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(54) **FLEXIBLE DISPLAY DEVICE AND METHOD FOR DETECTING BENDING STATE THEREOF**

(71) Applicant: **Sharp Kabushiki Kaisha**, Sakai City ,Osaka (JP)

(72) Inventors: **Kazuo TAKIZAWA**, Sakai City (JP); **Noritaka KISHI**, Sakai City (JP); **Naoko GOTOH**, Sakai City (JP); **Hideki UCHIDA**, Sakai City (JP); **Katsuhiro KIKUCHI**, Sakai City (JP)

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(57) **ABSTRACT**

An organic EL panel **10** is a bendable display panel including a plurality of pixel circuits **60** each having a light emitting element and a drive element. A data line drive circuit **15** performs, by driving data lines, an operation of writing a voltage to a control terminal of the drive element and an operation of measuring a current flowing through the drive element for the pixel circuits **60** selected by a scanning line drive circuit **14**. A bending detection unit **90** detects a bending state of the organic EL panel **10** based on a measurement result of the current flowing through the drive element. A correction unit **80** corrects a video signal VS1 based on the detected bending state. With this, the bending state of a screen is detected and a change in brightness or color when the screen is bent is prevented.

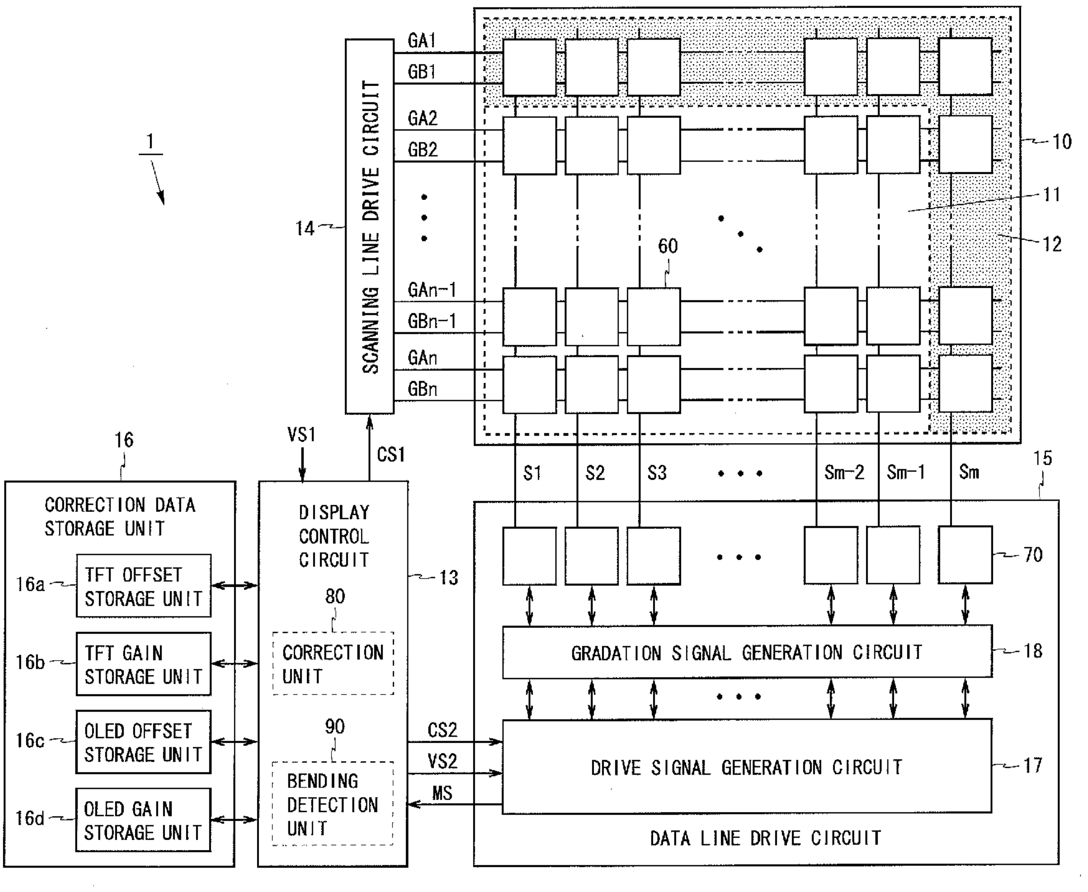


Fig. 1

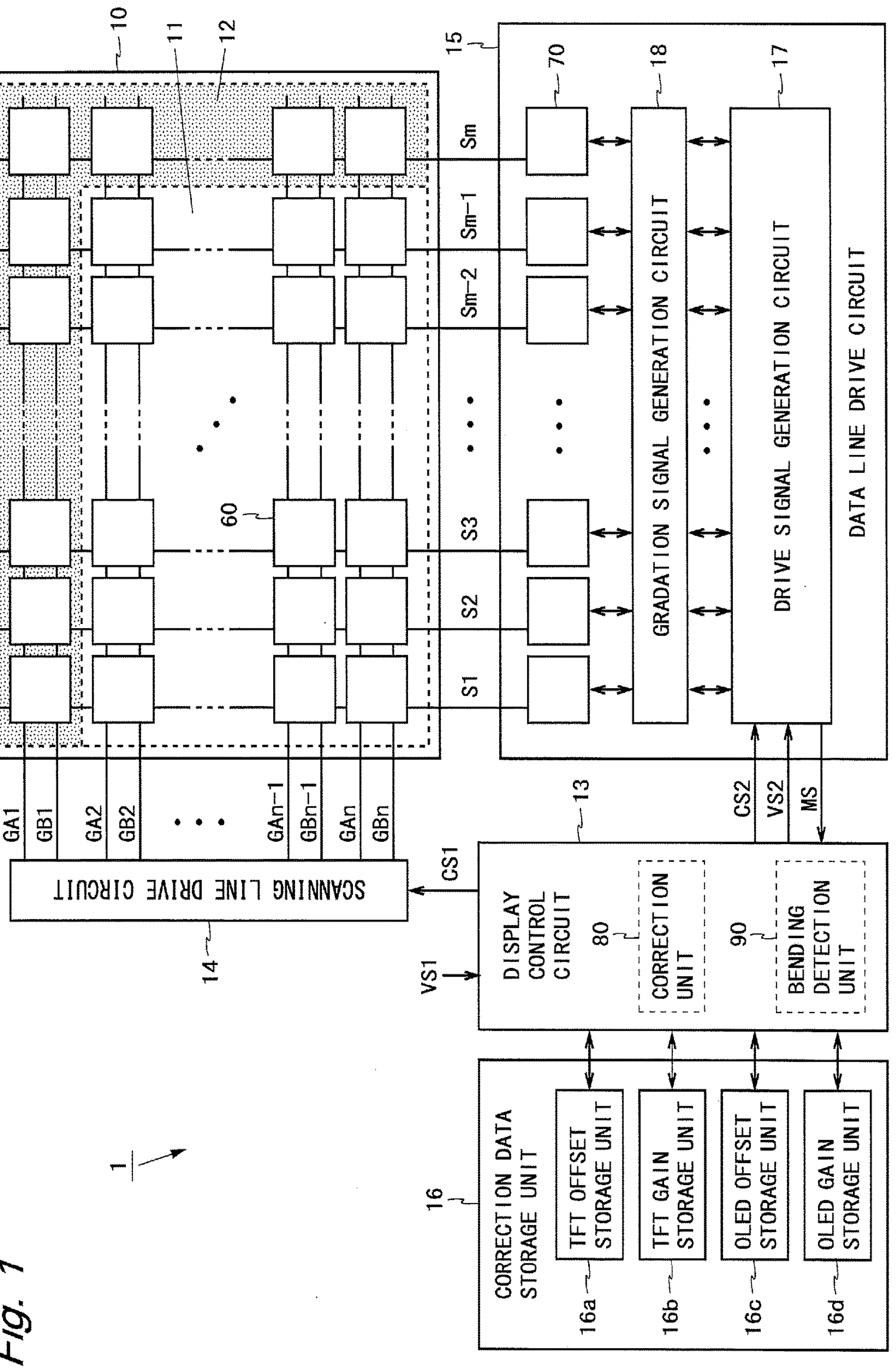

1
10
11
12
15
70
18
17
Sm
Sm−1
Sm−2
S3
S2
S1
60
GRADATION SIGNAL GENERATION CIRCUIT
DRIVE SIGNAL GENERATION CIRCUIT
DATA LINE DRIVE CIRCUIT
GA1
GB1
GA2
GB2
GAn−1
GBn−1
GAn
GBn
SCANNING LINE DRIVE CIRCUIT
14
CS1
VS1
13
CS2
VS2
MS
DISPLAY CONTROL CIRCUIT
80
CORRECTION UNIT
90
BENDING DETECTION UNIT
16
CORRECTION DATA STORAGE UNIT
TFT OFFSET STORAGE UNIT
16a
TFT GAIN STORAGE UNIT
16b
OLED OFFSET STORAGE UNIT
16c
OLED GAIN STORAGE UNIT
16d

Fig. 2

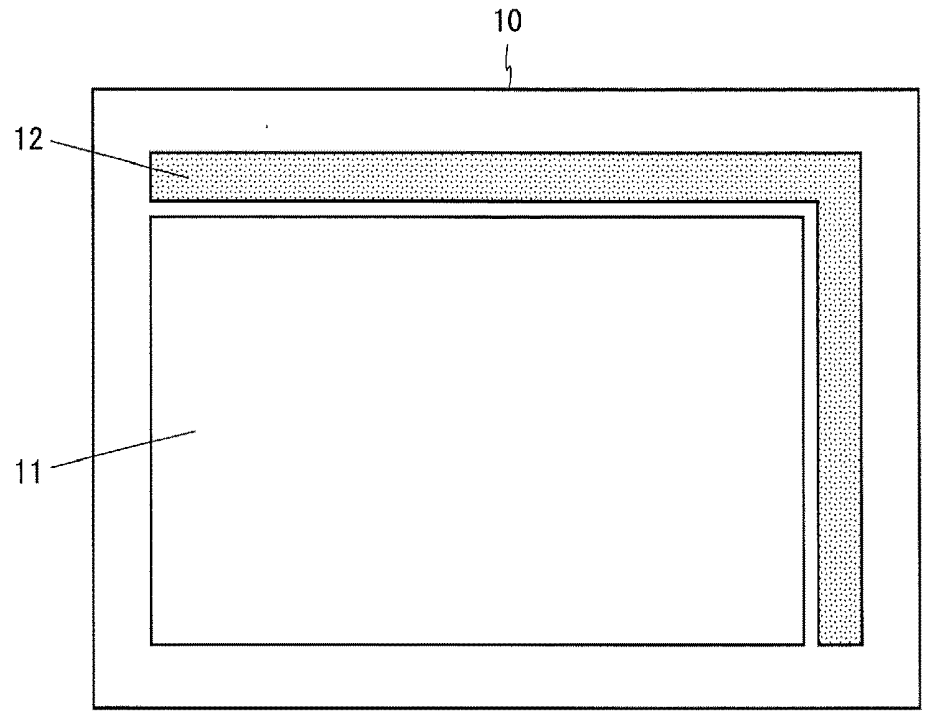


Fig. 3

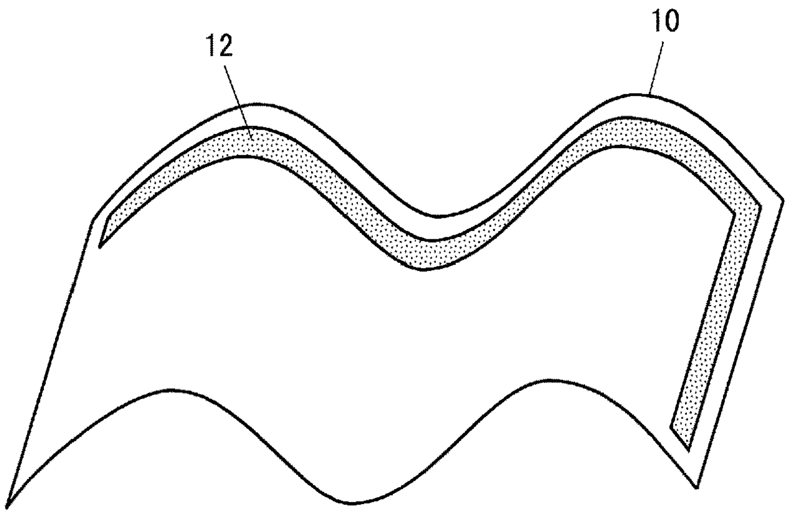


Fig. 4

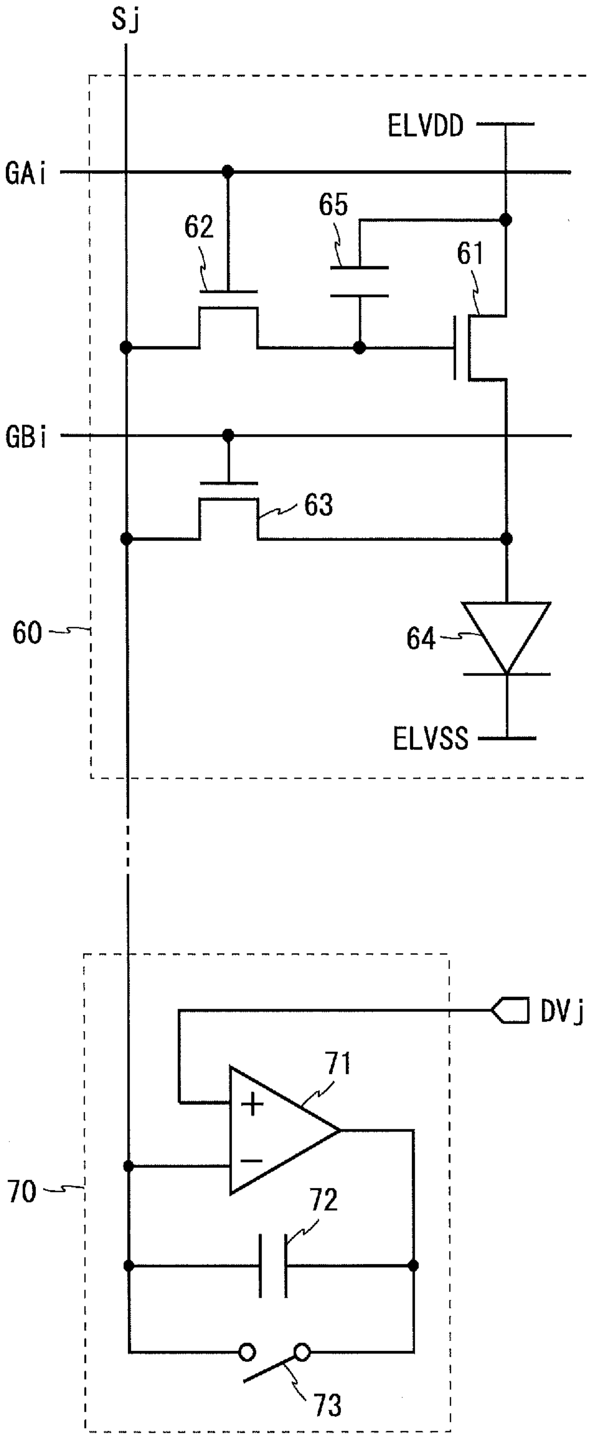


Fig. 5

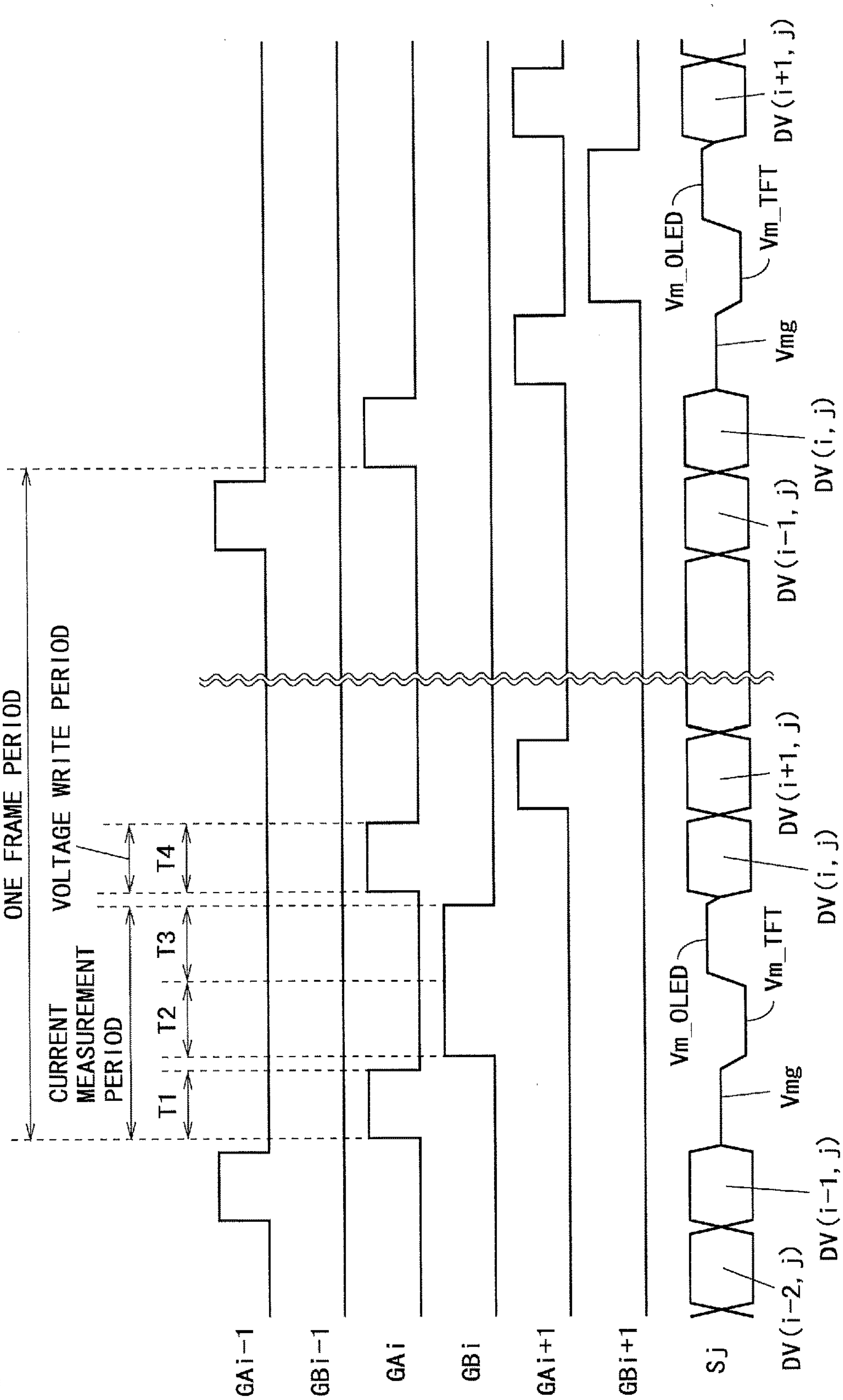

ONE FRAME PERIOD
CURRENT MEASUREMENT PERIOD
VOLTAGE WRITE PERIOD
T1
T2
T3
T4
GAi-1
GBi-1
GAi
GBi
GAi+1
GBi+1
Sj
DV(i-2, j)
DV(i-1, j)
Vmg
Vm_OLED
Vm_TFT
DV(i, j)
DV(i+1, j)

Fig. 6A

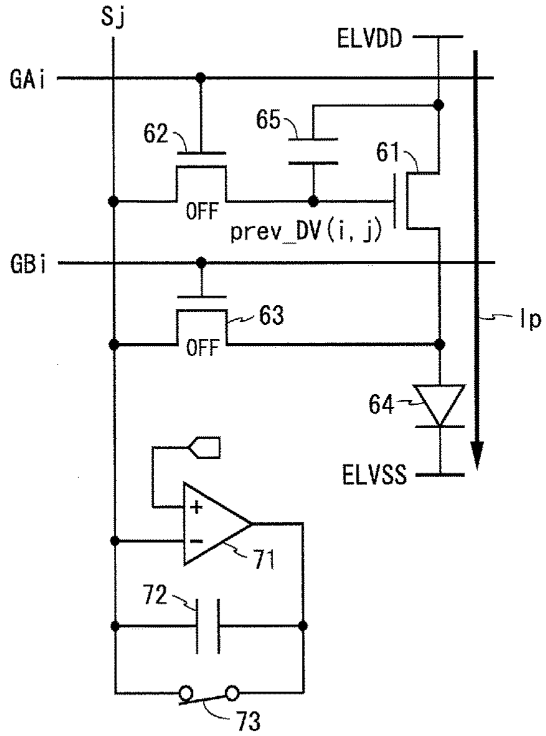

Sj
ELVDD
GAi
62
65
61
OFF
prev_DV(i, j)
GBi
63
OFF
Ip
64
ELVSS
71
72
73

Fig. 6B

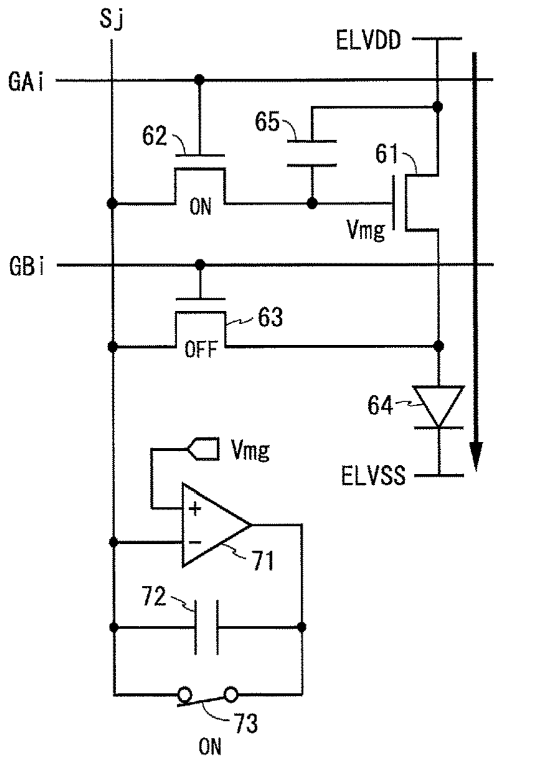

Sj
ELVDD
GAi
62
65
61
ON
Vmg
GBi
63
OFF
64
ELVSS
Vmg
71
72
73
ON

Fig. 6C

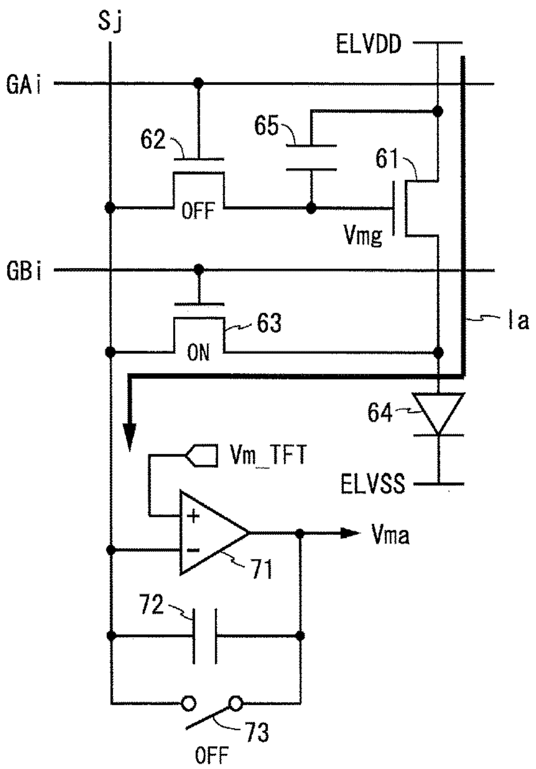

Sj
ELVDD
GAi
62
65
61
OFF
Vmg
GBi
63
ON
Ia
64
Vm_TFT
ELVSS
Vma
71
72
73
OFF

Fig. 6D

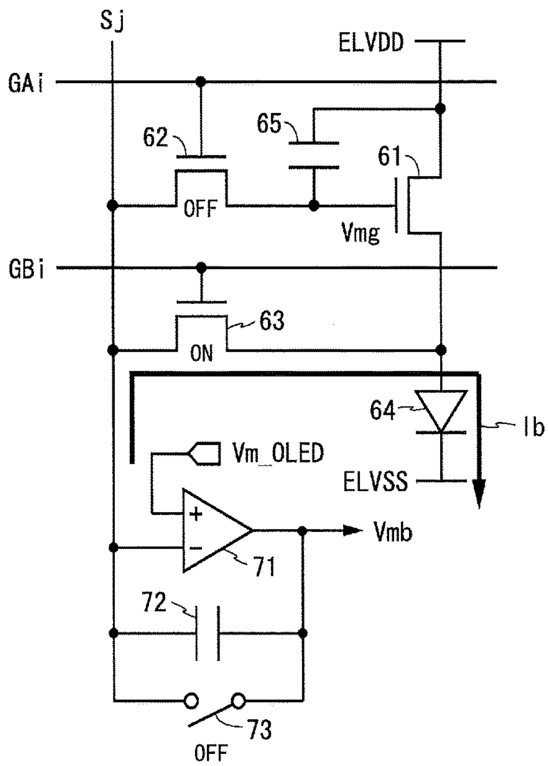

Sj
ELVDD
GAi
62
65
61
OFF
Vmg
GBi
63
ON
64
Ib
Vm_OLED
ELVSS
Vmb
71
72
73
OFF

Fig. 6E

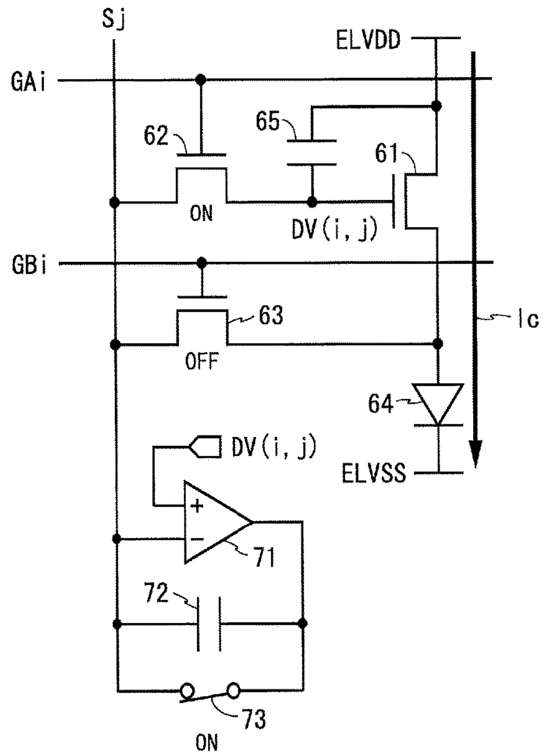

Sj
ELVDD
GAi
62
65
61
ON
DV(i, j)
GBi
63
OFF
Ic
64
DV(i, j)
ELVSS
71
72
73
ON

Fig. 7

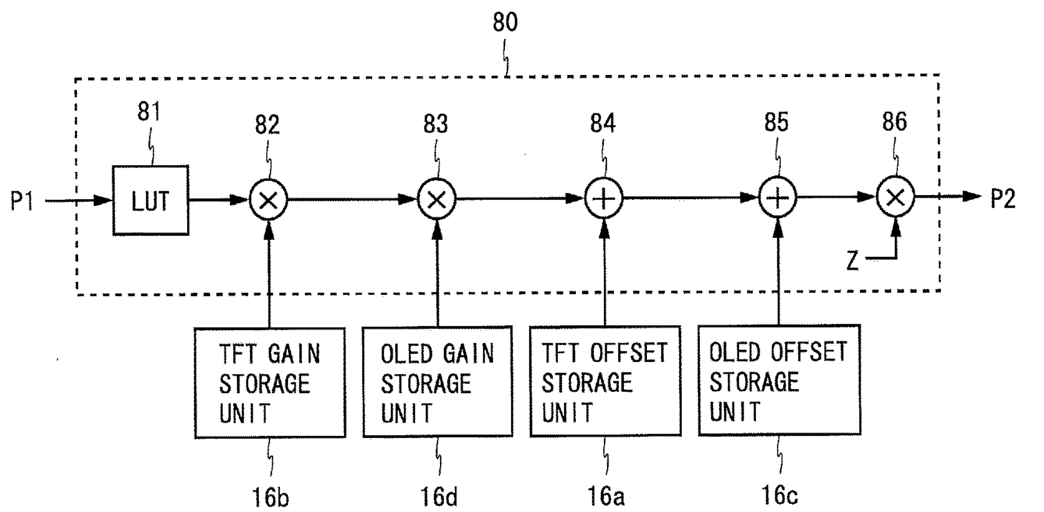

80
81
82
83
84
85
86
P1
LUT
P2
Z
TFT GAIN STORAGE UNIT
OLED GAIN STORAGE UNIT
TFT OFFSET STORAGE UNIT
OLED OFFSET STORAGE UNIT
16b
16d
16a
16c

Fig. 8

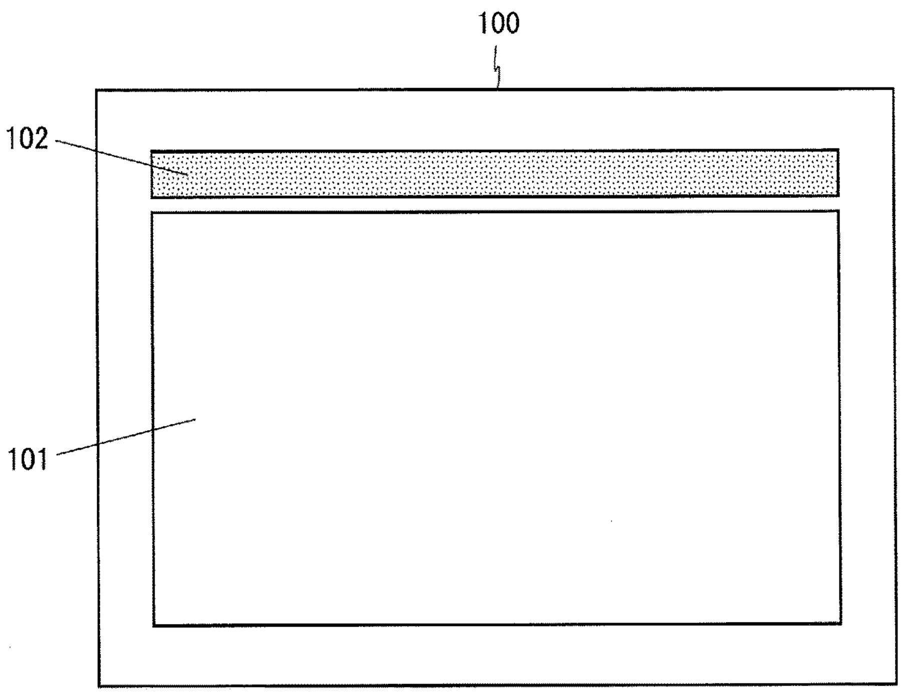


Fig. 9

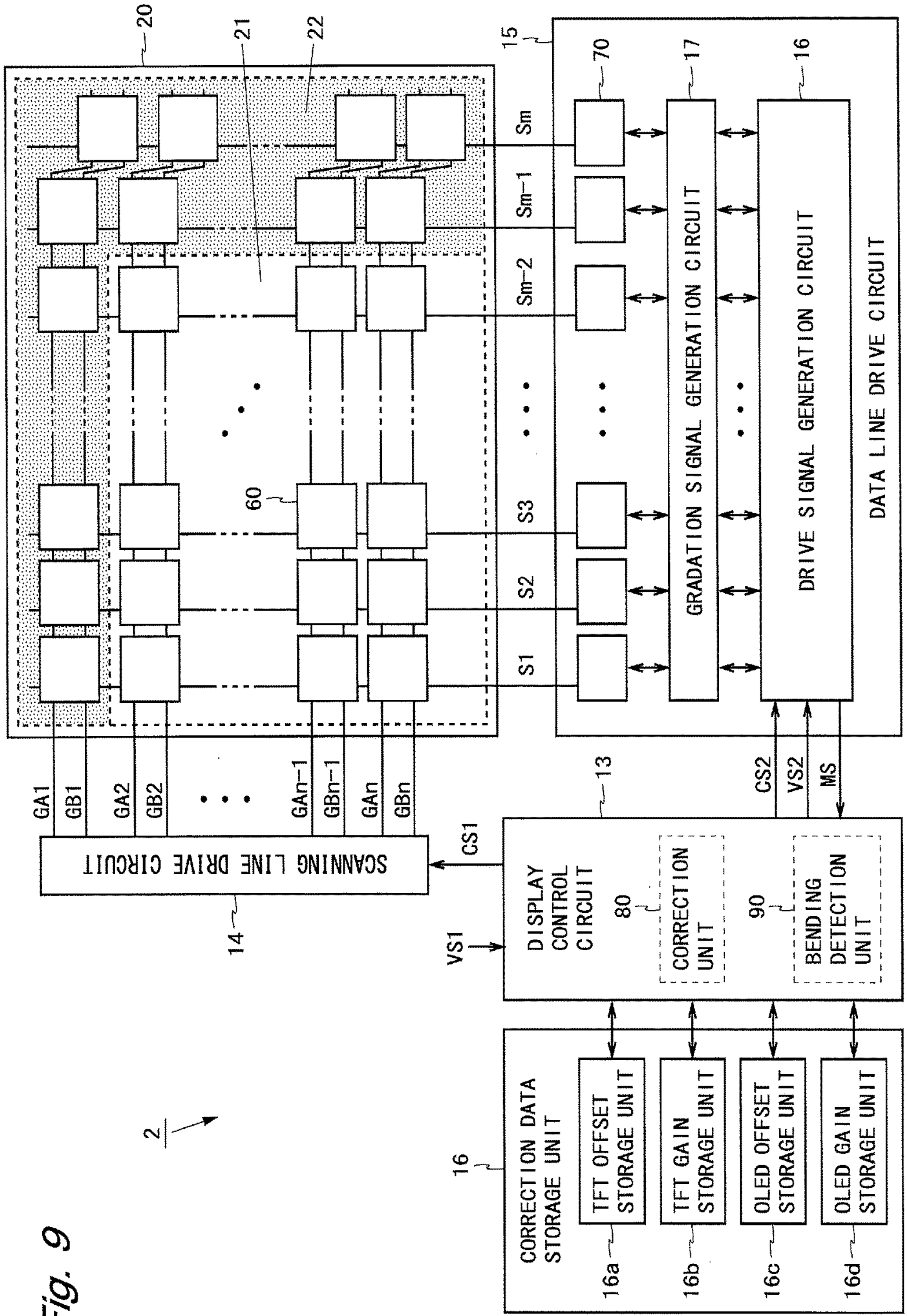

2
20
21
22
15
70
17
16
Sm
Sm−1
Sm−2
S3
S2
S1
60
DATA LINE DRIVE CIRCUIT
DRIVE SIGNAL GENERATION CIRCUIT
GRADATION SIGNAL GENERATION CIRCUIT
GA1
GB1
GA2
GB2
GAn−1
GBn−1
GAn
GBn
SCANNING LINE DRIVE CIRCUIT
14
CS1
13
CS2
VS2
MS
VS1
DISPLAY CONTROL CIRCUIT
80
CORRECTION UNIT
90
BENDING DETECTION UNIT
16
CORRECTION DATA STORAGE UNIT
16a
TFT OFFSET STORAGE UNIT
16b
TFT GAIN STORAGE UNIT
16c
OLED OFFSET STORAGE UNIT
16d
OLED GAIN STORAGE UNIT

Fig. 10

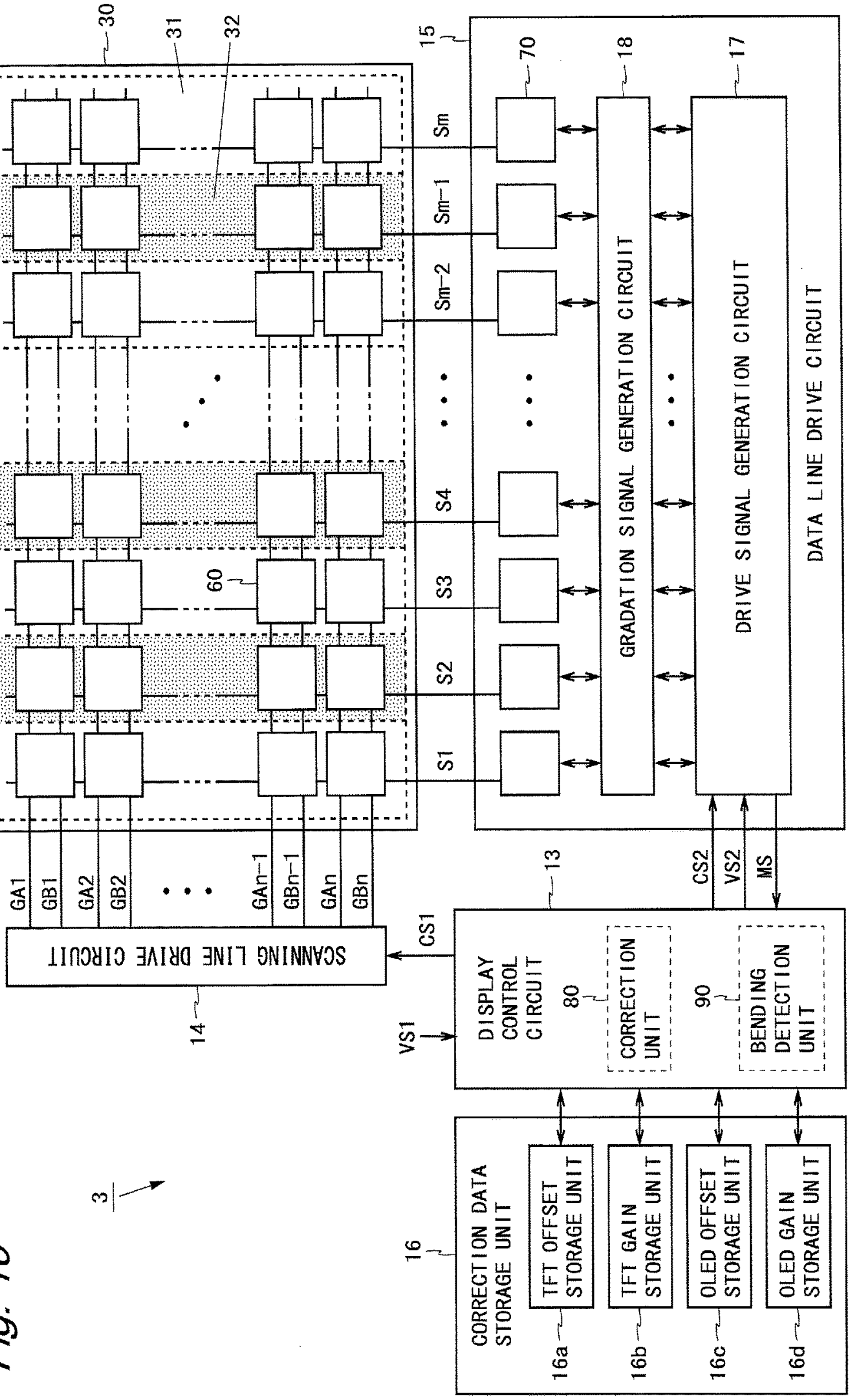

3
30
31
32
60
S1
S2
S3
S4
Sm-2
Sm-1
Sm
15
70
18
17
GRADATION SIGNAL GENERATION CIRCUIT
DRIVE SIGNAL GENERATION CIRCUIT
DATA LINE DRIVE CIRCUIT
GA1
GB1
GA2
GB2
GAn-1
GBn-1
GAn
GBn
SCANNING LINE DRIVE CIRCUIT
14
CS1
VS1
CS2
VS2
MS
13
DISPLAY CONTROL CIRCUIT
80
CORRECTION UNIT
90
BENDING DETECTION UNIT
16
CORRECTION DATA STORAGE UNIT
16a
TFT OFFSET STORAGE UNIT
16b
TFT GAIN STORAGE UNIT
16c
OLED OFFSET STORAGE UNIT
16d
OLED GAIN STORAGE UNIT

Fig. 11

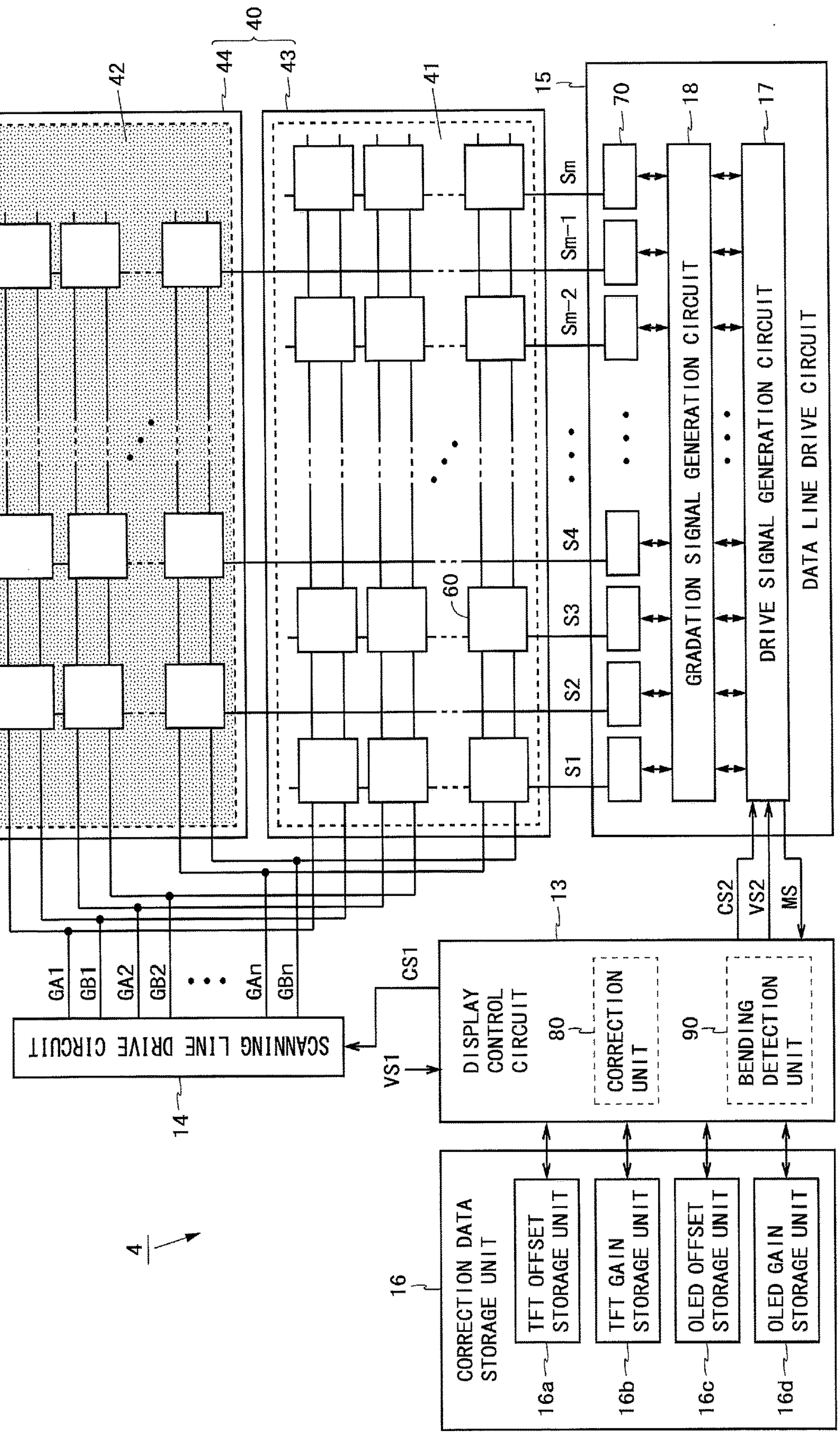

4
40
42
44
43
41
15
70
18
17
60
S1
S2
S3
S4
Sm-2
Sm-1
Sm
GRADATION SIGNAL GENERATION CIRCUIT
DRIVE SIGNAL GENERATION CIRCUIT
DATA LINE DRIVE CIRCUIT
CS2
VS2
MS
13
GA1
GB1
GA2
GB2
GAn
GBn
CS1
SCANNING LINE DRIVE CIRCUIT
14
VS1
DISPLAY CONTROL CIRCUIT
80
CORRECTION UNIT
90
BENDING DETECTION UNIT
16
CORRECTION DATA STORAGE UNIT
TFT OFFSET STORAGE UNIT
16a
TFT GAIN STORAGE UNIT
16b
OLED OFFSET STORAGE UNIT
16c
OLED GAIN STORAGE UNIT
16d

Fig. 12

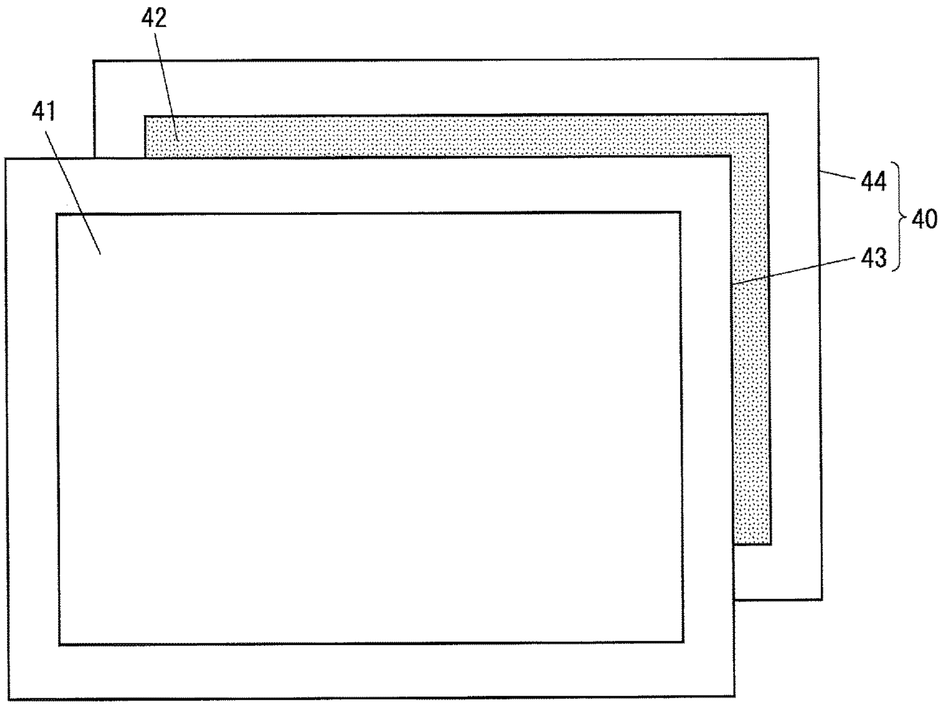
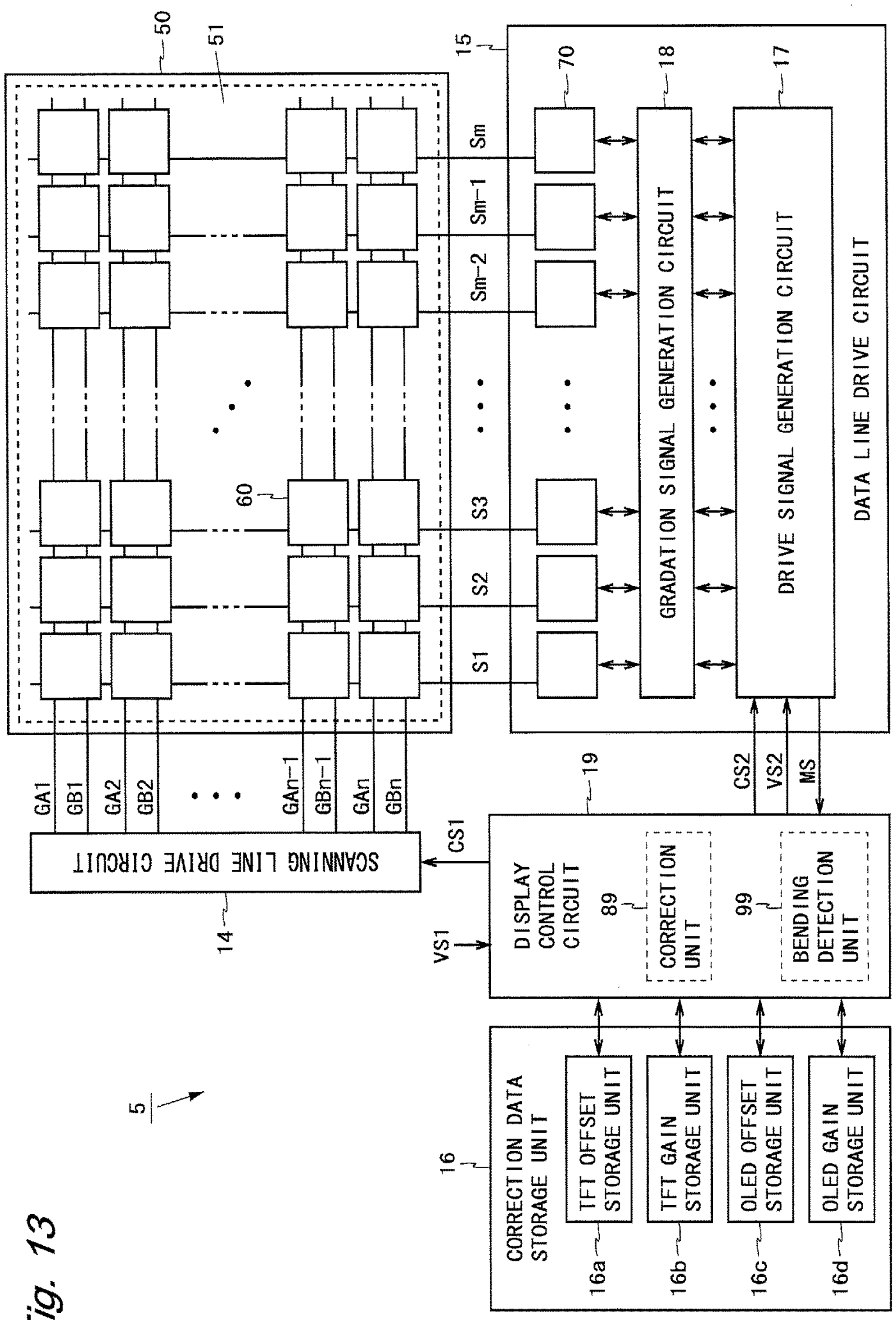


Fig. 13



5
50
51
60
GA1
GB1
GA2
GB2
GAn-1
GBn-1
GAn
GBn
SCANNING LINE DRIVE CIRCUIT
14
CS1
VS1
S1
S2
S3
Sm-2
Sm-1
Sm
15
70
18
17
GRADATION SIGNAL GENERATION CIRCUIT
DRIVE SIGNAL GENERATION CIRCUIT
DATA LINE DRIVE CIRCUIT
CS2
VS2
MS
19
DISPLAY CONTROL CIRCUIT
89
CORRECTION UNIT
99
BENDING DETECTION UNIT
16
CORRECTION DATA STORAGE UNIT
16a
TFT OFFSET STORAGE UNIT
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TFT GAIN STORAGE UNIT
16c
OLED OFFSET STORAGE UNIT
16d
OLED GAIN STORAGE UNIT

Fig. 14

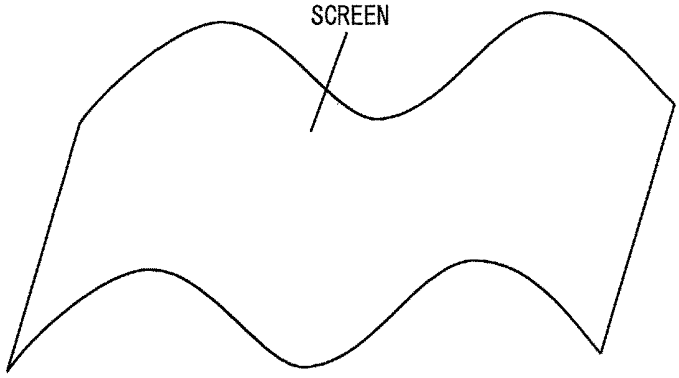


Fig. 15

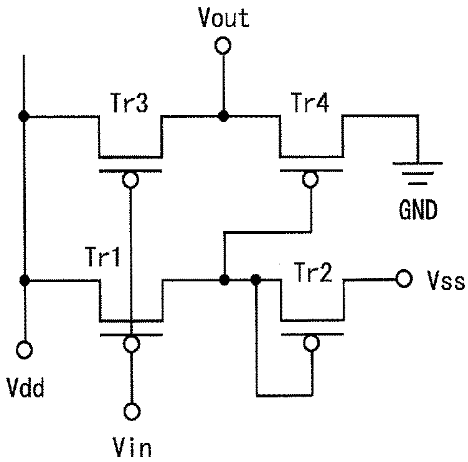
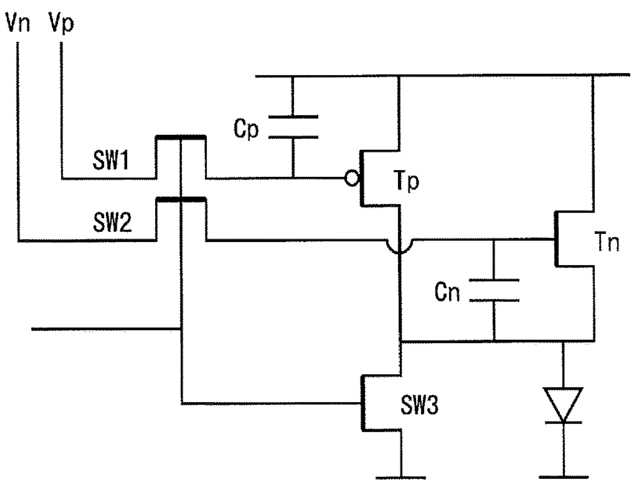


Fig. 16



FLEXIBLE DISPLAY DEVICE AND METHOD FOR DETECTING BENDING STATE THEREOF

TECHNICAL FIELD

[0001] The present invention relates to a display device, and in particular to a flexible display device having a bendable screen.

BACKGROUND ART

[0002] In recent years, an organic EL (Electro Luminescence) display device has been attracting attention as a thin, low-power consumption, high-speed response display device. The organic EL display device can be configured so that a screen is bendable at an arbitrary position, by using a plastic substrate or the like (see FIG. **14**). Hereinafter, a display device having a bendable screen is referred to as a "flexible display device".

[0003] For the flexible display device, the following techniques are known. Patent Document 1 describes a sensor device including a complementary type circuit shown in FIG. **15**. In the complementary type circuit shown in FIG. **15**, at least one of four transistors Tr**1** to Tr**4** is an organic TFT (Thin Film Transistor). Since an electrical characteristic of the organic TFT changes in accordance with a physical change, the organic TFT functions as a sensor element.

[0004] Patent document 2 describes a display device including a pixel circuit shown in FIG. **16**. The pixel circuit shown in FIG. **16** includes complementary type transistors Tp, Tn as drive elements. When the screen is bent, characteristics of the transistors Tp, Tn change in opposite directions. Since a current flowing through one transistor increases and a current flowing through the other transistor decreases, fluctuation in a current can be suppressed for the entire pixel circuit.

PRIOR ART DOCUMENTS

Patent Documents

[0005] [Patent Document 1] Japanese Laid-Open Patent Publication No. 2014-190699

[0006] [Patent Document 2] WO2005/109390

SUMMARY OF THE INVENTION

Problems to be Solved by the Invention

[0007] In the flexible display device, when the screen is bent, characteristics (threshold voltage, I-V characteristics, and the like) of a drive element in a pixel circuit change and an amount of a current flowing through the drive element to a light emitting element changes. Thus, the flexible display device has a problem that brightness or color may change when the screen is bent.

[0008] Conventional flexible display devices cannot solve this problem appropriately. For example, a method described in Patent Document 1 using the organic TFT as the sensor element has a problem that it is impossible to distinguish between TFT characteristics change caused by bending of the screen and TFT characteristics change caused by other factors. Furthermore, this method also has a problem that an amount of a detected current is large.

[0009] Therefore, an object of the present invention to provide a display device capable of detecting a bending state of a screen and prevent a change in brightness or color when the screen is bent.

Means for Solving the Problems

[0010] According to a first aspect of the present invention, there is provided a flexible display device including: a bendable display panel including a plurality of scanning lines, a plurality of data lines, and a plurality of pixel circuits each having a light emitting element and a drive element; a scanning line drive circuit configured to select the pixel circuits by driving the scanning lines; a data line drive circuit configured to perform, by driving the data lines, an operation of writing a voltage to a control terminal of the drive element and an operation of measuring a current flowing through the drive element for the pixel circuits selected by the scanning line drive circuit; and a bending detection unit configured to detect a bending state of the display panel based on a measurement result of the current flowing through the drive element.

[0011] According to a second aspect of the present invention, in the first aspect of the present invention, the pixel circuits are classified into display pixel circuits and measurement pixel circuits, and the bending detection unit is configured to detect the bending state of the display panel based on the measurement result of the current flowing through the drive element in the measurement pixel circuit.

[0012] According to a third aspect of the present invention, in the second aspect of the present invention, the display pixel circuits are arranged inside a display area, and the measurement pixel circuits are arranged outside the display area.

[0013] According to a fourth aspect of the present invention, in the third aspect of the present invention, the display area has a rectangular shape, and the measurement pixel circuits are arranged along two adjacent sides of the display area.

[0014] According to a fifth aspect of the present invention, in the third aspect of the present invention, the display area has a rectangular shape, and the measurement pixel circuits are arranged along one side of the display area.

[0015] According to a sixth aspect of the present invention, in the second aspect of the present invention, an arrangement manner of the measurement pixel circuits is different from an arrangement manner of the display pixel circuits.

[0016] According to a seventh aspect of the present invention, in the sixth aspect of the present invention, an arrangement interval of the measurement pixel circuits is different from an arrangement interval of the display pixel circuits.

[0017] According to an eighth aspect of the present invention, in the second aspect of the present invention, the display pixel circuits and the measurement pixel circuits are arranged inside a display area in a mixed manner.

[0018] According to a ninth aspect of the present invention, in the second aspect of the present invention, the display panel has a multi-layer structure including a layer in which the display pixel circuits are formed and a layer in which the measurement pixel circuits are formed.

[0019] According to a tenth aspect of the present invention, in the second aspect of the present invention, an electrical characteristic of the drive element in the measurement pixel circuit is different from an electrical characteristic of the drive element in the display pixel circuit.

[0020] According to an eleventh aspect of the present invention, in the tenth aspect of the present invention, a size of the drive element in the measurement pixel circuit is different from a size of the drive element in the display pixel circuit.

[0021] According to a twelfth aspect of the present invention, in the tenth aspect of the present invention, a type of the drive element in the measurement pixel circuit is different from a type of the drive element in the display pixel circuit.

[0022] According to a thirteenth aspect of the present invention, in the first aspect of the present invention, the flexible display device further includes a correction unit configured to correct a video signal based on the bending state detected by the bending detection unit, wherein the data line drive circuit is configured to apply, to the data lines, voltages based on the video signal corrected by the correction unit.

[0023] According to a fourteenth aspect of the present invention, in the thirteenth aspect of the present invention, the correction unit is configured to correct the video signal so as to compensate for a change of an amount of the current flowing through the drive element, the change caused by bending.

[0024] According to a fifteenth aspect of the present invention, in the fourteenth aspect of the present invention, the bending detection unit includes a first table configured to store a curvature of the display panel corresponding to a difference from an initial value with respect to an electrical characteristic of the drive element, and is configured to detect the curvature of the display panel as the bending state of the display panel by referring to the first table using an obtained difference from the initial value with respect to the electrical characteristic of the drive element, and the correction unit includes a second table configured to store a correction amount of the electrical characteristic of the drive element corresponding to the curvature of the display panel, and is configured to obtain the correction amount of the electrical characteristic of the drive element by referring to the second table using the curvature obtained by the bending detection unit and correct the video signal using the obtained correction amount.

[0025] According to a sixteenth aspect of the present invention, in the fourteenth aspect of the present invention, the correction unit is configured to obtain a first characteristic being an electrical characteristic of the drive element and a second characteristic being an electrical characteristic of the light emitting element, and the bending detection unit is configured to estimate, based on the second characteristic, a third characteristic being the electrical characteristic of the drive element when the display panel is not bent, and detect the bending state of the display panel by comparing the first characteristic and the third characteristic.

[0026] According to a seventeenth aspect of the present invention, in the thirteenth aspect of the present invention, the correction unit is configured to correct the video signal corresponding to a bent portion, to a non-display level.

[0027] According to an eighteenth aspect of the present invention, there is provided a method for detecting a bending state of a flexible display device having a bendable display panel including a plurality of scanning lines, a plurality of data lines, and a plurality of pixel circuits each having a light emitting element and a drive element, the method including steps of: selecting the pixel circuits by driving the scanning lines; performing, by driving the data lines, an operation of writing a voltage to a control terminal of the drive element and an operation of measuring a current flowing through the drive element for the pixel circuits selected using the scanning lines; and detecting a bending state of the display panel based on a measurement result of the current flowing through the drive element.

Effects of the Invention

[0028] According to the first or eighteenth aspect of the present invention, since an electrical characteristic of the drive element changes when a screen is bent, the bending state of the screen can be detected based on the measurement result of the current flowing through the drive element. Furthermore, a change in brightness or color when the screen is bent can be prevented by correcting a video signal based on the detected bending state.

[0029] According to the second aspect of the present invention, the measurement pixel circuits are provided separately from the display pixel circuits, and the bending state of the screen can be detected based on the measurement result of the current flowing through the drive element in the measurement pixel circuit.

[0030] According to the third aspect of the present invention, the bending state of the screen can be detected without affecting display by arranging the measurement pixel circuits outside the display area in which the display pixel circuits are arranged.

[0031] According to the fourth aspect of the present invention, the bending state of the screen can be detected even when the screen is bent in any direction by arranging the measurement pixel circuits along two perpendicular directions.

[0032] According to the fifth aspect of the present invention, the bending state of the screen can be detected when the screen is bent in a direction in which the measurement pixel circuits are arranged by arranging the measurement pixel circuits along one direction.

[0033] According to the sixth or seventh aspect of the present invention, the bending state of the screen can be detected with high accuracy by arranging the display pixel circuits and the measurement pixel circuits in different manners (different intervals).

[0034] According to the eighth aspect of the present invention, a local bending state of the screen can be detected by arranging the display pixel circuits and the measurement pixel circuits in the mixed manner.

[0035] According to the ninth aspect of the present invention, problems that occur when two types of pixel circuits are formed in the same layer can be solved by forming the display pixel circuits and the measurement pixel circuits in different layers.

[0036] According to the tenth, eleventh or twelfth aspect of the present invention, the bending state of the screen can be detected with high accuracy by making the electrical characteristic (size, type) of the drive element different between the display pixel circuit and the measurement pixel circuit.

[0037] According to the thirteenth aspect of the present invention, the change in brightness or color when the screen is bent can be prevented by correcting the video signal based on the detected bending state.

[0038] According to the fourteenth aspect of the present invention, the change in brightness or color when the screen is bent can be prevented by correcting the video signal to compensate for the change of the amount of the current flowing through the drive element, the change caused by bending.

[0039] According to the fifteenth aspect of the present invention, the curvature of the display panel can be detected by referring to the first table, and the correction amount of the electrical characteristic of the drive element can be obtained using the second table. Therefore, the video signal can be corrected based on the obtained correction amount, and the change in brightness or color when the screen is bent can be prevented.

[0040] According to the sixteenth aspect of the present invention, the bending state of the display panel can be detected, by estimating the electrical characteristic of the drive element when the display panel is not bent based on the electrical characteristic of the light emitting element and comparing the obtained electrical characteristic of the drive element and the estimated electrical characteristic of the drive element. Therefore, the video signal can be corrected based on the detected bending state, and the change in brightness or color when the screen is bent can be prevented.

[0041] According to the seventeenth aspect of the present invention, the change in brightness or color when the screen is bent can be hidden by correcting the video signal so as not to display the bent portion.

BRIEF DESCRIPTION OF THE DRAWINGS

[0042] FIG. **1** is a block diagram showing a configuration of an organic EL display device according to a first embodiment of the present invention.

[0043] FIG. **2** is a diagram showing a schematic configuration of an organic EL panel of the organic EL display device shown in FIG. **1**.

[0044] FIG. **3** is a diagram showing the organic EL panel shown in FIG. **2** in a bent state.

[0045] FIG. **4** is a circuit diagram of a pixel circuit and an output/measurement circuit of the organic EL display device shown in FIG. **1**.

[0046] FIG. **5** is a timing chart of the organic EL display device shown in FIG. **1**.

[0047] FIG. **6**A is a diagram showing an operation of the circuit shown in FIG. **4**.

[0048] FIG. **6**B is a diagram showing the operation of the circuit shown in FIG. **4**.

[0049] FIG. **6**C is a diagram showing the operation of the circuit shown in FIG. **4**.

[0050] FIG. **6**D is a diagram showing the operation of the circuit shown in FIG. **4**.

[0051] FIG. **6**E is a diagram showing the operation of the circuit shown in FIG. **4**.

[0052] FIG. **7** is a diagram for explaining a correction processing in a correction unit of the organic EL display device shown in FIG. **1**.

[0053] FIG. **8** is a diagram showing a schematic configuration of an organic EL panel of an organic EL display device according to a modification of the first embodiment of the present invention.

[0054] FIG. **9** is a block diagram showing a configuration of an organic EL display device according to a second embodiment of the present invention.

[0055] FIG. **10** is a block diagram showing a configuration of an organic EL display device according to a third embodiment of the present invention.

[0056] FIG. **11** is a block diagram showing a configuration of an organic EL display device according to a fourth embodiment of the present invention.

[0057] FIG. **12** is a diagram showing a configuration of an organic EL panel of the organic EL display device shown in FIG. **11**.

[0058] FIG. **13** is a block diagram showing a configuration of an organic EL display device according to a fifth embodiment of the present invention.

[0059] FIG. **14** is a diagram showing a screen of a flexible display device in a bent state.

[0060] FIG. **15** is a circuit diagram of a complementary type circuit included in a conventional sensor device.

[0061] FIG. **16** is a circuit diagram of a pixel circuit included in a conventional display device.

MODES FOR CARRYING OUT THE INVENTION

First Embodiment

[0062] FIG. **1** is a block diagram showing a configuration of an organic EL display device according to a first embodiment of the present invention. An organic EL display device **1** shown in FIG. **1** includes an organic EL panel **10**, a display control circuit **13**, a scanning line drive circuit **14**, a data line drive circuit **15**, and a correction data storage unit **16**. The organic EL display device **1** is a flexible display device having a bendable screen and has a function of detecting a bending state of the screen. Hereinafter, it is assumed that m and n are integers not less than 2, i is an integer not less than 1 and not more than n, and j is an integer not less than 1 and not more than m.

[0063] As shown in FIG. **1**, the organic EL panel **10** includes 2n scanning lines GA**1** to GAn, GB**1** to GBn, m data lines S**1** to Sm, and (m=n) pixel circuits **60**. The scanning lines GA**1** to GAn, GB**1** to GBn are arranged in parallel with each other. The data lines S**1** to Sm are arranged in parallel with each other so as to intersect with the scanning lines GA**1** to GAn, GB**1** to GBn perpendicularly. The scanning lines GA**1** to GAn and the data lines S**1** to Sm intersect at (m=n) positions. The (m=n) pixel circuits **60** are arranged corresponding to (m=n) intersections. Each pixel circuit **60** is connected to one scanning line and one data line. Hereinafter, an extending direction of the scanning lines GA**1** to GAn, GB**1** to GBn is referred to as a row direction, and an extending direction of the data lines S**1** to Sm is referred to as a column direction.

[0064] The display control circuit **13** is a control circuit of the organic EL display device **1**, and includes a correction unit **80** and a bending detection unit **90**. To the display control circuit **13**, a video signal VS**1** is input from an outside of the organic EL display device **1**. The display control circuit **13** outputs a control signal CS**1** to the scanning line drive circuit **14** and outputs a control signal CS**2** and a video signal VS**2** to the data line drive circuit **15**. The control signal CS**1** includes, for example, a gate start pulse, a gate clock, and the like. The control signal CS**2** includes, for example, a source start pulse, a source clock, and the like. The video signal VS**2** is obtained by performing a correction processing on the video signal VS**1** in the correction unit **80**. Details of the correction unit **80** and the bending detection unit **90** will be described later.

[0065] The scanning line drive circuit **14** selects the pixel circuits **60** by driving the scanning lines GA**1** to GAn, GB**1** to GBn. More specifically, the scanning line drive circuit **14** selects one scanning line from among the scanning lines GA**1** to GAn based on the control signal CS**1**, and applies an ON level voltage (here, a high-level voltage) to the selected scanning line. With this, m pixel circuits **60** connected to the selected scanning line are selected collectively. The data line drive circuit **15** drives the data lines S**1** to Sm based on the control signal CS**2** and the video signal VS**2**. More specifically, the data line drive circuit **15** applies m voltages in accordance with the video signal VS**2** (hereinafter referred to as data voltages) to the data lines S**1** to Sm, respectively in accordance with the control signal CS**2**. With this, them data voltages are written to the selected m pixel circuits **60**, respectively.

[0066] The data line drive circuit **15** includes a drive signal generation circuit **17**, a gradation signal generation circuit **18**, and m output/measurement circuits (a combination of an output circuit and a measurement circuit) **70**. Each output/measurement circuit **70** corresponds to one of the data lines S**1** to Sm. The drive signal generation circuit **17** generates control signals for driving the data lines S**1** to Sm. The gradation signal generation circuit **18** generates the data voltages to be applied to the data lines S**1** to Sm as gradation signals. The output/measurement circuit **70** has a function of applying the data voltage to the corresponding data line and a function of measuring a current flowing through the corresponding data line. The data voltage applied to the data line is written to a gate terminal of a drive element in the pixel circuit **60**. The current flowing through the data line is a current flowing through the drive element in the pixel circuit **60**. The data line drive circuit **15** outputs a monitor signal MS indicating a measurement result of the current flowing through the data line (that is, the current flowing through the drive element in the pixel circuit **60**) to the display control circuit **13**. In this manner, the data line drive circuit **15** performs, by driving the data lines S**1** to Sm, an operation of writing a voltage to the gate terminal of the drive element and an operation of measuring the current flowing through the drive element for the pixel circuits **60** selected by the scanning line drive circuit **14**.

[0067] The correction unit **80** obtains the video signal VS**2** by obtaining characteristics of the drive element and an organic EL element in the pixel circuit **60** based on the monitor signal MS and correcting the video signal VS**1** using the obtained characteristics. The correction data storage unit **16** is a working memory of the correction unit **80**. The correction data storage unit **16** includes a TFT offset storage unit **16***a*, a TFT gain storage unit **16***b*, an OLED offset storage unit **16***c*, and an OLED gain storage unit **16***d*. The TFT offset storage unit **16***a* stores a threshold voltage of the drive element for each pixel circuit **60**. The TFT gain storage unit **16***b* stores a gain of the drive element for each pixel circuit **60**. The OLED offset storage unit **16***c* stores a threshold voltage of the organic EL element for each pixel circuit **60**. The OLED gain storage unit **16***d* stores a gain of the organic EL element for each pixel circuit **60**.

[0068] FIG. **2** is a diagram showing a schematic configuration of the organic EL panel **10**. As shown in FIG. **2**, the organic EL panel **10** includes a display unit **11** and a detection unit **12**. The display unit **11** includes the pixel circuits **60** in second to n-th rows and first to (m−1)-th columns, and the detection unit **12** includes the pixel circuits **60** in a first row or an m-th column (see FIG. **1**). The display unit **11** has a rectangular shape, and the detection unit **12** is provided along two adjacent sides (an upper side and a right side in FIG. **2**) of the display unit **11**.

[0069] Hereinafter, the pixel circuit included in the display unit **11** is referred to as a "display pixel circuit", and the pixel circuit included in the detection unit **12** is referred to as a "measurement pixel circuit". The (m×n) pixel circuits **60** are classified into the display pixel circuits and the measurement pixel circuits. In the present embodiment, the display pixel circuits are arranged inside a display area, and the measurement pixel circuits are arranged outside the display area. More specifically, the display area has a rectangular shape, and the measurement pixel circuits are arranged along two adjacent sides of the display area.

[0070] The organic EL panel **10** is configured so as to be bendable at an arbitrary position in the row direction and the column direction, by using a plastic substrate or the like. FIG. **3** is a diagram showing the organic EL panel **10** in a bent state. In FIG. **3**, the organic EL panel **10** is bent three times in the row direction.

[0071] The scanning lines GA**1** to GAn, GB**1** to GBn, the data lines S**1** to Sm, and the (m=n) pixel circuits **60** are formed on the organic EL panel **10** shown in FIG. **1**. In addition, all or a part of other circuits included in the organic EL display device **1** (the display control circuit **13**, the scanning line drive circuit **14**, the data line drive circuit **15**, and the correction data storage unit **16**) may be formed on the organic EL panel **10**. The same holds true for each embodiment described later.

[0072] FIG. **4** is a circuit diagram of the pixel circuit **60** and the output/measurement circuit **70**. FIG. **4** describes the pixel circuit **60** in an i-th row and a j-th column and the output/measurement circuit **70** corresponding to a data line Sj. The pixel circuit **60** includes transistors **61** to **63**, an organic EL element **64**, and a capacitor **65**. The transistors **61** to **63** are N-channel type TFTs. A drain terminal of the transistor **61** is connected to a high-level power supply line having a high-level power supply potential ELVDD. A gate terminal of the transistor **61** is connected to one conduction terminal (right-side conduction terminal in FIG. **4**) of the transistor **62**. A source terminal of the transistor **61** is connected to an anode terminal of the organic EL element **64** and one conduction terminal (right-side conduction terminal in FIG. **4**) of the transistor **63**. A cathode terminal of the organic EL element **64** is connected to a low-level power supply line having a low-level power supply potential ELVSS. The other conduction terminals of the transistors **62**, **63** are connected to the data line Sj. A gate terminal of the transistor **62** is connected to a scanning line GAi, and a gate terminal of the transistor **63** is connected to a scanning line GBi. The capacitor **65** is provided between the drain terminal and the gate terminal of the transistor **61**. The transistor **61** functions as a drive element and the organic EL element **64** functions as a light emitting element.

[0073] The output/measurement circuit **70** includes an operational amplifier **71**, a capacitor **72**, and a switch **73**. A data voltage DVj output from a D/A conversion circuit (not shown) included in the gradation signal generation circuit **18** is applied to a non-inverting input terminal of the operational amplifier **71**. An inverting input terminal of the operational amplifier **71** is connected to the data line Sj. One end of the capacitor **72** is connected to the inverting input terminal of the operational amplifier **71**, and the other end of the capacitor **72** is connected to an output terminal of the operational amplifier **71**. Similarly, one end of the switch **73** is connected to the inverting input terminal of the operational amplifier **71**, and the other end of the switch **73** is connected to the output terminal of the operational amplifier **71**. In this manner, the capacitor **72** and the switch **73** are provided in parallel between the inverting input terminal and the output terminal of the operational amplifier **71**.

[0074] When the switch **73** is in an ON state, the operational amplifier **71** functions as a buffer amplifier. At this time, the non-inverting input terminal and the inverting input terminal of the operational amplifier **71** are short-circuited virtually, and the data voltage DVj applied to the non-inverting input terminal of the operational amplifier **71** is applied to the data line Sj. When the switch **73** is in an OFF state, the operational amplifier **71** and the capacitor **72** function as an integration amplifier. At this time, an output voltage of the operational amplifier **71** changes in accordance with an amount of the current flowing through the data line Sj. In this manner, the output/measurement circuit **70** selectively performs an operation of applying the data voltage to the data line Sj and an operation of measuring the current flowing through the data line Sj, in accordance with a state of the switch **73**.

[0075] The organic EL display device **1** measures the currents for the pixel circuits **60** in one row in one frame period. Hereinafter, a row for which the currents are measured in a certain frame period is referred to as a measurement target row, and other rows are referred to as normal rows. The measurement target row is switched every frame period. When the i-th row is the normal row, the scanning line drive circuit **14** applies the ON level voltage to the scanning line GAi, and the data line drive circuit **15** applies m data voltages to be written to the pixel circuits **60** in the i-th row, to the data lines S**1** to Sm. When the i-th row is the measurement target row, the scanning line drive circuit **14** and the data line drive circuit **15** drive the scanning lines GAi, GBi and the data lines S**1** to Sm as shown in FIG. **5**.

[0076] FIG. **5** is a timing chart of the organic EL display device **1**. FIG. **5** shows changes in voltages of the scanning lines GAi, GBi and the data line Sj in a case where the i-th row is the measurement target row. In FIG. **5**, periods T**1** to T**3** constitute a current measurement period of the pixel circuits **60** in the i-th row, and a period T**4** is a voltage write period after the current measurement period of the pixel circuits **60** in the i-th row. FIG. **6**A to **6**E are diagrams showing an operation of the circuit shown in FIG. **4**. The operation of the circuit shown in FIG. **4** will be described below with reference to FIG. **5** and FIGS. **6**A to **6**E.

[0077] Before the period T**1**, the potentials of the scanning lines GAi, GBi are at a low level. At this time, the transistors **62**, **63** are in the OFF state (see FIG. **6**A). A gate voltage of the transistor **61** is kept at a data voltage prev_DV (i, j) written previously, by an action of the capacitor **65**. The transistor **61** is in the ON state, and a current Ip in accordance with a gate-source voltage of the transistor **61** flows through the transistor **61** and the organic EL element **64**. The organic EL element **64** emits light at a brightness in accordance with the previous data voltage prev_DV(i,j).

[0078] In the period T**1**, the potential of the scanning line GAi becomes a high level. Thus, the transistor **62** becomes the ON state (see FIG. **6**B). Furthermore, in the period T**1**, the switch **73** becomes the ON state, and a reference voltage Vmg is applied to the non-inverting input terminal of the operational amplifier **71**. Since the operational amplifier **71** functions as the buffer amplifier, the reference voltage Vmg is applied to the data line Sj and the gate voltage of the transistor **61** becomes Vmg.

[0079] In the period T**2**, the potential of the scanning line GAi becomes the low level and the potential of the scanning line GBi becomes the high level. Thus, the transistor **62** becomes the OFF state and the transistor **63** becomes the ON state (see FIG. **6**C). Furthermore, in the period T**2**, the switch **73** becomes the OFF state, and a first measurement voltage Vm_TFT for obtaining characteristics of the transistor **61** is applied to the non-inverting input terminal of the operational amplifier **71**. The first measurement voltage Vm_TFT is determined so that a current Ia flows from the high-level power supply line via the transistor **61** and the transistor **63** to the output/measurement circuit **70** at this time. The operational amplifier **71** and the capacitor **72** function as the integration amplifier, and the operational amplifier **71** outputs a voltage Vma in accordance with the current Ia. The current Ia flowing through the transistor **61** in the period T**2** can be measured by converting the voltage Vma to a current value.

[0080] In the period T**3**, a second measurement voltage Vm_OLED for obtaining characteristics of the organic EL element **64** is applied to the non-inverting input terminal of the operational amplifier **71** (see FIG. **6**D). The second measurement voltage Vm_OLED is determined so that a current Ib flows from the output/measurement circuit **70** through the transistor **63** and the organic EL element **64** to the low-level power supply line at this time. The operational amplifier **71** and the capacitor **72** function as the integration amplifier, and the operational amplifier **71** outputs a voltage Vmb in accordance with the current Ib. The current Ib flowing through the organic EL element **64** in the period T**3** can be measured by converting the voltage Vmb to a current value.

[0081] In the period T**4**, the potential of the scanning line GAi becomes the high level and the potential of the scanning line GBi becomes the low level. Thus, the transistor **62** becomes the ON state and the transistor **63** becomes the OFF state (see FIG. **6**E). Furthermore, in the period T**4**, the switch **73** becomes the ON state, and a new data voltage DV(i,j) is applied to the non-inverting input terminal of the operational amplifier **71**. Since the operational amplifier **71** functions as the buffer amplifier, the data voltage DV(i,j) is applied to the data line Sj and the gate voltage of the transistor **62** becomes DV(i,j).

[0082] After the period T**4**, the potentials of the scanning lines GAi, GBi become the low level. Therefore, as before the period T**1**, a current Ic in accordance with the gate-source voltage of the transistor **61** flows through the organic EL element **64**. The organic EL element **64** emits light at a brightness in accordance with the data voltage DV(i,j) written in the period T**4**.

[0083] In the period T**2**, when the reference voltage Vmg is applied to the gate terminal of the transistor **61** and the first measurement voltage Vm_TFT is applied to the source terminal of the transistor **61**, the current Ia flowing through the transistor **61** is measured. In the period T**3**, when the second measurement voltage Vm_OLED is applied to the anode terminal of the organic EL element **64**, the current Ib flowing through the organic EL element **64** is measured.

[0084] In the timing chart shown in FIG. **5**, the voltage write period T**4** is provided after the current measurement period T**1** to T**3**, and the organic EL element **64** emits light after the period T**4**. Alternatively, a black write period may be provided after the current measurement period T**1** to T**3**, and the organic EL element **64** may not emit light after the period T**4**.

[0085] Hereinafter, the correction unit **80** will be described. As described above, the data line drive circuit **15** outputs the monitor signal MS indicating the measurement result of the current flowing through the data line, to the display control circuit **13**. The correction unit **80** obtains the threshold voltage and the gain of the transistor **61** for each pixel circuit **60** based on the measurement result of the current Ia flowing through the transistor **61** (specifically, a result of converting a measurement result of the output voltage Vma of the operational amplifier **71** in the period T**2**, to the current value). The obtained threshold voltage and gain are stored in the TFT offset storage unit **16***a* and the TFT gain storage unit **16***b*, respectively. Furthermore, the correction unit **80** obtains the threshold voltage and the gain of the organic EL element **64** for each pixel circuit **60** based on the measurement result of the current Ib flowing through the organic EL element **64** (specifically, a result of converting a measurement result of the output voltage Vmb of the operational amplifier **71** in the period T**3**, to a current value). The obtained threshold voltage and gain are stored in the OLED offset storage unit **16***c* and the OLED gain storage unit **16***d*, respectively.

[0086] The correction unit **80** may obtain the threshold voltage and the gain of the transistor **61** by an arbitrary method based on the measurement result of the current Ia, and may obtain the threshold voltage and the gain of the organic EL element **64** by an arbitrary method based on the measurement result of the current Ib. For example, the correction unit **80** may measure the current Ia when a relatively low first measurement voltage is applied and the current Ia when a relatively high first measurement voltage is applied for each pixel circuit **60**, and may obtain the threshold voltage and the gain of the transistor **61** by solving an equation in which the threshold voltage and the gain are unknown. Alternatively, for each pixel circuit **60**, the correction unit **80** may update the threshold voltage of the transistor **61** stored in the TFT offset storage unit **16***a* in accordance with a comparison result between the measurement result of the current Ia when the relatively low first measurement voltage is applied and an ideal value of the current Ia, and may update the gain of the transistor **61** stored in the TFT gain storage unit **16***b* in accordance with a comparison result between the measurement result of the current Ia when the relatively high first measurement voltage is applied and the ideal value of the current Ia.

[0087] FIG. **7** is a diagram for explaining a correction processing in the correction unit **80**. As shown in FIG. **7**, the correction unit **80** includes a lookup table (hereinafter referred to as a LUT) **81**, multipliers **82**, **83**, **86**, and adders **84**, **85**. Hereinafter, a processing on a gradation data P**1** of a certain pixel included in the video signal VS**1** will be described. Here, the pixel circuit corresponding to this pixel is referred to as PX.

[0088] The LUT **81** performs a gamma correction on the gradation data P**1**. The multiplier **82** multiplies the gradation data after the gamma correction by the gain of the transistor **61** in the pixel circuit PX, the gain read out from the TFT gain storage unit **16***b*. The multiplier **83** multiplies an output of the multiplier **82** by the gain of the organic EL element **64** in the pixel circuit PX, the gain read from the OLED gain storage unit **16***d*. The adder **84** adds, to an output of the multiplier **83**, the threshold voltage of the transistor **61** in the pixel circuit PX, the threshold voltage read from the TFT offset storage unit **16***a*. The adder **85** adds, to an output of the adder **84**, the threshold voltage of the organic EL element **64** in the pixel circuit PX, the threshold voltage read from the OLED offset storage unit **16***c*. The multiplier **86** multiplies an output of the adder **85** by a coefficient Z for compensating for an attenuation of the data voltage. An output of the multiplier **86** becomes a corrected gradation data P**2** subjected to the correction processing on the gradation data P**1**. The video signal VS**2** output from the display control circuit **13** includes the corrected gradation data P**2**.

[0089] Hereinafter, the bending detection unit **90** will be described. As described above, the correction unit **80** obtains the threshold voltage and the gain of the transistor **61** for the pixel circuit **60** included in the organic EL panel **10**. This processing is performed not only for the display pixel circuits included in the display unit **11** but also for the measurement pixel circuits included in the detection unit **12**. When the organic EL panel **10** is bent, a channel region (a region where drain/source electrodes and a gate electrode overlap in a planer view) of the transistor **61** in the measurement pixel circuit is deformed. Accordingly, electrical characteristics (threshold voltage and I-V characteristic) of the transistor **61** in the measurement pixel circuit change, and the amount of the current flowing through the transistor **61** in the measurement pixel circuit changes. Thus, the bending detection unit **90** detects a bending state of the organic EL panel **10** based on a change in the amount of the current flowing through the transistor **61** in the measurement pixel circuit.

[0090] The bending detection unit **90** stores an initial value Vth**0** of the threshold voltage and an initial value β**0** of the gain of the transistor **61** for each measurement pixel circuit. Here, the initial value means a value obtained at first after a power is supplied to the organic EL display device **1**. When the correction unit **80** obtains the threshold voltage Vth and the gain β of the transistor **61** in the measurement pixel circuit, the correction unit **80** outputs these values to the bending detection unit **90**. The bending detection unit **90** calculates a difference ΔVth (=Vth−Vth**0**) between the initial value Vth**0** of the threshold voltage and the newly obtained threshold voltage Vth, and a difference Δβ (=β-β**0**) between the initial value β**0** of the gain and the newly obtained gain. Based on the obtained differences ΔVth, Δβ, the bending detection unit **90** obtains the bending state of the organic EL panel **10** at a position of the measurement pixel circuit. The bending detection unit **90** may determine whether the organic EL panel **10** is bent, may obtain a value indicating a degree of bending of the organic EL panel **10** in a stepwise manner, or may obtain a bending amount as a numerical value. The bending detection unit **90** outputs the detected bending state to the correction unit **80**.

[0091] The correction unit **80** corrects the video signal VS**1** based on the bending state detected by the bending detection unit **90**. More specifically, based on the bending state detected by the bending detection unit **90**, the correction unit **80** corrects the video signal VS**1** so as to compensate for a change of the amount of the current flowing through the transistor **61** in the display pixel circuit, the change caused by bending. For example, the bending detection unit **90** includes a curvature LUT for storing a curvature of the organic EL panel **10** corresponding to a combination of values of the differences ΔVth, Δβ, and obtains the curvature of the organic EL panel **10** at the position of the measurement pixel circuit by referring to the curvature LUT using the obtained differences ΔVth, Δβ. The correction unit **80** includes a correction LUT for storing correction amounts of the threshold voltage and the gain of the transistor **61** corresponding to the curvature, obtains the correction amounts of the threshold voltage and the gain of the transistor **61** by referring to the correction LUT using the curvature obtained by the correction unit **80**, and corrects the video signal VS**1** using the obtained correction amounts. A change in brightness or color when the screen is bent can be prevented by correcting the video signal VS**1** in this manner. Alternatively, the correction unit **80** may correct the video signal VS**1** corresponding to a bent portion, to a non-display level (for example, black level) based on the bending state detected by the bending detection unit **90**. With this, the change in brightness or color when the screen is bent can be hidden.

[0092] The bending state detected by the bending detection unit **90** can be used for other than described above. For example, when the organic EL panel has a touch panel function, the display control circuit may stop the touch panel function when detecting that the organic EL panel is bent.

[0093] As described above, the organic EL display device **1** according to the present embodiment includes a bendable display panel (organic EL panel **10**) having a plurality of the scanning lines GA**1** to GAn, GB**1** to GBn, a plurality of the data lines S**1** to Sm, and a plurality of the pixel circuits **60** each having the drive element (transistor **61**) and the light emitting element (organic EL element **64**), the scanning line drive circuit **14** for selecting the pixel circuits **60** by driving the scanning lines GA**1** to GAn, GB**1** to GBn, the data line drive circuit **15** for performing, by driving the data lines S**1** to Sm, an operation of writing a voltage to a control terminal of the drive element (gate terminal of the transistor **61**) and an operation of measuring the current flowing through the drive element for the pixel circuit **60** selected by the scanning line drive circuit **14**, and the bending detection unit **90** for detecting the bending state of the display panel based on the measurement result of the current Ia flowing through the drive element. According to the organic EL display device **1** according to the present embodiment, since an electrical characteristic of the drive element changes when the screen is bent, the bending state of the screen can be detected based on the measurement result of the current flowing through the drive element.

[0094] Furthermore, the pixel circuits **60** are classified into the display pixel circuits (pixel circuits included in the display unit **11**) and the measurement pixel circuits (pixel circuits included in the detection unit **12**), and the bending detection unit **90** detects the bending state of the display panel based on the measurement result of the current flowing through the drive element in the measurement pixel circuit. In this manner, the measurement pixel circuits are provided separately from the display pixel circuits, and the bending state of the screen can be detected based on the measurement result of the current flowing through the drive element in the measurement pixel circuit. Furthermore, the display pixel circuits are arranged inside the display area, and the measurement pixel circuits are arranged outside the display area. The bending state of the screen can be detected without affecting display by arranging the measurement pixel circuits outside the display area in which the display pixel circuits are arranged in this manner. Furthermore, the display area has the rectangular shape, and the measurement pixel circuits are arranged along two adjacent sides of the display area. With this, the bending state of the screen can be detected even when the screen is bent in any direction.

[0095] Furthermore, the organic EL display device **1** includes the correction unit **80** for correcting the video signal VS**1** based on the bending state detected by the bending detection unit **90**, and the data line drive circuit **15** applies, to the data lines S**1** to Sm, voltages based on the video signal VS**2** corrected by the correction unit **80**. The change in brightness or color when the screen is bent can be prevented by correcting the video signal VS**1** based on the detected bending state in this manner. The correction unit **80** may correct the video signal VS**1** so as to compensate for the change of the amount of the current flowing through the drive element, the change caused by bending. The change in brightness or color when the screen is bent can be prevented by correcting the video signal to compensate for the change of the amount of the current flowing through the drive element, the change caused by bending. Furthermore, the correction unit **80** may correct the video signal VS**1** corresponding to the bent portion, to the non-display level. The change in brightness or color when the screen is bent can be hidden by correcting the video signal VS**1** so as to not display the bent portion in this manner.

[0096] In the organic EL display device **1**, the measurement pixel circuits are arranged along two sides of the display area. Alternatively, the measurement pixel circuits may be arranged along one side of the display area, as shown in FIG. **8**. In an organic EL panel **100** shown in FIG. **8**, a display unit **101** has a rectangular shape, and a detection unit **102** is provided along one side (upper side in FIG. **8**) of the display unit **101**. The display unit **101** includes the pixel circuits in the second to n-th rows, and the detection unit **12** includes the pixel circuits in the first row. The bending state of the screen can be detected when the screen is bent in a direction in which the measurement pixel circuits are arranged by arranging the measurement pixel circuits along one direction in this manner.

Second Embodiment

[0097] FIG. **9** is a block diagram showing a configuration of an organic EL display device according to a second embodiment of the present invention. An organic EL display device **2** shown in FIG. **9** is obtained by replacing the organic EL panel **10** with an organic EL panel **20**, in the organic EL display device **1** according to the first embodiment. Hereinafter, among constituent elements of each embodiment, the same elements as those of the first embodiment are provided with the same reference numerals, and the description thereof will be omitted.

[0098] The organic EL panel **20** is different from the organic EL panel **10** in the following points. The organic EL panel **20** has a display unit **21** and a detection unit **22**. The display unit **21** includes the pixel circuits **60** in the second to n-th rows and the first to (m−2)-th columns, and the detection unit **22** includes the pixel circuits **60** in the first row or the (m−1)-th to m-th columns. The pixel circuits **60** in the m-th column are arranged at positions shifted by ½ row from the pixel circuits **60** in the (m−1)-th column (positions shifted downward in FIG. **9**). In this manner, in the organic EL display device **2**, an arrangement manner of the measurement pixel circuits is different from an arrangement manner of the display pixel circuits. Furthermore, an arrangement interval of the measurement pixel circuits is different from an arrangement interval of the display pixel circuits, and is half of the arrangement interval of the display pixel circuits.

[0099] In the organic EL display device **1** according to the first embodiment, the measurement pixel circuits are arranged in the same manner as the display pixel circuits. Specifically, in the organic EL display device **1**, the measurement pixel circuits are arranged in the same arrangement interval as that of the display pixel circuits to form one column. According to the organic EL display device **1**, the bending state of the organic EL panel **10** can be obtained with an accuracy of the arrangement interval of the display pixel circuits.

[0100] On the other hand, in the organic EL display device **2**, the measurement pixel circuits are arranged to form two columns, and the measurement pixel circuits in two columns are arranged at positions shifted by ½ row of the arrangement interval of the display pixel circuits. Specifically, the pixel circuits **60** in the (m−1)-th column are arranged in the same manner as the display pixel circuits, and the pixel circuits **60** in the m-th column are arranged in positions shifted by ½ row from the display pixel circuits. Therefore, according to the organic EL display device **2**, the bending state of the organic EL panel **20** can be obtained with higher accuracy than the organic EL display device **1** (with an accuracy of ½ of the arrangement interval of the display pixel circuits).

[0101] As described above, in the organic EL display device **2** according to the present embodiment, the arrangement manner (arrangement interval) of the measurement pixel circuits is different from the arrangement manner of the display pixel circuits. According to the organic EL display device **2**, the bending state of the screen can be detected with high accuracy by arranging the display pixel circuits and the measurement pixel circuits in different manners (different intervals).

[0102] Note that the organic EL panel **20** includes the measurement pixel circuits in one row and the measurement pixel circuits in two columns. Alternatively, the organic EL panel may include the measurement pixel circuits in any number of rows, or may include the measurement pixel circuits in any number of columns. When the organic EL panel includes the measurement pixel circuits in p rows (p is an integer not less than 2), the measurement pixel circuits in the p rows are arranged at positions shifted by 1/p column for each row. When the organic EL panel includes the measurement pixel circuits in q columns (q is an integer not less than 2), the measurement pixel circuits in the q columns are arranged at positions shifted by 1/q row for each column. As a number of rows or a number of columns of the measurement pixel circuits increases, the bending state of the organic EL panel can be detected with higher accuracy.

Third Embodiment

[0103] FIG. **10** is a block diagram showing a configuration of an organic EL display device according to a third embodiment of the present invention. An organic EL display device **3** shown in FIG. **10** is obtained by replacing the organic EL panel **10** with an organic EL panel **30**, in the organic EL display device **1** according to the first embodiment.

[0104] The organic EL panel **30** is different from the organic EL panel **10** in the following points. The organic EL panel **30** has a display unit **31** and a detection unit **32**. The display unit **31** includes the pixel circuits **60** in odd-numbered columns, and the detection unit **32** includes the pixel circuits **60** in even-numbered columns. In this manner, in the organic EL display device **3** according to the present embodiment, the display area has a rectangular shape, and the display pixel circuits and the measurement pixel circuits are arranged inside the display area in a mixed manner. In other words, the measurement pixel circuits are arranged inside the display area having the rectangular shape, together with the display pixel circuits. According to the organic EL display device **3**, a local bending of the screen can be detected.

[0105] In the organic EL panel **30**, the display unit **31** including the pixel circuits **60** in one column and the detection unit **32** including the pixel circuits **60** in one column are alternately arranged in the row direction. Alternatively, a display unit including the pixel circuits **60** in an arbitrary number of columns and a detection unit including the pixel circuits **60** in an arbitrary number of columns may be arranged alternately in the row direction. Furthermore, a display unit including the pixel circuits **60** in any number of rows and a detection unit including the pixel circuits **60** in any number of rows may be arranged alternately in the column direction.

Fourth Embodiment

[0106] FIG. **11** is a block diagram showing a configuration of an organic EL display device according to a fourth embodiment of the present invention. An organic EL display device **4** shown in FIG. **11** is obtained by replacing the organic EL panel **10** with an organic EL panel **40**, in the organic EL display device **1** according to the first embodiment.

[0107] The organic EL panel **40** is different from the organic EL panel **10** in the following points. FIG. **12** is a diagram showing a schematic configuration of the organic EL panel **40**. As shown in FIGS. **11** and **12**, the organic EL panel **40** has a multi-layer structure (two-layer structure) including a layer in which a display unit **41** is formed (hereinafter referred to as a display layer **43**) and a layer in which a detection unit **42** is formed (hereinafter referred to as a detection layer **44**). As with the organic EL panel **30**, the display unit **41** includes the pixel circuits **60** in the odd-numbered columns, and the detection unit **42** includes the pixel circuits **60** in the even-numbered columns. The display layer **43** and the detection layer **44** are formed separately, and the organic EL panel **40** is formed by pasting the display layer **43** and the detection layer **44** together.

[0108] In a case where a size or type of the drive element are made different between the display pixel circuit and the measurement pixel circuit as in a fifth embodiment described later, when two types of pixel circuits are formed in the same layer, problems such as mixing of materials used for forming the pixel circuits may occur. In the organic EL display device **4**, since the display pixel circuits and the measurement pixel circuits are formed in different layers, problems that occur when the two types of pixel circuits are formed in the same layer do not occur. Furthermore, when a failure occurs in one layer, by changing only the layer in which the failure occurs, a yield of the organic EL panel **40** can be improved and a cost of the organic EL display device **4** can be reduced.

[0109] As described above, in the organic EL display device **4** according to the present embodiment, the display panel (the organic EL panel **40**) has a multi-layer structure including a layer in which the display pixel circuits are formed (display layer **43**) and a layer in which the measurement pixel circuits are formed (detection layer **44**). According to the organic EL display device **4**, the problems that occur when the two types of pixel circuits are formed in the same layer can be solved by forming the display pixel circuits and the measurement pixel circuits in different layers.

Fifth Embodiment

[0110] An organic EL display device according to a fifth embodiment of the present invention has the same configuration as any one of the organic EL display devices **1** to **4** according to the first to fourth embodiments. The organic EL display device according to the present embodiment has a feature that an electrical characteristic of the drive element in the measurement pixel circuit is different from an electrical characteristic of the drive element in the display pixel circuit.

[0111] In the organic EL display device according to the present embodiment, a transistor whose change in an amount of a current is small (more preferably, the amount of the current does not change) when the screen is bent is used for the drive element in the display pixel circuit. On the other hand, a transistor whose change in the amount of the current is large when the screen is bent is used for the drive element in the measurement pixel circuit.

[0112] For example, as the drive element in the measurement pixel circuit, a transistor having a size different from that of the drive element in the display pixel circuit (a transistor larger than the drive element in the display pixel circuit) may be used. Specifically, as the drive element in the measurement pixel circuit, there may be used a transistor having a shorter channel length than that of the drive element in the display pixel circuit or a transistor having a longer channel width than that of the drive element in the display pixel circuit. Alternatively, as the drive element in the measurement pixel circuit, a transistor (for example, an organic TFT) of a different type from that of the drive element in the display pixel circuit may be used. Specifically, the drive element in the display pixel circuit may be formed using amorphous silicon or crystalline silicon, and the drive element in the measurement pixel circuit may be formed using an oxide semiconductor having a small off-current.

[0113] As described above, in the organic EL display device according to the present embodiment, the electrical characteristic (size, type) of the drive element in the measurement pixel circuit is different from the electrical characteristic (size, type) of the drive element in the display pixel circuit. Therefore, the bending state of the screen can be detected with high accuracy.

Sixth Embodiment

[0114] FIG. **13** is a block diagram showing a configuration of an organic EL display device according to a sixth embodiment of the present invention. An organic EL display device **5** shown in FIG. **13** is obtained by respectively replacing the organic EL panel **10** and the display control circuit **13** with an organic EL panel **50** and a display control circuit **19**, in the organic EL display device **1** according to the first embodiment. The display control circuit **19** is obtained by respectively replacing the correction unit **80** and the bending detection unit **90** with a correction unit **89** and a bending detection unit **99**, in the display control circuit **13**.

[0115] The organic EL panel **50** is different from the organic EL panel **50** in that it has a display unit **51** and does not have a detection unit. The display unit **51** includes all of the pixel circuits **60** included in the organic EL panel **50**.

[0116] The correction unit **89** obtains the threshold voltage and the gain of the transistor **61** for each display pixel circuit. The bending detection unit **99** stores the initial value Vth**0** of the threshold voltage and the initial value β**0** of the gain of the transistor **61** for each display pixel circuit. When the correction unit **89** obtains the threshold voltage Vth and the gain β of the transistor **61** in the display pixel circuit, the correction unit **89** outputs these values to the bending detection unit **99**. The bending detection unit **99** obtains the difference ΔVth between the initial value Vth**0** of the threshold voltage and the newly obtained threshold voltage Vth and the difference Δβ between the initial value β**0** of the gain and the newly obtained gain β. The bending detection unit **99** obtains the bending state of the organic EL panel **50** at a position of the display pixel circuit when the obtained differences ΔVth, Δβ are large. As with the correction unit **80** according to the first embodiment, the correction unit **89** corrects the video signal VS**1** based on the bending state detected by the bending detection unit **90**.

[0117] Alternatively, the correction unit **89** may obtain an electrical characteristic of the transistor **61** (hereinafter referred to as a first characteristic) and an electrical characteristic of the organic EL element **64** (hereinafter referred to as a second characteristic), and the bending detection unit **99** may detect the bending state of the organic EL panel **50** by estimating the characteristic of the transistor **61** when the organic EL panel **50** is not bent (hereinafter referred to as a third characteristic) based on the second characteristic and comparing the first characteristic and the third characteristic.

[0118] Specifically, in addition to the above-described curvature LUT, the bending detection unit **99** includes two types of aging LUTs (an aging LUT for the transistor and an aging LUT for the organic EL element). The aging LUT for the organic EL element stores aging time corresponding to the output voltage Vmb of the operational amplifier **71** in the period T**3**. The aging LUT for the transistor stores the threshold voltage and the gain of the transistor corresponding to the aging time. First, the bending detection unit **99** obtains the aging time by referring to the aging LUT for the organic EL element using the voltage Vmb measured in the period T**3**. Next, the bending detection unit **99** estimates the threshold voltage and the gain of the transistor **61** when the organic EL panel **50** is not bent by referring to the aging LUT for the transistor using the obtained aging time. Furthermore, the bending detection unit **99** detects the bending state of the organic EL panel **50** by comparing the threshold voltage and the gain of the transistor **61** based on the voltage Vma measured in the period T**2** with the threshold voltage and the gain of the transistor **61** estimated using the two types of the aging LUTs. Also in this case, the correction unit **89** corrects the video signal VS**1** based on the bending state detected by the bending detection unit **90**.

[0119] As described above, in the organic EL display device **5** according to the present embodiment, the organic EL panel **50** includes only the display pixel circuits (pixel circuits included in the display unit **51**), and the bending detection unit **90** detects the bending state of the display panel based on the measurement result of the current flowing through the drive element in the display pixel circuit. According to the organic EL display device **5**, a yield of the organic EL panel **50** can be improved and a cost of the organic EL display device can be reduced by using the display pixel circuits as the measurement pixel circuits.

[0120] Note that the organic EL display device according to the first to sixth embodiments measure currents for the pixel circuits **60** in one row in one frame period. Alternatively, the organic EL display device of the present invention may measure the currents for the pixel circuits **60** in a plurality of rows sequentially row by row in one frame period. Furthermore, the organic EL display device of the present invention may select the pixel circuits **60** in a plurality of rows collectively and may measure the current flowing through the data lines from the plurality of the pixel circuits **60**. In the organic EL display devices according to the first to sixth embodiments, the display area has a rectangular shape. Alternatively, in the organic EL display device of the present invention, the display area may have a shape other than a rectangle (for example, an elliptical shape or a diamond shape).

[0121] In the first to sixth embodiments, as an example, the organic EL display devices including the pixel circuit **60** and the output/measurement circuit **70** are described. The present invention can also be applied to an organic EL display device including other pixel circuits and other current measurement circuits. Furthermore, the present invention can be applied to a flexible display device other than the organic EL display device.

[0122] This application is an application claiming priority based on Japanese Patent Application No. 2015-235388 filed on Dec. 2, 2015 entitled "Flexible display device and method for detecting bending state thereof", and the content of which is incorporated herein by reference.

INDUSTRIAL APPLICABILITY

[0123] Since the display device of the present invention has a feature that a bending state of a screen can be detected and a change in brightness or color when the screen is bent can be prevented, the display device can be used for various types of flexible display devices including an organic EL display device.

DESCRIPTION OF REFERENCE CHARACTERS

[0124] **1**, **2**, **3**, **4**, **5**: ORGANIC EL DISPLAY DEVICE

[0125] **10**, **20**, **30**, **40**, **50**, **100**: ORGANIC EL PANEL

[0126] **11**, **21**, **31**, **41**, **51**, **101**: DISPLAY UNIT

[0127] **12**, **22**, **32**, **42**, **102**: DETECTION UNIT

[0128] **13**, **19**: DISPLAY CONTROL CIRCUIT

[0129] **14**: SCANNING LINE DRIVE CIRCUIT

[0130] **15**: DATA LINE DRIVE CIRCUIT

[0131] **16**: CORRECTION DATA STORAGE UNIT

[0132] **43**: DISPLAY LAYER

[0133] **44**: DETECTION LAYER

[0134] **60**: PIXEL CIRCUIT

[0135] **61**: TRANSISTOR (DRIVE ELEMENT)

[0136] **64**: ORGANIC EL ELEMENT (LIGHT EMITTING ELEMENT)

[0137] **70**: OUTPUT/MEASUREMENT CIRCUIT

[0138] **80**, **89**: CORRECTION UNIT

[0139] **90**, **99**: BENDING DETECTION UNIT

1. A flexible display device comprising:

a bendable display panel including a plurality of scanning lines, a plurality of data lines, and a plurality of pixel circuits each having alight emitting element and a drive element;

a scanning line drive circuit configured to select the pixel circuits by driving the scanning lines;

a data line drive circuit configured to perform, by driving the data lines, an operation of writing a voltage to a control terminal of the drive element and an operation of measuring a current flowing through the drive element for the pixel circuits selected by the scanning line drive circuit; and

a bending detection unit configured to detect a bending state of the display panel based on a measurement result of the current flowing through the drive element.

2. The flexible display device according to claim **1**, wherein

the pixel circuits are classified into display pixel circuits and measurement pixel circuits, and

the bending detection unit is configured to detect the bending state of the display panel based on the measurement result of the current flowing through the drive element in the measurement pixel circuit.

3. The flexible display device according to claim **2**, wherein

the display pixel circuits are arranged inside a display area, and

the measurement pixel circuits are arranged outside the display area.

4. The flexible display device according to claim **3**, wherein

the display area has a rectangular shape, and

the measurement pixel circuits are arranged along two adjacent sides of the display area.

5. The flexible display device according to claim **3**, wherein

the display area has a rectangular shape, and

the measurement pixel circuits are arranged along one side of the display area.

6. The flexible display device according to claim **2**, wherein an arrangement manner of the measurement pixel circuits is different from an arrangement manner of the display pixel circuits.

7. The flexible display device according to claim **6**, wherein an arrangement interval of the measurement pixel circuits is different from an arrangement interval of the display pixel circuits.

8. The flexible display device according to claim **2**, wherein the display pixel circuits and the measurement pixel circuits are arranged inside a display area in a mixed manner.

9. The flexible display device according to claim **2**, wherein the display panel has a multi-layer structure including a layer in which the display pixel circuits are formed and a layer in which the measurement pixel circuits are formed.

10. The flexible display device according to claim **2**, wherein an electrical characteristic of the drive element in the measurement pixel circuit is different from an electrical characteristic of the drive element in the display pixel circuit.

11. The flexible display device according to claim **10**, wherein a size of the drive element in the measurement pixel circuit is different from a size of the drive element in the display pixel circuit.

12. The flexible display device according to claim **10**, wherein a type of the drive element in the measurement pixel circuit is different from a type of the drive element in the display pixel circuit.

13. The flexible display device according to claim **1**, further comprising a correction unit configured to correct a video signal based on the bending state detected by the bending detection unit, wherein

the data line drive circuit is configured to apply, to the data lines, voltages based on the video signal corrected by the correction unit.

14. The flexible display device according to claim **13**, wherein the correction unit is configured to correct the video signal so as to compensate for a change of an amount of the current flowing through the drive element, the change caused by bending.

15. The flexible display device according to claim **14**, wherein

the bending detection unit includes a first table configured to store a curvature of the display panel corresponding to a difference from an initial value with respect to an electrical characteristic of the drive element, and is configured to detect the curvature of the display panel as the bending state of the display panel by referring to the first table using an obtained difference from the initial value with respect to the electrical characteristic of the drive element, and

the correction unit includes a second table configured to store a correction amount of the electrical characteristic of the drive element corresponding to the curvature of the display panel, and is configured to obtain the correction amount of the electrical characteristic of the drive element by referring to the second table using the curvature obtained by the bending detection unit and correct the video signal using the obtained correction amount.

16. The flexible display device according to claim **14**, wherein

the correction unit is configured to obtain a first characteristic being an electrical characteristic of the drive element and a second characteristic being an electrical characteristic of the light emitting element, and

the bending detection unit is configured to estimate, based on the second characteristic, a third characteristic being the electrical characteristic of the drive element when the display panel is not bent, and detect the bending state of the display panel by comparing the first characteristic and the third characteristic.

17. The flexible display device according to claim **13**, wherein the correction unit is configured to correct the video signal corresponding to a bent portion, to a non-display level.

18. A method for detecting a bending state of a flexible display device having a bendable display panel including a plurality of scanning lines, a plurality of data lines, and a plurality of pixel circuits each having a light emitting element and a drive element, the method comprising steps of:

selecting the pixel circuits by driving the scanning lines;

performing, by driving the data lines, an operation of writing a voltage to a control terminal of the drive element and an operation of measuring a current flowing through the drive element for the pixel circuits selected using the scanning lines; and

detecting a bending state of the display panel based on a measurement result of the current flowing through the drive element.

* * * * *

专利名称(译)	柔性显示装置和用于检测其弯曲状态的方法		
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[标]申请(专利权)人(译)	夏普株式会社		
申请(专利权)人(译)	夏普株式会社		
当前申请(专利权)人(译)	夏普株式会社		
[标]发明人	TAKIZAWA KAZUO KISHI NORITAKA GOTOH NAOKO UCHIDA HIDEKI KIKUCHI KATSUHIRO		
发明人	TAKIZAWA, KAZUO KISHI, NORITAKA GOTOH, NAOKO UCHIDA, HIDEKI KIKUCHI, KATSUHIRO		
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摘要(译)

有机EL面板 10 是可弯曲的显示面板，包括多个像素电路 60 ，每个像素电路具有发光元件和驱动元件。数据线驱动电路 15 通过驱动数据线执行将电压写入驱动元件的控制端子的操作和测量流过驱动元件的电流的操作用于像素电路 60 由扫描线驱动电路选择 14 。弯曲检测单元 90 基于流过驱动元件的电流的测量结果来检测有机EL面板的弯曲状态 10。校正单元 80 基于检测到的弯曲状态校正视频信号VS 1。由此，检测屏幕的弯曲状态，并且防止屏幕弯曲时亮度或颜色的变化。