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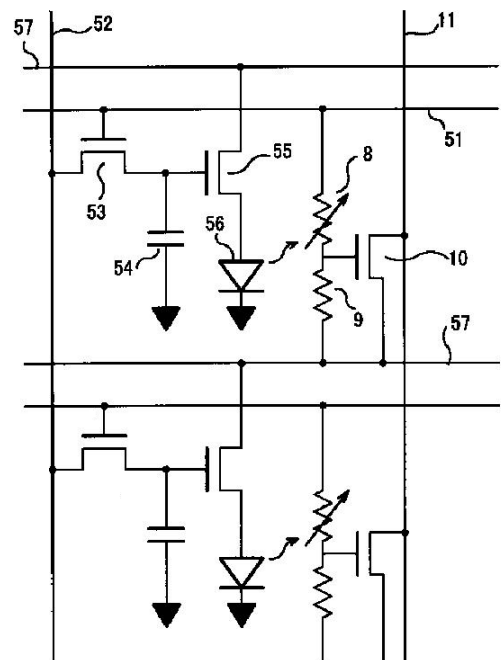
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(54) [Title of the Invention] Spontaneous Light-Emitting Display Device

(57) [Abstract]

[Problem] An object of the present invention is to reduce the variation in brightness among pixels.

[Solution] A spontaneous light-emitting display device is provided that comprises a plurality of light-emitting elements arranged in a matrix and light-detecting elements receiving light emitted from each of the light-emitting elements, wherein the amount of light emitted from the light-emitting elements is controlled by the light-detecting elements.



[Claims]

[Claim 1] A spontaneous light-emitting display device comprising a plurality of light-emitting elements arranged in a matrix and light-detecting elements receiving light emitted from each of the light-emitting elements, wherein the amount of light emitted from the light-emitting elements is controlled by signals from the light-detecting elements.

[Claim 2] In a display device comprising a plurality of first vertical scanning lines, a first transistor provided near the intersection of a vertical scanning line and a first horizontal scanning line and controlled by the vertical scanning line, a capacitor connected to the first horizontal scanning line via the first transistor, a second transistor connected to the first horizontal scanning line via the first transistor and controlled by the first horizontal scanning line, and light-emitting elements connected to a power supply line via the second transistor, the spontaneous light-emitting display device according to claim 1 characterized in that light-detecting elements and a resistor are connected in series between a first vertical scanning line and the power supply line, a third transistor is controlled by the potential at the connection point between the light-detecting elements and the resistor, the power supply line is connected to a second horizontal scanning line via the third transistor, and the light-detecting elements are configured to receive light from the light-emitting elements.

[Claim 3] In a display device comprising a plurality of first vertical scanning lines, a first transistor provided near the intersection of a vertical scanning line and a first horizontal scanning line and controlled by the vertical scanning line, a capacitor connected to the first horizontal scanning line via the first transistor, a second transistor connected to the first horizontal scanning line via the first transistor and controlled by the first horizontal scanning line, and light-emitting elements connected to a power supply line via the second transistor, the spontaneous light-emitting display device according to claim 2 characterized in that light-detecting elements and a resistor are connected in series between a first vertical scanning line and the power supply line, a third transistor is controlled by the potential at the connection point between the light-detecting elements and the resistor, the power supply line is connected to a second horizontal scanning line via the third transistor, the light-detecting elements are configured to receive light from the light-emitting elements, a control circuit is provided for reading signals from the light-detecting elements via the second horizontal scanning line, memory is provided for storing signals from each light-emitting element as data, and a means is provided for modulating a signal voltage to be applied to the light-emitting elements based on data in the memory and applying the signal voltage to the first horizontal scanning line.

[Claim 4] In a display device comprising a plurality of first vertical scanning lines, a first transistor provided near the intersection of a vertical scanning line and a first horizontal scanning line and controlled by the vertical scanning line, a capacitor connected to the first horizontal scanning line via the first transistor, a second transistor connected to the first horizontal scanning line via the first transistor and controlled by the first horizontal scanning line, and a light-emitting element connected to a power supply line via the second transistor, the spontaneous light-emitting display device according to claim 1 characterized in that a fourth transistor controlled by a first vertical scanning line, a light-detecting element, and a capacitor are connected in series between the first vertical scanning line and the power supply line, the connection point between the light-detecting element and the capacitor is connected to a second horizontal scanning line via the fourth transistor, and the light-detecting elements are configured to receive light from the light-emitting elements.

[Claim 5] In a display device comprising a plurality of first vertical scanning lines, a first transistor provided near the intersection of a vertical scanning line and a first horizontal

scanning line and controlled by the vertical scanning line, a capacitor connected to the first horizontal scanning line via the first transistor, a second transistor connected to the first horizontal scanning line via the first transistor and controlled by the first horizontal scanning line, and a light-emitting element connected to a power supply line via the second transistor, the spontaneous light-emitting display device according to claim 4 characterized in that a fourth transistor controlled by a first vertical scanning line, a light-detecting element, and a capacitor are connected in series between the first vertical scanning line and the power supply line, the connection point between the light-detecting element and the capacitor is connected to a second horizontal scanning line via the fourth transistor, the light-detecting elements are configured to receive light from the light-emitting elements, a control circuit is provided for reading signals from the light-detecting elements via the second horizontal scanning line, memory is provided for storing signals from each light-emitting element as data, and a means is provided for modulating a signal voltage to be applied to the light-emitting elements based on data in the memory and applying the signal voltage to the first horizontal scanning line.

[Claim 6] The spontaneous light-emitting display device according to any of claims 1 to 5, wherein the light-detecting element is composed of amorphous silicon.

[Claim 7] The spontaneous light-emitting display device according to claim 2 or 3, wherein a light-detecting element and the resistor are both composed of amorphous silicon, and a light-shielding film is formed between the amorphous silicon constituting the resistor and the light-emitting element.

[Claim 8] The spontaneous light-emitting display device according to any of claims 1 to 7, wherein an organic EL element is used as the light-emitting element.

[Detailed Description of the Invention]

[0001]

[Technical Field of the Invention] The present invention relates to a spontaneous light-emitting display device provided with a light-emitting element matrix, and the object of the present invention is to suppress brightness variation in the display.

[0002]

[Prior Art] Organic EL display panels using organic EL in the panel have reached a practical level. Because organic EL displays have excellent features that cannot be obtained by liquid crystal displays, such as spontaneous light emission, high-speed response, and a wide angle of view, flat panels that can clearly display characters, graphics, and moving images are widely expected. The organic EL displays can be classified passive matrix type (PM type) and active matrix type (AM type) displays depending on the drive method used.

[0003] Because a PM type is provided with a drive circuit on the outside of the organic EL panel and the structure of the organic EL panel itself is simple, it is said that lower costs can be realized. At present, PM type organic EL panels are being manufactured as products for use in vehicles and mobile phones. Because an organic EL is a current-driven element, the current flowing to each light-emitting pixel has to be of equal magnitude to eliminate variations in the brightness of an organic EL panel. However, it is difficult to provide an equal current and reduce power consumption due to problems (1) to (3) below.

(1) In order to make the brightness of all pixels uniform, the current flowing to each of the pixels has to be equal. Therefore, one of the positive and negative electrodes of each pixel

has to act as a constant current source. However, the driving voltage of a matrix electrode on the other side has to be increased so that the voltage drop caused by the resistance component in the bus line has no effect. This causes an increase in power consumption. When the driving voltage cannot be increased sufficiently, a voltage drop corresponding to the length of the bus line to each pixel affects the amount of current for light emission. More specifically, a constant current source is not obtained and variations in brightness occur.

(2) In order to obtain a predetermined surface brightness, the PM type needs to emit light with an N-fold instantaneous brightness, where N is the number of scanning lines in the display panel. Because the current flowing to a pixel is usually proportional to the emitted brightness, the current is N-fold. Because an organic EL experiences a reduction in light emission efficiency when the current is increased, an N-fold pixel current or greater is required to obtain the predetermined surface brightness. Therefore, the power consumption increases as the number N of scanning lines increases. This problem aggravates problem (1).

(3) Because an organic EL panel has a surface structure, a capacitive load is connected to each element in parallel when viewed as an equivalent circuit. When the pixel current increases or the number of pixels and the repetition frequency increases, the charging/discharging current to the capacitive load increases and power consumption increases. Due to problem (2), power consumption caused by the capacitive load increases considerably in the PM type. Because of these problems, the PM type is currently manufactured as products with a screen size of no more than a few inches and 10,000 pixels or so.

[0004] AM-type organic EL panels can alleviate these problems. In the case of problem (1), the AM type has a TFT drive circuit provided in each pixel, so a large current does not have to flow instantaneously. As a result, the voltage drop due to the bus line problem in (1) is reduced and the applied voltage can be reduced. In this way, power consumption can be reduced significantly relative to the PM type. Because the applied voltage can be reduced, a slightly higher applied voltage can be set so that the voltage drop corresponding to the length of the bus line to each pixel does not affect the pixel current level, and uniform brightness can be obtained. In the case of problem (2), the AM type has a TFT drive circuit provided for each pixel and a low pixel current is used irrespective of the number N of the scanning lines. As a result, an increase of power consumption does not occur due to the reduction in light emission efficiency caused by an increase in a pixel current. In the case of problem (3), the AM type has a TFT drive circuit provided for each pixel and a low pixel current is used irrespective of the number N of the scanning lines. Therefore, a low charge/discharge current to the capacitive load is sufficient, and power consumption due to this effect is small. In this way, an AM type organic EL can reduce variations in brightness and power consumption.

[0005] However, the AM type has a significant drawback. Specifically, it is hard to create a driving element with a uniform characteristic over the entire organic EL panel region. As a result, the current value flowing to each pixel is different and the brightness varies.

[0006] Fig. 5 shows a pixel drive circuit used to cause pixels in an AM type organic EL panel of the prior art to emit light. This drive circuit is described in, for example, JP 2784615 B2. The operations performed by this drive circuit will be explained with reference to Fig. 5. The first transistor 53 can be, for example, an N-channel type FET and operate as a switching element. The second transistor 55 can be, for example, a P-channel FET and operate as a drive element. The capacitor 54 is a capacitive load connected to the drain terminal of the first transistor 53. An organic EL element serving as the light-emitting element 56 is connected to the drain terminal of the second transistor 54. The drain terminal of the first transistor 53 is connected to the gate terminal of the second transistor 55. Scanning signals

are applied from the first vertical scanning line 51 to the gate terminal of the first transistor 53. Image signals are applied from the first horizontal scanning line 52 to the source terminal. Here, 57 is the power supply line.

[0007] The light emitting mode will now be described. First, a scanning line signal is applied to the gate terminal of the first transistor 53. When an image signal is applied at a predetermined voltage to the source terminal of the first transistor 53 at this time, the capacitor 54 connected to the drain terminal of the first transistor 53 holds a voltage level V1 corresponding to the level of the image signal. If the level of the voltage level V1 held at the gate voltage of the second transistor 55 is large enough to allow the drain current to flow, then a current corresponding to the magnitude of the voltage level V1 flows through the drain of the second transistor 55. This drain current becomes the light emission current of the light-emitting element 56. Brightness is proportional to the level of the light emission current. Fig. 6 is a characteristic diagram used to explain the variation in brightness that occurs when light is emitted by this operation. This characteristic diagram shows the relationship between the gate-source voltage and the drain current of the second transistor 55. When the first transistor 53 and the second transistor 55 are made of low-temperature polysilicon, FETs with the same characteristics cannot be obtained over the entire display panel due to the production method for low-temperature polysilicon. For example, the first transistor 53 and the second transistor 55 have the variations in characteristics shown in Fig. 6. When voltage level V1 is applied to a second transistor 55 with such characteristics, the level of the drain current varies from Ia to Ib. Because an organic EL emits light with a brightness proportional to the level of the current, variations in the characteristics of the second transistor 55 appear as variations in the emission brightness. In particular, variations in characteristics such as those shown in Fig. 6 cannot be prevented using a method that modulates brightness using an analog amount, that is, a method that controls emission brightness based on the voltage level V1.

[0008] Therefore, according to the relationship between the gate-source voltage and the drain current of the second transistor 55 shown in Fig. 7, in a digital brightness control method that keeps the brightness at a level where the voltage level V1 is always a constant value, the level at which current saturation occurs is used. In this way, variations in brightness that occur in the analog brightness control system can be prevented. However, due to the characteristics of the relationship between the gate-source voltage and the drain current of the second transistor 55 shown in Fig. 8, the saturation current is not the same. As a result, variations in brightness occur even in the digital brightness control method. Fig. 9 is a circuit diagram showing the drive circuit described in "Active Matrix OLED Displays with Po-SiTFT. The 10th International Workshop on Inorganic & OEL. pp. 347-356," which is another example of the prior art in which variations in the characteristics of the drive element are improved. In this prior art example, the second transistors 55A, 55B serving as drive element are connected in parallel to average out the variations in the characteristics.

[0009]

[Problem to Be Solved by the Invention] Because spontaneous light-emitting display devices of the prior art have this configuration, when the threshold voltage of the transistor serving as the drive element varies, the voltage applied to the light-emitting elements varies and the brightness of each pixel varies at the same gradation.

[0010] Meanwhile, because the variation in the threshold voltage of the transistor is canceled in order to suppress the variation in brightness, a spontaneous light-emitting display device using four transistors for a single pixel has been proposed. However, while this method suppresses the variation in transistor threshold voltage, variations in the characteristics of

the light-emitting elements themselves cannot be suppressed, and the brightness of each pixel varies when displayed at the same gradation.

[0011]

[Means for Solving the Problem] The first aspect of the present invention comprises a plurality of light-emitting elements arranged in a matrix and light-detecting elements receiving light emitted from each of the light-emitting elements, wherein the amount of light emitted from the light-emitting elements is controlled by signals from the light-detecting elements.

[0012] In a display device comprising a plurality of first vertical scanning lines, a first transistor provided near the intersection of a vertical scanning line and a first horizontal scanning line and controlled by the vertical scanning line, a capacitor connected to the first horizontal scanning line via the first transistor, a second transistor connected to the first horizontal scanning line via the first transistor and controlled by the first horizontal scanning line, and light-emitting elements connected to a power supply line via the second transistor, the second aspect of the present invention is characterized in that light-detecting elements and a resistor are connected in series between a first vertical scanning line and the power supply line, a third transistor is controlled by the potential at the connection point between the light-detecting elements and the resistor, the power supply line is connected to a second horizontal scanning line via the third transistor, and the light-detecting elements are configured to receive light from the light-emitting elements.

[0013] The third aspect of the present invention is the spontaneous light-emitting display device according in the second aspect of the present invention characterized in that a control circuit is provided for reading signals from the light-detecting elements via the second horizontal scanning line, memory is provided for storing signals from each light-emitting element as data, and a means is provided for modulating a signal voltage to be applied to the light-emitting elements based on data in the memory and applying the signal voltage to the first horizontal scanning line.

[0014] In a display device comprising a plurality of first vertical scanning lines, a first transistor provided near the intersection of a vertical scanning line and a first horizontal scanning line and controlled by the vertical scanning line, a capacitor connected to the first horizontal scanning line via the first transistor, a second transistor connected to the first horizontal scanning line via the first transistor and controlled by the first horizontal scanning line, and a light-emitting element connected to a power supply line via the second transistor, the fourth aspect of the present invention is characterized in that a fourth transistor controlled by a first vertical scanning line, a light-detecting element, and a capacitor are connected in series between the first vertical scanning line and the power supply line, the connection point between the light-detecting element and the capacitor is connected to a second horizontal scanning line via the fourth transistor, and the light-detecting elements are configured to receive light from the light-emitting elements.

[0015] In a display device comprising a plurality of first vertical scanning lines, a first transistor provided near the intersection of a first vertical scanning line and a first horizontal scanning line and controlled by the vertical scanning line, a capacitor connected to the first horizontal scanning line via the first transistor, a second transistor connected to the first horizontal scanning line via the first transistor and controlled by the first horizontal scanning line, and a light-emitting element connected to a power supply line via the second transistor, the fifth aspect of the present invention is characterized in that a fourth transistor controlled by a first vertical scanning line, a light-detecting element, and a capacitor are connected in series between the first vertical scanning line and the power supply line, the connection point

between the light-detecting element and the capacitor is connected to a second horizontal scanning line via the fourth transistor, the light-detecting elements are configured to receive light from the light-emitting elements, a control circuit is provided for reading signals from the light-detecting elements via the second horizontal scanning line, memory is provided for storing signals from each light-emitting element as data, and a means is provided for modulating a signal voltage to be applied to the light-emitting elements based on data in the memory and applying the signal voltage to the first horizontal scanning line.

[0016] The sixth aspect of the present invention is the first to fifth aspect of the present invention characterized in that the light-detecting element is composed of amorphous silicon.

[0017] The seventh aspect of the present invention is the second or third aspect of the present invention characterized in that a light- detecting element and the resistor are both composed of amorphous silicon, and a light-shielding film is formed between the amorphous silicon constituting the resistor and the light-emitting element.

[0018] The eighth aspect of the present invention is the first to seventh aspect of the present invention characterized in that an organic EL element is used as the light-emitting element.

[0019]

[Embodiments of the Invention] Embodiments of the present invention will now be described with reference to the drawings. In the drawings, identical or comparable components are denoted by the same reference numbers.

First Embodiment

Fig. 1 is a circuit diagram showing a pixel in the spontaneous light-emitting display device according to the first embodiment of the present invention. In this figure, 51 denotes a first vertical scanning line, 52 denotes a first horizontal scanning line, 53 denotes a first transistor, 54 denotes a capacitor, 55 denotes a second transistor, and 56 denotes a light-emitting element that is an organic EL element. Here, 57 denotes a power supply line. Also, 8 denotes a light-detecting element and 9 denotes a resistor. The light-detecting element 8 and the resistor 9 are connected in series between the first vertical scanning line 51 and the first vertical scanning line 57 in the next stage. In addition, 10 denotes a third transistor whose gate is connected to the connection point between the light-detecting element 8 and the resistor 9, and 11 denotes a second horizontal scanning line. The drain of the third transistor 10 is connected to the second horizontal scanning line 11. Because the configuration in the lower half of the drawing is the configuration of the next stage and is the same as that of the upper half, further description has been omitted.

[0020] The operations will now be described. When the first vertical scanning line 51 is activated, the first transistor 53 enters a conductive state so that the voltage of the first horizontal scanning line 52 is charged to the capacitor 54 via the first transistor. At the same time, the voltage charged to the capacitor 54 is connected to the gate of the second transistor 55, causing the second transistor 55 to enter a conductive state so that a current is supplied from the power supply line 57 to the light-emitting element 56 and the light-emitting element 56 emits light. An amount of light emitted is controlled by the voltage value applied to the gate of the second transistor 55, and the voltage for this is maintained by the capacitor 54 and the light-emitting element 56 continuously emits light as described above after the first vertical scanning line 51 is deactivated and the first transistor 53 enters a non-conductive state.

[0021] The current flowing to the light-emitting element 56 is controlled by the voltage value applied to the gate of the second transistor 55, and the current value I_d and the voltage value V_g applied to the gate of the second transistor 55 have the relationship shown in Equation (1).

$$I_d = kxV_d x (V_g - V_{th}) \dots 1$$

Here, V_d represents the voltage applied between the source and the drain of the transistor, V_{th} represents the threshold voltage of the transistor, and k represents a constant determined by the channel length, the channel width, and the carrier mobility of the second transistor 55. Specifically, the current value I_d of the second transistor 55 is determined by the threshold voltage V_{th} of the transistor minus the gate voltage V_g of the second transistor 55. Because V_{th} varies greatly from transistor to transistor, the same brightness cannot be obtained when the same V_g is applied as described above.

[0022] In the first embodiment, light from the light-emitting element 56 can be detected by the photo-detecting element 8. When the first vertical scanning line 51 is activated, the voltage between the power supply line 57 and the first vertical scanning line 51 is applied to the light-detecting element 8 and the resistor 9. At the same time, a voltage corresponding to brightness data is applied to the first horizontal scanning line 52 and the light-emitting element 56 emits light. However, the resistance value of the light-detecting element 8 is rapidly reduced and the voltage at the connection point between the light-detecting element 8 and the resistor 9 approaches the voltage of the first vertical scanning line 51 due to light emission. Because this connection point is connected to the gate of the third transistor 10, the third transistor 10 is rendered conductive by the voltage, the second horizontal scanning line 11 is connected to the power supply line 57 via the third transistor 10 and the electric potential of the second horizontal scanning line 11 becomes almost equal to that of the power supply line 7. By observing the electric potential of the second horizontal scanning line 11, it is possible to determine that the light-emitting element 56 corresponding to the activated first vertical scanning line 51 is emitting light. Specifically, the voltage at which the light-emitting element 56 starts to emit light is determined by successively changing the voltage data for the first horizontal scanning line 52, for example, raising the voltage in steps.

[0023] Fig. 2 shows the control circuit for the spontaneous light-emitting display device in the first embodiment. Here, 21 denotes a vertical scanning circuit for controlling the first vertical scanning line 51, 22 denotes a first horizontal scanning circuit for controlling the first horizontal scanning line 52, 23 denotes a second horizontal scanning circuit for controlling the second horizontal scanning line 11, 24 denotes a portion of the display in which a large number of pixels including the light-emitting element 56 and the light-detecting element 8 are formed in a matrix, 25 denotes a memory for storing the voltage of the first horizontal scanning line 52 at the time of detection by the light-detecting element 8, and 26 denotes a voltage converting circuit for converting voltage to be applied to the first horizontal scanning line 52 based on data in the memory 25. Specifically, the voltage at which each pixel stored in the memory 25 starts to emit light is added to voltage corresponding to the brightness to be emitted by the pixel.

[0024] Fig. 3 is a cross-sectional view showing a pixel unit in the first embodiment. In this figure, 40 denotes a transparent insulating substrate, 41 denotes a light-shielding film, 42 denotes a hole injection layer, and 43 denotes an electron injection layer.

[0025] The first transistor 53, the second transistor 55, the third transistor 10, and the capacitor 54 are formed on the transparent insulating substrate 40. An interlayer insulating film is formed, an amorphous silicon layer is formed on top, and an electrode is provided so that a light-detecting element 8 and the resistor 9 are formed. By providing the light-shielding

film 41 only on top of the resistor 9, the light-detecting element 8 and the resistor 9 can be created separately using the same amorphous silicon. Also, by laminating a hole injection layer 42, an light-emitting element 56, and a electron injection layer 43 via the interlayer insulating film, a spontaneous light-emitting display device with paired light-emitting elements 56 and light-detecting elements 8 can be realized.

[0026] Because the spontaneous light-emitting display device in the first embodiment is constituted as described above, the voltage at which each pixel starts to emit light can be detected in advance by the light-detecting element 8 and can be stored in the memory 25, and a threshold voltage at which a light-emitting element 56 starts to emit light can be added to a voltage corresponding to a certain brightness in order to accurately display the brightness required of each pixel. As a result, the display has the desired brightness unaffected by threshold variations in the second transistor 55.

[0027]

Second Embodiment

Fig. 4 is a circuit diagram showing the drive circuit for a pixel in the spontaneous light-emitting display device according to the second embodiment of the present invention. In this figure, 51 denotes a first vertical scanning line, 52 denotes a first horizontal scanning line, 53 denotes a first transistor, 54 denotes a capacitor, 55 denotes a second transistor, 56 denotes a light-emitting element, and 57 denotes a power supply line. In addition, 8 denotes a light-detecting element, 11 denotes a second horizontal scanning line, 30 denotes a fourth transistor, and 31 denotes a second capacitor. In the present embodiment, one of the terminals of the light-detecting element 8 is connected to the power supply line 57 and the other terminal is connected to the first vertical scanning line 51 via the second capacitor 31. The gate terminal of the fourth transistor 30 is connected to the first vertical scanning line 51 and is controlled by the first vertical scanning line 51, the source terminal is connected to the connection point between the light-detecting element 8 and the second capacitor, and the electric potential at the connection point for the light-detecting element 8 and the second capacitor is applied to the second horizontal scanning line 11 when rendered conductive. The drain terminal of the fourth transistor 30 is connected to the second horizontal scanning line.

[0028] The operations will now be described. In the second embodiment, the circuitry is constituted as described above. Thus, when the first vertical scanning line 51 is activated, both the first transistor 53 and the fourth transistor 30 enter a conductive state. Data is written from the first horizontal scanning line 52 to the capacitor 54. When the voltage value of the data does not reach a voltage at which the second transistor 55 can be rendered conducting, that is, the light-emitting element 56 does not emit light at the threshold voltage of the second transistor 55, the light-detecting element 8 remains at high resistance, and at the electric potential of the connection point between the light-detecting element 8 and the second capacitor, voltage drawn from the potential of the power supply line 57 by the activation voltage of the first vertical scanning line 51 is supplied to the second horizontal scanning line 11 via the fourth transistor 30. However, when the voltage of the data supplied from the first horizontal scanning line 52 reaches a voltage at which the second transistor 55 becomes conductive, a current is supplied to the light-emitting element 56 and the light-emitting element 56 emits light. When the light-detecting element 8 detects the light, the resistance value of the light-detecting element 8 is reduced, and the electric potential of the power supply line 57 is supplied to the second horizontal scanning line 11 via the fourth transistor 30.

[0029] In this way, the threshold voltage of the second transistor 55 can be detected using the voltage of the data provided to the first horizontal scanning line 52 and, as in the case of the first embodiment, the voltage can be stored in the memory 25 and the threshold voltage at which a light-emitting element 56 starts to emit light can be applied to the voltage corresponding to a certain brightness in order to accurately display the brightness required of each pixel. As a result, the display has the desired brightness unaffected by threshold variations in the second transistor 55. While light-emitting elements were used as the spontaneous light-emitting display elements in the above description, the present invention is not limited to this type of display element.

[0030]

[Effects of the Invention] In the first aspect of the present invention, the amount of light emitted from the light-emitting elements is controlled by the voltage from a light-detecting element formed to receive light emitted from the light-emitting element. As a result, variations in brightness can be suppressed by correcting the threshold voltage of the transistor.

[0031] The second aspect of the present invention is the first aspect, wherein light-detecting elements and a resistor are connected in series and the threshold voltage of the transistor is detected using the potential at the connection point. As a result, a simple circuit can be used to detect the variation in the threshold voltage of the transistor.

[0032] The third aspect of the present invention is the second aspect, wherein a control circuit is provided for reading signals from the light-detecting elements and memory is provided for storing signals from each light-emitting element as data. As a result, signal voltage applied to a light-emitting element can be modulated based on the data in the memory, and variations in brightness can be suppressed.

[0033] The fourth aspect of the present invention is the first aspect, wherein light-detecting elements and a capacitor are connected in series, the potential at the connection point is read from a transistor controlled by a vertical scanning line, and the threshold voltage of the transistor is detected. As a result, the direct current can be suppressed, and variations in the threshold voltage of transistors can be detected while holding down power consumption.

[0034] The fifth aspect of the present invention is the fourth aspect, wherein light-detecting elements and a capacitor are connected in series, the potential at the connection point is read from a transistor controlled by a vertical scanning line, a control circuit is provided for reading signals from the light-detecting elements, and memory is provided for storing signals from each light-emitting element as data. As a result, the signal voltage to be applied to a light emitting element can be modulated based on the data in the memory, and variations in brightness can be suppressed while holding down power consumption.

[0035] The sixth aspect of the present invention is any of the first to fifth aspects, wherein the light-detecting element is composed of amorphous silicon. As a result, the light-emitting elements can be formed using a simple process, and a spontaneous light-emitting display device with little variation in brightness can be realized at low cost.

[0036] The seventh aspect of the present invention is the second or third aspect, wherein a light- detecting element and the resistor are both composed of amorphous silicon, and a light-shielding film is formed only on the resistor. As a result, a spontaneous light-emitting display device with little variation in brightness can be realized at low cost.

[0037] The eighth aspect of the present invention is any of the first to seventh aspects, wherein an organic EL element is used as the light-emitting element. As a result, a low-voltage, high-brightness spontaneous light-emitting display device can be realized.

[Brief Description of the Drawings]

[Fig. 1] Fig. 1 is a circuit diagram showing the configuration of the drive circuit in the first embodiment of the present invention.

[Fig. 2] Fig. 2 is a conceptual diagram showing the configuration of the control circuit for the spontaneous light-emitting display device in the first embodiment of the present invention.

[Fig. 3] Fig. 3 is a cross-sectional diagram showing the circuit configuration in the first embodiment of the present invention.

[Fig. 4] Fig. 4 is a circuit diagram showing the configuration of the drive circuit in the second embodiment of the present invention.

[Fig. 5] Fig. 5 is a circuit diagram showing the configuration of a spontaneous light-emitting display device according to the prior art.

[Fig. 6] Fig. 6 is a characteristic diagram used to explain operations performed by a spontaneous light-emitting display device of the prior art.

[Fig. 7] Fig. 7 is a characteristic diagram used to explain operations performed by a spontaneous light-emitting display device of the prior art.

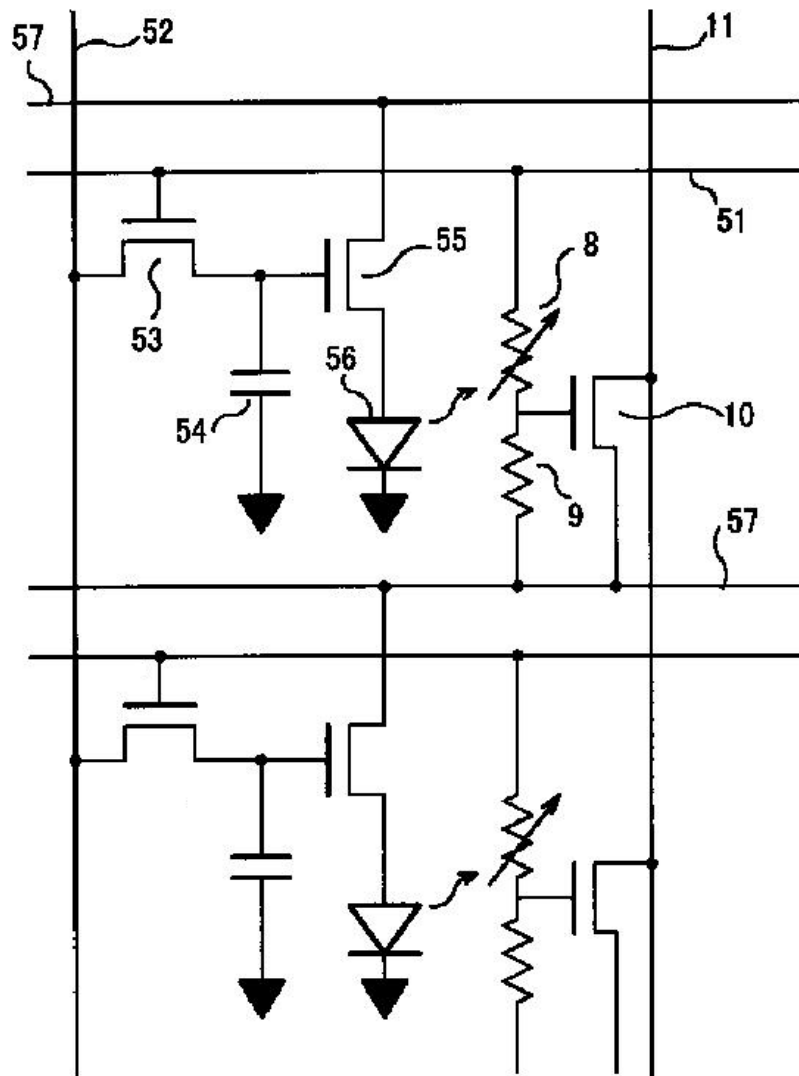
[Fig. 8] Fig. 8 is a characteristic diagram used to explain operations performed by a spontaneous light-emitting display device of the prior art.

[Fig. 9] Fig. 9 is a circuit diagram showing the configuration of another spontaneous light-emitting display device according to the prior art.

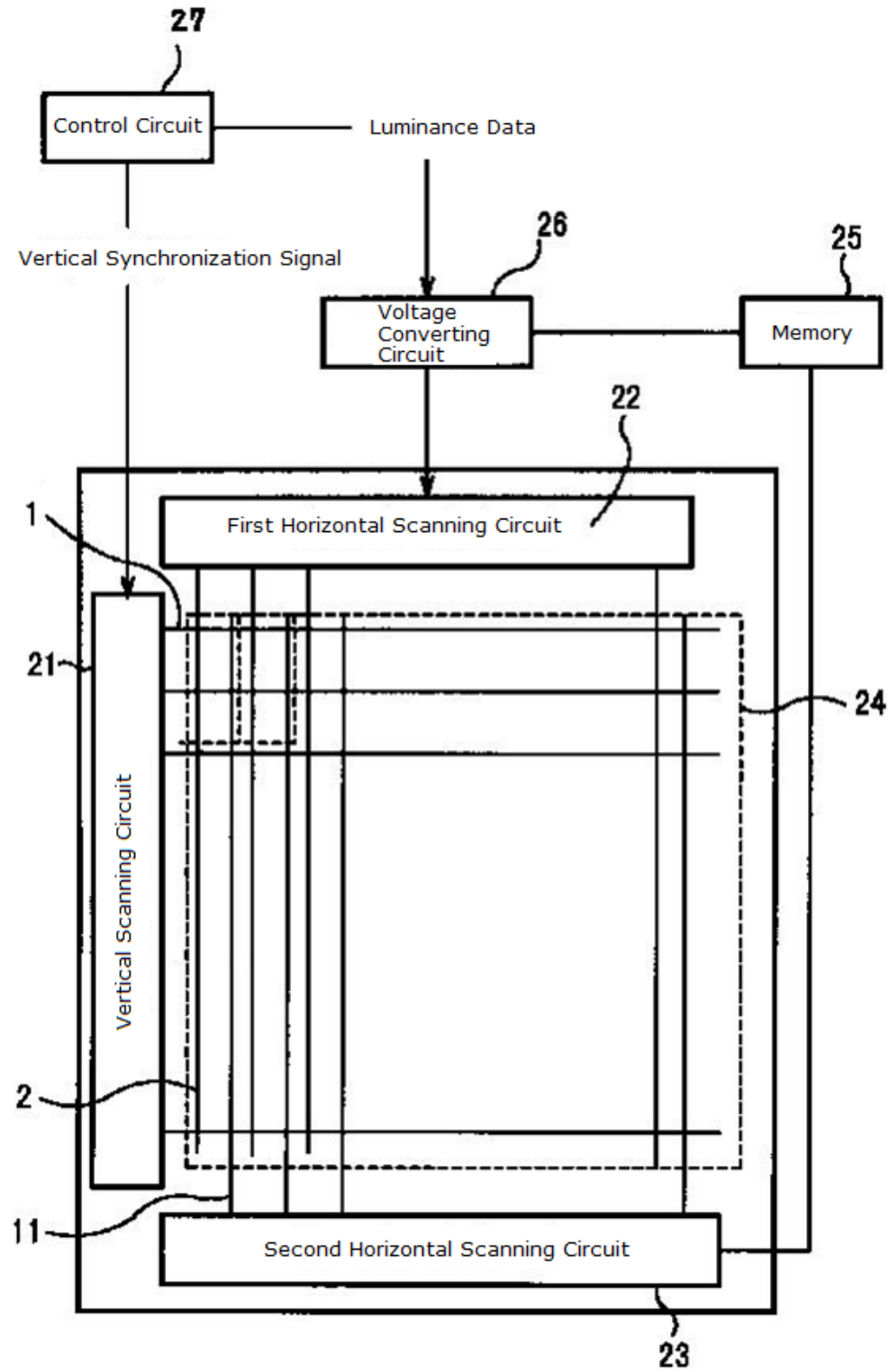
[Key to the Drawings]

8: Light-detecting element
9: Resistor
10: Third transistor
11: Second horizontal scanning line
51: First vertical scanning line
52: First horizontal scanning line
53: First transistor
54: Capacitor
55: Second transistor
56: EL element
57: Power supply line
30: Fourth transistor
31: Second capacitor

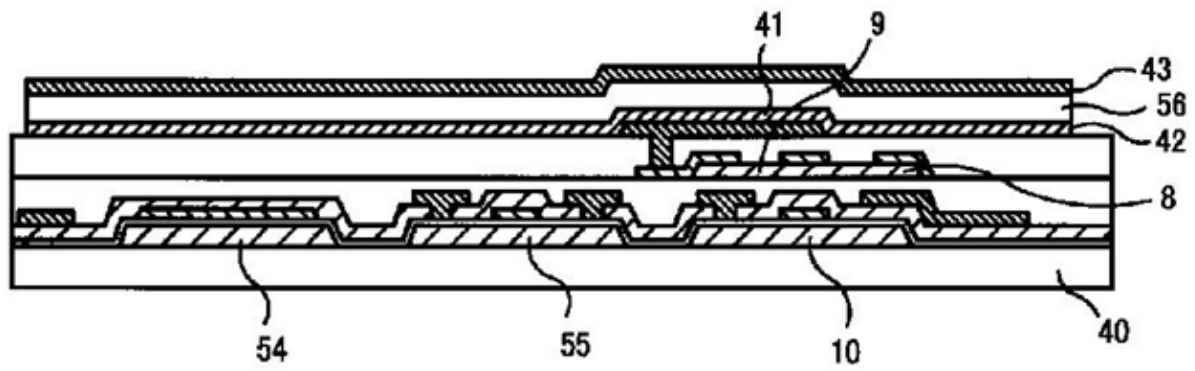
[Fig. 1]



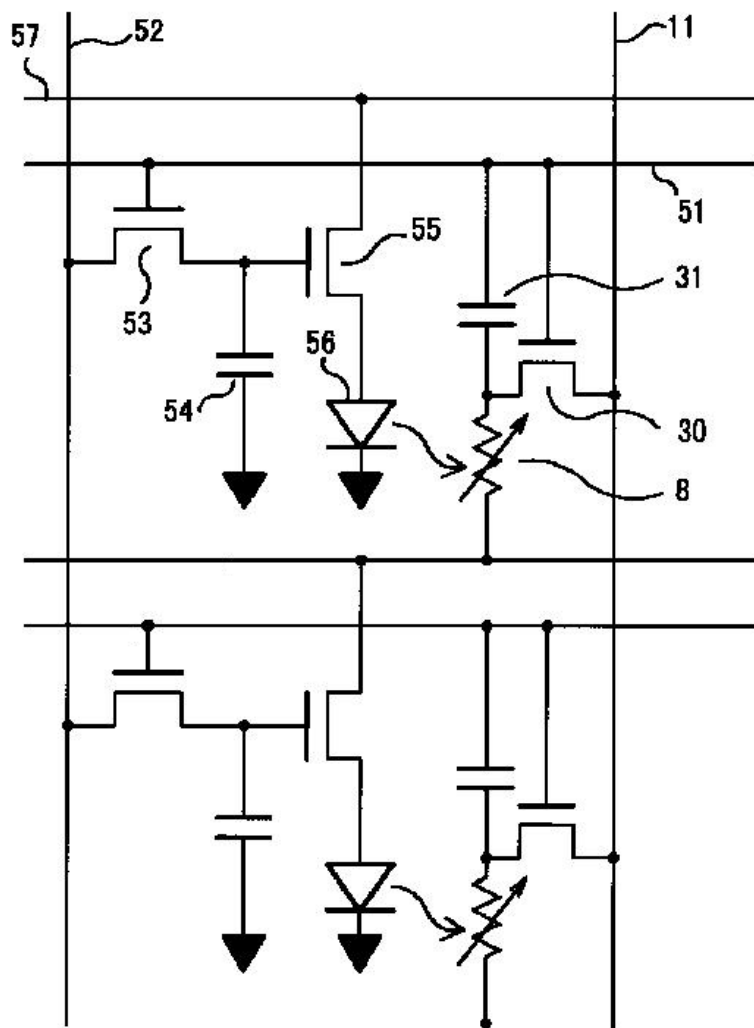
[Fig. 2]



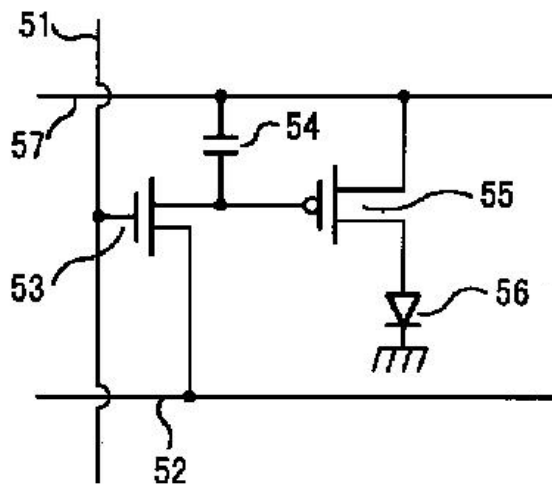
[Fig. 3]



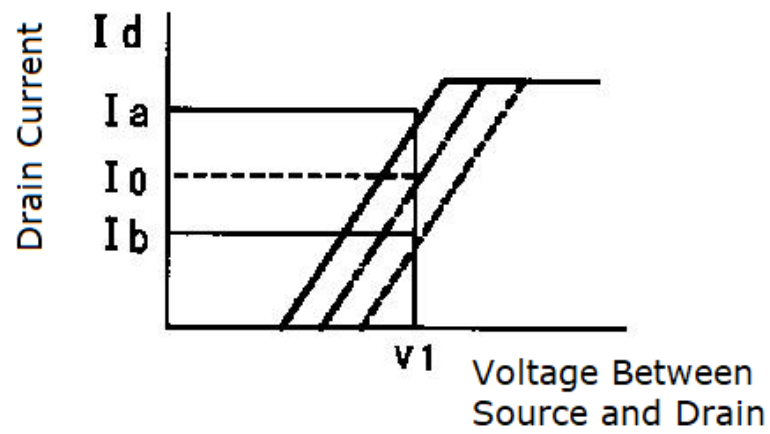
[Fig. 4]



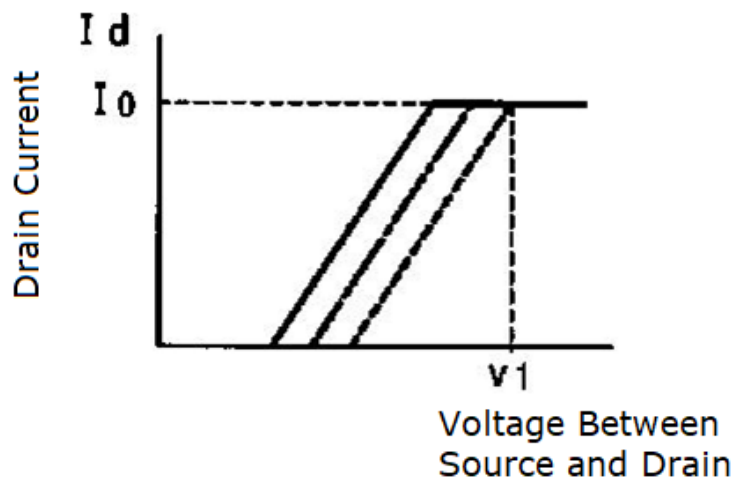
[Fig. 5]



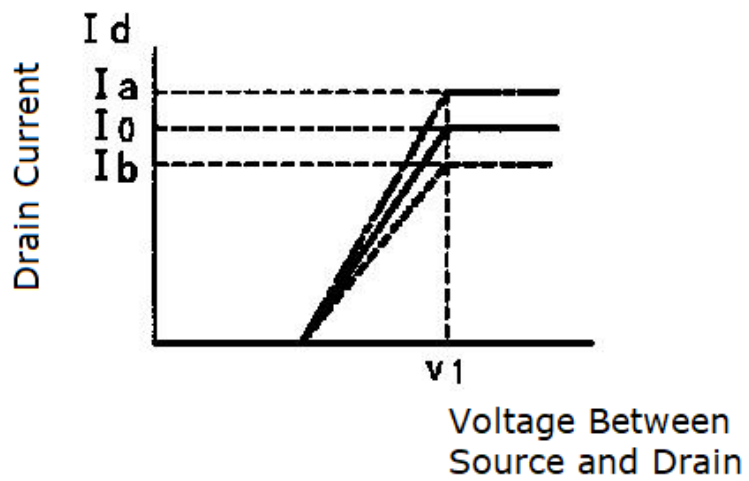
[Fig. 6]



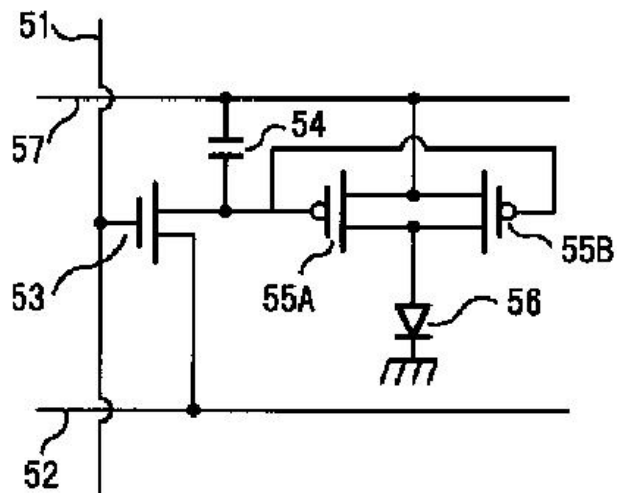
[Fig. 7]



[Fig. 8]



[Fig. 9]



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TRANSLATOR CERTIFICATION

Date: January 18, 2023

To whom it may concern:

I, Frank McGee, a translator fluent in the English and Japanese languages, on behalf of Morningside Translations, do solemnly and sincerely declare that the following is, to the best of my knowledge and belief, a true and correct translation of the document(s) listed below in a form that best reflects the intention and meaning of the original text.

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code.

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