viewing angle normalized luminance ILm, respectively, and the control circuit is configured to generate the first display signal voltage and the second display signal voltage that are to be supplied to the first sub-pixel and the second sub-pixel of each of the 1st pixel to the mth pixel such that, for each pixel of the plurality of color display pixels, the maximum value of the difference between a respective frontal luminance ratio of the respective one of said pixels and an oblique 60° luminance ratio of said respective one of said pixels is not more than 0.25, wherein the frontal luminance ratios of respective pixels are obtained by normalizing the 1st frontal normalized luminance NL1 to the mth frontal normalized luminance NLm with respect to a highest one of the 1st frontal normalized luminance NL1 to the mth frontal normalized luminance NLm, and wherein the oblique 60° luminance ratios of the pixels are obtained by normalizing the 1st oblique viewing angle normalized luminance IL1 to the mth oblique viewing angle normalized luminance ILm with respect to a highest one of the 1st oblique viewing angle normalized luminance IL1 to the mth oblique viewing angle normalized luminance ILm.

CLAIMS

1. A liquid crystal display device, comprising:

a plurality of pixels arranged in a matrix of rows and columns; and

a control circuit configured to receive an input display signal that is indicative of a grayscale level which is to be exhibited by the plurality of pixels and supply a display signal voltage to each of the plurality of pixels,

wherein the plurality of pixels form a plurality of color display pixels, each of the plurality of color display pixels including three or more pixels which exhibit different colors,

each of the plurality of pixels includes a first sub-pixel electrically connected to a first source bus line via a first TFT and a second sub-pixel electrically connected to a second source bus line via a second TFT, and

the control circuit is configured to generate a first display signal voltage and a second display signal voltage that are to be supplied to the first sub-pixel and the second sub-pixel of an arbitrary one of the plurality of pixels based on a grayscale level to be exhibited by the arbitrary pixel and grayscale levels to be exhibited by two or more remaining pixels included in a color display pixel to which the arbitrary pixel belongs that are indicated by the input

display signal, and output the generated first and second display signal voltages to the first source bus line and the second source bus line, respectively,

wherein the plurality of color display pixels each include m pixels, from a 1st pixel to a mth pixel, where m is an integer which is not less than 3, grayscale levels which are to be exhibited by the 1st pixel to the mth pixel are 1st grayscale level GL1 to m^{th} grayscale level GLm,

wherein luminances at a front viewing angle of the 1st pixel to the mth pixel achieved when the 1st pixel to the mth pixel exhibit the 1st grayscale level GL1 to the mth grayscale level GLm, which are normalized on the assumption that a luminance at the front viewing angle achieved when a highest grayscale level is exhibited is 1, are 1st frontal normalized luminance NL1 to m^{th} frontal normalized luminance NLm, respectively,

wherein luminances at an oblique 60° viewing angle of the 1st pixel to the mth pixel which are normalized on the assumption that a luminance at the oblique 60° viewing angle achieved when a highest grayscale level is exhibited is 1 are 1st oblique viewing angle normalized luminance IL1 to m^{th} oblique viewing angle normalized luminance ILm, respectively, and

the control circuit is configured to generate the first display signal voltage and the second display signal voltage

that are to be supplied to the first sub-pixel and the second sub-pixel of each of the 1st pixel to the mth pixel such that, for each pixel of the plurality of color display pixels, the maximum value of the difference between a respective frontal luminance ratio of the respective one of said pixels and an oblique 60° luminance ratio of said respective one of said pixels is not more than 0.25,

wherein the frontal luminance ratios of respective pixels are obtained by normalizing the 1st frontal normalized luminance NL1 to the mth frontal normalized luminance NLm with respect to a highest one of the 1st frontal normalized luminance NL1 to the mth frontal normalized luminance NLm, and wherein the oblique 60° luminance ratios of the pixels are obtained by normalizing the 1st oblique viewing angle normalized luminance IL1 to the mth oblique viewing angle normalized luminance ILm with respect to a highest one of the 1st oblique viewing angle normalized luminance IL1 to the mth oblique viewing angle normalized luminance ILm.

2. The liquid crystal display device of claim 1, wherein for one grayscale level which is to be exhibited by the arbitrary pixel, the control circuit is capable of generating the first display signal voltage and the second display signal voltage that have two or more different absolute values according to the grayscale levels to be exhibited by the two or more

remaining pixels.

3. The liquid crystal display device of claim 1 or 2,

wherein the 1st grayscale level GL1 to the mth grayscale level GLm include at least two different grayscale levels, and

wherein the control circuit is configured to generate voltages which have equal absolute values as the first display signal voltage and the second display signal voltage respectively supplied to the first sub-pixel and the second sub-pixel of a pixel which is to exhibit a grayscale level of a largest value among the 1st grayscale level GL1 to the mth grayscale level GLm.

4. The liquid crystal display device of claim 3, wherein the control circuit is configured to generate the first display signal voltage and the second display signal voltage respectively supplied to the first sub-pixel and the second sub-pixel of each of the plurality of pixels except for said pixel which is to exhibit the grayscale level of the largest value among the m pixels included in the color display pixel such that a difference between the absolute values of the first display signal voltage and the second display signal voltage is a maximum.

5. The liquid crystal display device of any of claims 1 to 3, wherein

the first source bus line and the second source bus line extend in the column direction,

in each of the plurality of pixels, the first sub-pixel and the second sub-pixel are arranged in the column direction, and

a polarity of the first display signal voltage supplied from the first source bus line and a polarity of the second display signal voltage supplied from the second source bus line are each constant within a frame.

6. The liquid crystal display device of claim 4, wherein the polarity of the first display signal voltage supplied from the first source bus line and the polarity of the second display signal voltage supplied from the second source bus line are opposite to each other in a frame.

7. The liquid crystal display device of claim 4 or 5, wherein

some of the plurality of pixels which are arranged in the column direction are to exhibit a same color, and

two sub-pixels which belong to two pixels adjacent to each other in the column direction and which are electrically connected to the first source bus line are adjacent to each other in the column direction.

8. The liquid crystal display device of any of claims 1 to 6, wherein each of the plurality of color display pixels includes a red pixel, a green pixel, and a blue pixel.

9. The liquid crystal display device of claim 7, wherein each of the plurality of color display pixels further includes a yellow pixel.

10. The liquid crystal display device of any of claims 1 to 8, wherein the first TFT and the second TFT include a semiconductor oxide layer as an active layer, the semiconductor oxide layer including an In-Ga-Zn-O semiconductor.

11. The liquid crystal display device of claim 10, wherein the In-Ga-Zn-O semiconductor includes crystalline portion.

CLAIMS

1. A liquid crystal display device, comprising:

a plurality of pixels arranged in a matrix of rows and columns; and

a control circuit configured to receive an input display signal that is indicative of a grayscale level which is to be exhibited by the plurality of pixels and supply a display signal voltage to each of the plurality of pixels,

wherein the plurality of pixels form a plurality of color display pixels, each of the plurality of color display pixels including three or more pixels which exhibit different colors,

each of the plurality of pixels includes a first sub-pixel electrically connected to a first source bus line via a first TFT and a second sub-pixel electrically connected to a second source bus line via a second TFT, and

the control circuit is configured to generate a first display signal voltage and a second display signal voltage that are to be supplied to the first sub-pixel and the second sub-pixel of an arbitrary one of the plurality of pixels based on a grayscale level to be exhibited by the arbitrary pixel and grayscale levels to be exhibited by two or more remaining pixels included in a color display pixel to which the arbitrary pixel belongs that are indicated by the input

display signal, and output the generated first and second display signal voltages to the first source bus line and the second source bus line, respectively.

2. The liquid crystal display device of claim 1, wherein for one grayscale level which is to be exhibited by the arbitrary pixel, the control circuit is capable of generating the first display signal voltage and the second display signal voltage that have two or more different absolute values according to the grayscale levels to be exhibited by the two or more remaining pixels.

3. The liquid crystal display device of claim 1 or 2, wherein

an arbitrary one of the plurality of color display pixels includes m pixels, from a 1st pixel to a mth pixel, where m is an integer which is not less than 3, grayscale levels which are to be exhibited by the 1st pixel to the mth pixel are 1st grayscale level GL1 to mth grayscale level GLm, luminances at a front viewing angle of the 1st pixel to the mth pixel achieved when the 1st pixel to the mth pixel exhibit the 1st grayscale level GL1 to the mth grayscale level GLm which are normalized on the assumption that a luminance at the front viewing angle achieved when a highest grayscale level is exhibited is 1 are 1st frontal normalized luminance NL1 to mth frontal normalized luminance NLm, respectively,

luminances at an oblique 60° viewing angle of the 1st pixel to the mth pixel which are normalized on the assumption that a luminance at the oblique 60° viewing angle achieved when a highest grayscale level is exhibited is 1 are 1st oblique viewing angle normalized luminance IL1 to mth oblique viewing angle normalized luminance ILm, respectively, and

the control circuit is configured to generate the first display signal voltage and the second display signal voltage that are to be supplied to the first sub-pixel and the second sub-pixel of each of the 1st pixel to the mth pixel such that the maximum value of the difference between frontal luminance ratios between pixels which are obtained by normalizing the 1st frontal normalized luminance NL1 to the mth frontal normalized luminance NLm with respect to a highest one of the 1st frontal normalized luminance NL1 to the mth frontal normalized luminance NLm and oblique 60° luminance ratios between pixels which are obtained by normalizing the 1st oblique viewing angle normalized luminance IL1 to the mth oblique viewing angle normalized luminance ILm with respect to a highest one of the 1st oblique viewing angle normalized luminance IL1 to the mth oblique viewing angle normalized luminance ILm is not more than 0.25.

4. The liquid crystal display device of any of claims 1 to 3, wherein

an arbitrary one of the plurality of color display pixels includes m pixels, from the 1st pixel to the mth pixel, where m is an integer which is not less than 3, the grayscale levels which are to be exhibited by the 1st pixel to the mth pixel are the 1st grayscale level GL1 to the mth grayscale level GLm, respectively, the 1st grayscale level GL1 to the mth grayscale level GLm include at least two different grayscale levels, and

the control circuit is configured to generate voltages which have equal absolute values as the first display signal voltage and the second display signal voltage respectively supplied to the first sub-pixel and the second sub-pixel of a pixel which is to exhibit a grayscale level of a largest value among the 1st grayscale level GL1 to the mth grayscale level GLm.

5. The liquid crystal display device of claim 4, wherein the control circuit is configured to generate the first display signal voltage and the second display signal voltage respectively supplied to the first sub-pixel and the second sub-pixel of each of the plurality of pixels exclusive of a pixel which exhibits a highest grayscale level among the m pixels included in the color display pixel such that a difference between the absolute values of the first display signal voltage and the second display signal voltage is a

maximum.

6. The liquid crystal display device of any of claims 1 to 5, wherein

the first source bus line and the second source bus line extend in the column direction,

in each of the plurality of pixels, the first sub-pixel and the second sub-pixel are arranged in the column direction, and

a polarity of the first display signal voltage supplied from the first source bus line and a polarity of the second display signal voltage supplied from the second source bus line are each constant within a frame.

7. The liquid crystal display device of claim 6, wherein the polarity of the first display signal voltage supplied from the first source bus line and the polarity of the second display signal voltage supplied from the second source bus line are opposite to each other in a frame.

8. The liquid crystal display device of claim 6 or 7, wherein

some of the plurality of pixels which are arranged in the column direction are to exhibit a same color, and

two sub-pixels which belong to two pixels adjacent to each other in the column direction and which are electrically

connected to the first source bus line are adjacent to each other in the column direction.

9. The liquid crystal display device of any of claims 1 to 8, wherein each of the plurality of color display pixels includes a red pixel, a green pixel, and a blue pixel.

10. The liquid crystal display device of claim 9, wherein each of the plurality of color display pixels further includes a yellow pixel.

11. The liquid crystal display device of any of claims 1 to 10, wherein the first TFT and the second TFT include a semiconductor oxide layer as an active layer, the semiconductor oxide layer including an In-Ga-Zn-O semiconductor.

12. The liquid crystal display device of claim 11, wherein the In-Ga-Zn-O semiconductor includes crystalline portion.