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(54) **PIXEL DRIVING CIRCUIT, DISPLAY PANEL AND DRIVING METHOD THEREOF, AND DISPLAY DEVICE**

(57) The present disclosure provides a pixel driving circuit, a display substrate and a driving method thereof, and a display device, wherein the pixel driving circuit comprises: a driving unit, a data voltage write unit, an energy storage unit, a threshold compensation unit and a touch driving compensation unit. The energy storage unit comprises a first energy storage end and a second energy storage end. The touch driving compensation unit is connected to the second energy storage end of the energy storage unit to compensate the voltage of the second energy storage end in a touch phase, so as to maintain that driving current generated by the driving unit does not vary with time. The pixel driving circuit provided by the present disclosure can allow luminance of a driven electroluminescent element does not vary with time in a touch phase, thereby avoiding affecting light emission display of the driven electroluminescent element.

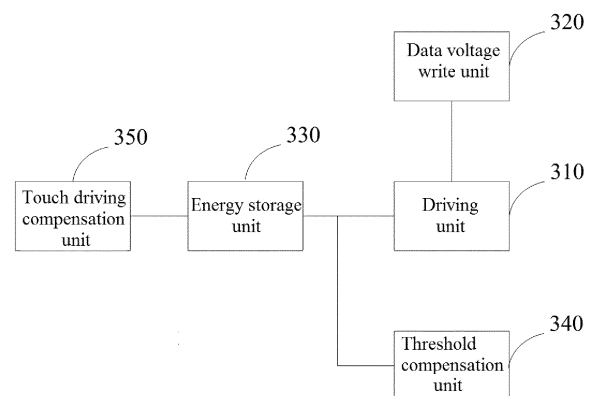


FIG. 1

Description

[0001] This application claims the benefit and priority of Chinese Patent Application No. 201510391775.0 filed July 6, 2015. The entire disclosure of the above application is incorporated herein by reference.

FIELD

[0002] The present disclosure relates to the field of display technologies, and more particularly, to a pixel driving circuit, a display substrate and a driving method thereof, and a display device.

BACKGROUND

[0003] With respect to an existing display device, an organic light emitting diode (OLED) functioning as a current-mode light-emitting device is increasingly used in the field of high performance display due to its characteristics such as autoluminescence, fast response, wide viewing angle, availability of being fabricated on a flexible substrate and so on. OLED display devices may be classified into two types according to different drive modes, namely, a passive matrix driving OLED (PMOLED) and an active matrix driving OLED (AMOLED). An AMOLED display is expected to replace a liquid crystal display (LCD) and become a next-generation new-type flat panel display due to its advantages such as low manufacturing cost, high response speed, power saving, DC drive, portability and wide working temperature range, etc.

[0004] In another aspect, with rapid progress of display technologies, a display device having touch function becomes gradually and increasingly popular with people due to its advantages such as a visualized operation and so on. In an existing OLED display device, a cathode of OLED therein is reused as a touch electrode. In this way, an entire thickness of the display device may be reduced. When the cathode is reused as the touch electrode, a touch drive signal needs to be applied to the cathode, which may cause that electric current flowing through OLED changes because the voltage of the touch drive signal varies with time, thereby making luminance of the OLED vary with time and affecting light emission display.

SUMMARY

[0005] According to a first aspect of the present disclosure, there is provided a pixel driving circuit, including: a driving unit, a data voltage write unit, an energy storage unit, a threshold compensation unit and a touch driving compensation unit. The energy storage unit comprises a first energy storage end and a second energy storage end. The driving unit is connected to the first energy storage end, and is configured to generate a driving current for driving an electroluminescent element connected to the pixel driving circuit according to a difference value between a voltage of the first energy storage end and a

threshold voltage of the driving unit. The data voltage write unit is connected to the driving unit, and is configured to write a data voltage into the driving unit. The energy storage unit is configured to maintain a voltage difference between the first energy storage end and the second energy storage end when the first energy storage end is floating. The threshold compensation unit is connected to the driving unit and the first energy storage end, and is configured to compensate voltage of the first energy storage end, such that the voltage equals to a sum of the data voltage and the threshold voltage. The touch driving compensation unit is connected to the second energy storage end, and is configured to compensate a voltage of the second energy storage end in a touch phase, so as to maintain that driving current generated by the driving unit does not vary with time.

[0006] In embodiments of the present disclosure, the touch driving compensation unit comprises a first switching transistor, a compensation voltage input end and a first control signal input end. A first electrode of the first switching transistor is connected to the compensation voltage input end, a second electrode of the first switching transistor is connected to the second energy storage end, and a control electrode of the first switching transistor is connected to the first control signal input end. The compensation voltage input end is configured to input a touch drive signal.

[0007] In the embodiments of the present disclosure, the driving unit comprises a drive transistor, and a control electrode of the drive transistor is connected to the first energy storage end.

[0008] In the embodiments of the present disclosure, the energy storage unit comprises a capacitor connected between the first energy storage end and the second energy storage end.

[0009] In the embodiments of the present disclosure, the threshold compensation unit comprises a second switching transistor and a second control signal input end, wherein a first electrode of the second switching transistor is connected to a second electrode of the drive transistor, a second electrode of the second switching transistor is connected to the first energy storage end, and a control electrode of the second switching transistor is connected to the second control signal input end.

[0010] The data voltage write unit comprises a third switching transistor, a data voltage writing end and a third control signal input end, wherein a first electrode of the third switching transistor is connected to the data voltage writing end, a second electrode of the third switching transistor is connected to a first electrode of the drive transistor, and a control electrode of the third switching transistor is connected to the third control signal input end.

[0011] In the embodiments of the present disclosure, the second control signal input end and the third control signal input end are the same control signal input end, and the electric levels for turning on the second switching transistor and the third switching transistor are the same.

[0012] In the embodiments of the present disclosure,

a reset unit is further comprised, wherein the reset unit is connected to the first energy storage end and the second energy storage end, and is configured to reset the first energy storage end and the second energy storage end.

[0013] In the embodiments of the present disclosure, the reset unit comprises a fourth switching transistor, a fifth switching transistor, a fourth control signal input end, a fifth control signal input end and a reset voltage input end. A first electrode of the fourth switching transistor is connected to the second energy storage end, a second electrode is connected to the reset voltage input end, and a control electrode is connected to the fourth control signal input end. A first electrode of the fifth switching transistor is connected to the second energy storage end, a second electrode is connected to the first energy storage end, and a control electrode is connected to the fifth control signal input end.

[0014] In the embodiments of the present disclosure, a light emission control unit is further comprised, wherein the light emission control unit is connected to the driving unit, and is configured to control the input of an electric current generated by the driving unit to the electroluminescent element.

[0015] In the embodiments of the present disclosure, the light emission control unit comprises a sixth switching transistor, a seventh switching transistor, a work voltage input end and a sixth control signal input end. A first electrode of the sixth switching transistor is connected to the work voltage input end, a second electrode of the sixth switching transistor is connected to the second electrode of the third switching transistor and the first electrode of the drive transistor. A first electrode of the seventh switching transistor is connected to the first electrode of the second switching transistor and the second electrode of the drive transistor, and a second electrode of the seventh switching transistor is connected to the electroluminescent element. The electric levels for turning on the sixth switching transistor and the seventh switching transistor are the same, and the sixth control signal input end and the seventh control signal input end are the same control signal input end.

[0016] In the embodiments of the present disclosure, all the switching transistors and the drive transistor are P-type transistors. The control electrode of each of the P-type transistors is a gate electrode, the first electrode is a source electrode, and the second electrode is drain electrode.

[0017] According to a second aspect of the present disclosure, there is provided a display substrate, including: a base, an electroluminescent element array formed on the base, a pixel driving circuit array for driving each electroluminescent element in the electroluminescent element array, and a plurality of display signal lines, wherein the pixel driving circuit array comprises a plurality of foregoing pixel driving circuits, the plurality of display signal lines are respectively connected to the input ends in the pixel driving circuit. The electroluminescent element

array comprises a first electrode pattern, a second electrode pattern, and an electroluminescent layer disposed between the first electrode pattern and the second electrode pattern. The first electrode pattern comprises a plurality of first electrodes, wherein each of the first electrodes is connected to the corresponding pixel driving circuit.

[0018] The display substrate further comprises a plurality of touch signal lines, the second electrode pattern comprises a plurality of second electrodes, and the second electrodes are connected to the touch signal lines and function as touch electrodes.

[0019] In the embodiments of the present disclosure, the second electrodes in the second electrode pattern are divided into a plurality of rows, the second electrodes in odd-numbered rows and the second electrodes in even-numbered rows are disposed in a staggered manner in a column direction. In each odd-numbered row, the second electrodes in the same row are connected to the same touch signal line. In the even-numbered rows, the second electrodes in the same column are connected to the same touch signal line.

[0020] According to a third aspect of the present disclosure, there is provided a method for driving the foregoing display substrate, including a light emission phase which comprises a touch phase,

wherein in the touch phase of the light emission phase, a touch drive signal is applied to second electrodes in the second electrode pattern through the touch signal lines, and the touch driving compensation unit is controlled through the display signal lines to compensate the voltage of the second energy storage end, so as to maintain that electric current generated by the driving unit does not vary with time.

[0021] In the embodiments of the present disclosure, in the touch phase, a difference value between the voltage of a display drive signal applied to each display signal line and the voltage of the touch drive signal does not vary with time.

[0022] According to a fourth aspect of the present disclosure, there is provided a display device which comprises the foregoing display substrate.

[0023] The pixel driving circuit provided by the embodiments of the present disclosure comprises a touch driving compensation unit which can compensate the voltage of the second energy storage end in a touch phase, so as to maintain that driving current generated by the driving unit does not vary with time. In this way, in the touch phase, luminance of a driven electroluminescent element does not vary with time, thereby avoiding affecting light emission display of the driven electroluminescent element.

DRAWINGS

[0024] To describe technical solutions of embodiments of the present disclosure more clearly, the following will briefly introduce the accompanying drawings of the em-

bodiments. It should be known that the accompanying drawings in the following description merely involve with some embodiments of the present disclosure, but not limit the present disclosure, in which:

FIG. 1 is a block diagram of a pixel driving circuit according to a first embodiment of the present disclosure,

FIG. 2 is a schematic circuit diagram of the pixel driving circuit according to the embodiment as shown in FIG. 1,

FIG. 3 is a work timing diagram of the pixel driving circuit according to the embodiment as shown in FIG. 2,

FIG. 4 is a schematic state diagram of the pixel driving circuit in a first phase according to the embodiment as shown in FIG. 2,

FIG. 5 is a schematic state diagram of the pixel driving circuit in a second phase according to the embodiment as shown in FIG. 2,

FIG. 6 is a schematic state diagram of the pixel driving circuit in a third phase according to the embodiment as shown in FIG. 2,

FIG. 7 is a schematic state diagram of the pixel driving circuit in a fourth phase according to the embodiment as shown in FIG. 2,

FIG. 8 is a schematic structural diagram of a pixel unit in a display substrate according to a second embodiment of the present disclosure, and

FIG. 9 is a schematic diagram of a connection relation between a pixel unit and a touch signal line in the display substrate according to the second embodiment of the present disclosure.

DETAILED DESCRIPTION

[0025] The following further describes the concrete implementation manners of the present disclosure with reference to the accompanying drawings and embodiments. The following embodiments are merely intended to more clearly describe the technical solutions of the present disclosure, but not to limit the protection scope of the present disclosure.

[0026] FIG. 1 is a block diagram of a pixel driving circuit according to a first embodiment of the present disclosure. As shown in FIG. 1, the pixel driving circuit of this embodiment may be configured to drive an electroluminescent element, whose cathode is reused as a touch electrode, to display. See FIG. 1, the pixel driving circuit may comprise: a driving unit 310, a data voltage write unit 320, an energy storage unit 330, a threshold compensation unit 340 and a touch driving compensation unit 350. The energy storage unit 330 comprises a first energy storage end and a second energy storage end. The driving unit 310 is connected to the first energy storage end to generate a driving current for driving the electroluminescent element connected to the pixel driving circuit according to a difference value between voltage of the first

energy storage end and a threshold voltage of the driving unit 310. The data voltage write unit 320 is connected to the driving unit 310 to input data voltage to the driving unit 310. The energy storage unit 330 is configured to maintain a voltage difference between the first energy storage end and the second energy storage end when the first energy storage end is floating. The threshold compensation unit 340 is connected to the driving unit 310 and the first energy storage end to compensate the voltage of the first energy storage end, such that the voltage equals to a sum of the data voltage and the threshold voltage. The touch driving compensation unit 350 is connected to the second energy storage end to make driving compensation on the voltage of the second energy storage end in a touch phase, so as to maintain that the driving current generated by the driving unit 310 does not vary with time.

[0027] The pixel driving circuit provided by the embodiments of the present disclosure comprises the touch driving compensation unit 350 which can make driving compensation on the voltage of the second energy storage end in a touch phase, so as to maintain that driving current generated by the driving unit 310 does not vary with time. In this way, in the touch phase, luminance of the driven electroluminescent element does not vary with time, thereby avoiding affecting the light emission display of the driven electroluminescent element.

[0028] The "floating" here is consistent with what is understood in the prior art. For example, the first energy storage end being floating means a state in which the first energy storage end is neither supplied with voltage nor grounded so that electric charge is unable to flow in or flow out.

[0029] FIG. 2 is a schematic circuit diagram of the pixel driving circuit according to the embodiment as shown in FIG. 1. As shown in FIG. 2, the touch driving compensation unit 350 of this embodiment may specifically comprise a first switching transistor T1, a compensation voltage input end M and a first control signal input end Scan1. A source electrode of the first switching transistor T1 is connected to the compensation voltage input end M, a drain electrode is connected to the second energy storage end, and a gate electrode is connected to the first control signal input end Scan1. The compensation voltage input end M is configured to input a touch drive signal. Thus, by way of appropriate control, the voltage of the second energy storage end is compensated in real time to be the voltage of the touch drive signal inputted on the voltage input end M. The voltage difference between the second energy storage end and the first energy storage end maintains when the first energy storage end is floating, which enables the voltage of the first energy storage end to synchronously increase by a voltage equal to the voltage of the touch drive signal, thereby counteracting the impact of the touch drive signal applied to the cathode of the electroluminescent element on electric current flowing through the electroluminescent element.

[0030] The driving unit 310 may comprise a drive tran-

sistor (in the following, reference is made by taking an example in which the drive transistor is a P-type transistor). A gate electrode of the P-type drive transistor is connected to the first energy storage end. The energy storage unit 330 may comprise a capacitor C connected between the first energy storage end and the second energy storage end. Of course, in practical application, the foregoing driving unit 310 and the energy storage unit 330 may be replaced with other components having the same functions.

[0031] In the embodiments of the present disclosure, the threshold compensation unit 340 comprises a second switching transistor T2 and a second control signal input end Scan2, wherein a source electrode of the second switching transistor T2 is connected to a drain electrode of the P-type drive transistor, a drain electrode is connected to the first energy storage end, and a gate electrode is connected to the second control signal input end Scan2.

[0032] The data voltage write unit 320 comprises a third switching transistor T3, a data voltage writing end Data and a third control signal input end Scan3. A source electrode of the third switching transistor T3 is connected to the data voltage writing end, a drain electrode is connected to a source electrode of the P-type drive transistor, and a gate electrode is connected to the third control signal input end.

[0033] In this way, the data voltage write unit 320 can write data voltage into the source electrode of the P-type drive transistor, so that the P-type drive transistor may be turned on by the data voltage. The threshold compensation unit 340 may be connected to the drain electrode and the gate electrode of the P-type drive transistor, and the gate electrode of the P-type drive transistor is connected to a first end of the energy storage unit 330. Therefore, voltage of the gate electrode of the P-type drive transistor may gradually rise until it reaches the sum of the data voltage and the threshold voltage (a threshold of the P-type drive transistor generally is a negative value). In this way, a process of voltage writing and threshold compensation is completed. In a subsequent light emission process, the gate voltage of the P-type drive transistor is the sum of the data voltage and the threshold voltage, thus driving current generated by the drive transistor may be unrelated to the threshold voltage but is related to the data voltage, thereby avoiding threshold shift of the drive transistor to affect light emission display of the electroluminescent element.

[0034] Of course, in practical application, the foregoing threshold compensation module and the data voltage writing module may also be other structures as long as they can implement functions of the voltage writing and the threshold compensation, and specific structures of the threshold compensation module and the data voltage writing module may not affect the protection scope of the present disclosure.

[0035] In the embodiments of the present disclosure, the second control signal input end Scan2 and the third

control signal input end Scan3 may be the same control signal input end, and the electric levels for turning on the second switching transistor T2 and the third switching transistor T3 are the same. In this way, the data voltage writing and the threshold compensation may be carried out simultaneously, and it reduces the use of one control signal input end.

[0036] Further, the foregoing pixel driving circuit may further comprise a reset unit, wherein the reset unit is connected to the first energy storage end and the second energy storage end, and is configured to reset the first energy storage end and the second energy storage end.

[0037] In this way, reset of the first energy storage end and the second energy storage end can be implemented, thereby avoiding affecting light emission display of a next frame. In some pixel driving circuits, the foregoing reset unit is not an indispensable structure, and a technical solution in which no reset unit is provided also falls within the protection scope of the present disclosure.

[0038] In the embodiments of the present disclosure, the reset unit comprises a fourth switching transistor T4, a fifth switching transistor T5, a fourth control signal input end Scan4, a fifth control signal input end Scan5 and a reset voltage input end Vss, wherein a drain electrode of the fourth switching transistor T4 is connected to the reset voltage input end Vss, a source electrode is connected to the second energy storage end, and a gate electrode is connected to the fourth control signal input end Scan4. A source electrode of the fifth switching transistor T5 is connected to the second energy storage end, a drain electrode is connected to the first energy storage end, and a gate electrode is connected to the fifth control signal input end Scan5.

[0039] Further, in the embodiments of the present disclosure, the foregoing pixel driving circuit may further comprise a light emission control unit, wherein the light emission control unit is connected to the driving unit 310, and is configured to control the input of an electric current generated by the driving unit 310 to a corresponding electroluminescent element.

[0040] Specifically, the light emission control unit 310 comprises a sixth switching transistor T6, a seventh switching transistor T7, a work voltage input end Vdd, a sixth control signal input end Scan6 and a seventh control signal input end Scan6, wherein a source electrode of the sixth switching transistor T6 is connected to the work voltage input end Vdd, a drain electrode is connected to the drain electrode of the third switching transistor T3 and the source electrode of the P-type drive transistor, and a gate electrode is connected to the sixth control signal input end Scan6. A source electrode of the seventh switching transistor is connected to the source electrode of the second switching transistor and the drain electrode of the P-type drive transistor, a drain electrode is connected to a corresponding electroluminescent element, and a gate electrode is connected to the seventh control signal input end Scan6.

[0041] Further, the electric levels for turning on the

sixth switching transistor T6 and the seventh switching transistor T7 are the same, and the sixth control signal input end Scan6 and the seventh control signal input end Scan6 are the same control signal input end Scan6.

[0042] The sixth switching transistor T6 and the seventh switching transistor T7 are set as transistors having the same electric level for turning on and are connected to the same control signal input end Scan6, which may also reduce the number of used signal input ends.

[0043] In the embodiments of the present disclosure, all the switching transistors may be P-type transistors. The advantage is that various switching transistors and the drive transistor may be fabricated by means of a unified fabrication process so that fabrication difficulty is reduced. Of course, in practical application, a part of the transistors or all the transistors may be replaced with N-type drive transistors, and corresponding technical solutions may not depart from the scope of the present disclosure.

[0044] A description is made in the following with reference to a drive process of the pixel driving circuit.

[0045] See FIG. 2, in the embodiments of the present disclosure, the foregoing pixel driving circuit may comprise: seven P-type switching transistors T1-T7, one P-type drive transistor DT and one capacitor C, and the pixel driving circuit is connected to an anode of the electroluminescent element (expressed as OLED in FIG. 2). The foregoing pixel driving circuit 300 further comprises: control signal input ends Scan1-Scan6, a data voltage writing end Data and a compensation voltage input end M, additionally including a work voltage input end Vdd and a reset voltage input end Vss. The source electrode of the first switching transistor T1 is connected to the compensation voltage input end M, the drain electrode is connected to a second node N2, and the gate electrode is connected to the first control signal input end Scan1. The source electrode of the second switching transistor T2 is connected to a drain electrode of the P-type drive transistor DT, the drain electrode is connected to a first node N1, and the gate electrode is connected to the second control signal input end Scan2. The source electrode of the third switching transistor T3 is connected to the data voltage writing end Data, the drain electrode is connected to a source electrode of the P-type drive transistor DT, and the gate electrode is connected to the third control signal input end Scan3. The drain electrode of the fourth switching transistor T4 is connected to the reset voltage input end Vss, the source electrode is connected to the second node N2, and the gate electrode is connected to the fourth control signal input end Scan4. The drain electrode of the fifth switching transistor T5 is connected to the first node N1, the source electrode is connected to the second node N2, and the gate electrode is connected to the fifth control signal input end Scan5. The source electrode of the sixth switching transistor T6 is connected to the work voltage input end Vdd, and the drain electrode is connected to the drain electrode of the third switching transistor T3 and the source electrode of

the P-type drive transistor DT. The source electrode of the seventh switching transistor T7 is connected to the source electrode of the second switching transistor T2 and the drain electrode of the P-type drive transistor DT, and the drain electrode is connected to the anode of the electroluminescent element OLED. The gate electrodes of the sixth switching transistor T6 and of the seventh switching transistor T7 are connected to the sixth control signal input end Scan6, one electrode plate of the capacitor C is connected to the first node N1, and the other electrode plate is connected to the second node N2.

[0046] By using an appropriate driving method, the pixel driving circuit provided by the embodiments of the present disclosure may avoid threshold shift of the drive transistor from affecting light emission display and avoid a touch drive signal applied to the cathode from affecting light emission display. A description of working principles of the pixel driving circuit in FIG. 2 is made in the following with reference to FIG. 3-FIG. 7. FIG. 3 is a work timing diagram of the pixel driving circuit according to the embodiment as shown in FIG. 2. See FIG. 3, a drive process of the pixel driving circuit in FIG. 2 may be divided into four phases.

[0047] FIG. 4 is a schematic state diagram of the pixel driving circuit in a first phase according to the embodiment as shown in FIG. 2. The first phase S1 is a reset phase, during which a low-level voltage is applied to the control signal input ends Scan4 and Scan5, and a high-level voltage is applied to the other control signal input ends. See FIG. 4, at the moment, the fourth switching transistor T4 and the fifth switching transistor T5 are turned on, the other switching transistors are turned off, the reset voltage input end Vss is connected through T4 with the second node N2, and is connected through T5 with the first node N1, and the voltages of the second node N2 and the first node N1 are reset (for example, reset to 0V).

[0048] It is not difficult to understand that in the present disclosure, applying a low-level voltage to the control signal input ends Scan4 and Scan5 refers that corresponding signals are applied to display signal lines respectively connected to the control signal input ends Scan4 and Scan5, and similarly, voltages or signals applied to each input end in the following is also applied through the signal lines connected to the corresponding input ends.

[0049] FIG. 5 is a schematic state diagram of the pixel driving circuit in a second phase according to the embodiment as shown in FIG. 2. The second phase S2 is a charging phase, during which a low level voltage is applied to the control signal input ends Scan2, Scan3 and Scan4, and a high level voltage is applied to the other control signal input ends, and a corresponding data voltage Vdata is applied to the data voltage writing end Data. See FIG. 5, at the moment, the second switching transistor T2 and the third switching transistor T3 are turned on, the first node N1 is charged by the data voltage writing end Data through the third switching transistor T3, the drive transistor DT and the second switching transistor

T2, upon completion of charging, voltage of the first node N1 is set to $V_{data}-V_{th}$, wherein V_{th} represents the threshold voltage of the drive transistor DT. The fourth switching transistor T4 continues to be turned on, and voltage of the second node N2 is maintained to be reset voltage of 0V.

[0050] FIG. 6 is a schematic state diagram of the pixel driving circuit in a third phase according to the embodiment as shown in FIG. 2. The third phase S3 is a separate light emission phase, during which a low level voltage is applied to the control signal input ends Scan6 and Scan4, and a high level voltage is applied to the other control signal input ends. See FIG. 6, at the moment, the seventh switching transistor T7 and the sixth switching transistor T6 are turned on, the work voltage input end Vdd supplies power to the electroluminescent element OLED through the sixth switching transistor T6, the drive transistor DT and the seventh switching transistor T7, and at the moment the electroluminescent element OLED emits light. The fourth switching transistor T4 continues to be turned on, and the voltage of the second node N2 is maintained to be the reset voltage.

[0051] Light emission current flowing through OLED may be obtained according to a saturation current formula: $I=K(V_{gs}-V_{th})^2=K(V_{vdd}-(V_{data}-V_{th})-V_{th})=K(V_{vdd}-V_{data})^2$, wherein V_{gs} expresses a voltage difference between the gate electrode and the source electrode of the drive transistor DT, K is a constant related to the drive transistor DT, and Vdd is work voltage inputted at the work voltage input end Vdd.

[0052] As can be seen, the light emission current is unrelated to the threshold V_{th} of the drive transistor DT, thereby avoiding threshold shift of the drive transistor from affecting light emission display.

[0053] FIG. 7 is a schematic state diagram of the pixel driving circuit in a fourth phase according to the embodiment as shown in FIG. 2. The fourth phase S4 is a light emission and touch phase, during which, the light emission and the touch are carried out simultaneously. In this phase, a low level voltage is applied to the control signal input ends Scan1 and Scan6, a high level voltage is applied to the other control signal input ends, and a touch drive signal is applied to the compensation voltage input end M and the cathode T of OLED. See FIG. 7, at the moment, the sixth switching transistor T6 and the seventh switching transistor T7 continue to be turned on, and the first switching transistor T1 is turned on. Two ends of the capacitor C are floating, so that a voltage difference between the first node N1 and the second node N2 maintains unchanged, thus, voltage of the second node N2 is also set to ΔV when voltage of the touch drive signal is ΔV , and correspondingly, voltage of the first node N1 leaps to $V_{data}-V_{th}+\Delta V$, at the moment, the source voltage Vdd also changes to $V_{vdd}+\Delta V$.

[0054] It may be seen according to the saturation current formula that at the moment, $I=K(V_{gs}-V_{th})^2=K(V_{vdd}+\Delta V-(V_{data}-V_{th}+\Delta V)-V_{th})=K(V_{vdd}-V_{data})^2$. As can be seen, electric current flowing through the

electroluminescent element OLED maintains consistent in that in the separate light emission phase S3. That is, the electric current at the moment is not affected by variation of the voltage of the touch drive signal applied to the cathode T. In addition, in this phase, the voltage of the signal applied to each display drive signal line synchronously fluctuates with the voltage of the touch drive signal, with an amplitude being equal to a fluctuation amplitude of the voltage of the touch drive signal, which may effectively reduce a transmission delay of the touch drive signal caused by a capacitance between the cathode, the touch drive signal lines and the display signal lines.

[0055] It is easy to see that in the foregoing pixel driving circuit, the first switching transistor T1, the compensation voltage input end M and the control signal input end Scan1 jointly achieve the function of the compensation of the touch drive voltage, functioning as the touch driving compensation unit 350 in the pixel driving circuit. The third switching transistor T3, the data voltage writing end Data and the control signal input end Scan3 jointly constitute the data voltage write unit 320, and the second switching transistor T2 and the control signal input end Scan2 jointly constitute the threshold compensation unit 340. The fourth switching transistor T4, the fifth switching transistor T5, the control signal input ends Scan4, Scan5 and the reset voltage input end Vss respectively connected to T4, T5 jointly achieve the reset function, and function as the reset unit in the pixel driving circuit. The sixth switching transistor T6, the seventh switching transistor T7, the control signal input end Scan6 and the work voltage input end Vdd connected to T6 and T7 jointly achieve the function of light emission control, and function as the light emission control unit in the pixel driving circuit. The capacitor C constitutes the energy storage unit 330. Of course, in order to achieve basic objectives of the present disclosure, the foregoing function units are not necessarily set as the same as shown in FIG. 7, and are not indispensable structures in some pixel driving circuits.

[0056] Furthermore, in the embodiments of the present disclosure, control signals applied to the foregoing control signal input ends Scan2 and Scan3 are same, and the control signal input ends Scan2 and Scan3 may be the same control signal input end and connected to the same display control line.

[0057] FIG. 8 is a schematic structural diagram of a pixel unit in a display substrate according to a second embodiment of the present disclosure. The second embodiment of the present disclosure provides a display substrate including the foregoing pixel driving circuit, wherein the display substrate comprises: a base 100, an electroluminescent element array formed on the base 100, a pixel driving circuit array for driving each electroluminescent element in the electroluminescent element array, and a plurality of display signal lines, wherein a pixel driving circuit 300 in the pixel driving circuit array is the foregoing pixel driving circuit, the plurality of display signal lines are respectively connected to the corresponding input ends in the pixel driving circuit 300. The

electroluminescent element array comprises a first electrode pattern, a second electrode pattern, and an electroluminescent layer 230 disposed between the first electrode pattern and the second electrode pattern. The first electrode pattern comprises a plurality of first electrodes 210, wherein each of the first electrodes 210 is connected to a corresponding pixel driving circuit 300.

[0058] The display substrate further comprises a plurality of touch signal lines, the second electrode pattern comprises a plurality of second electrodes 220, and the second electrodes 220 are connected to the touch signal lines and function as touch electrodes.

[0059] The display substrate provided by the present disclosure can make driving compensation on the voltage of the second energy storage end in a touch phase, so as to maintain that driving current generated by the driving unit does not vary with time. In this way, in the touch phase, the luminance of a driven electroluminescent element does not vary with time, thereby avoiding affecting light emission display of the driven electroluminescent element.

[0060] In the embodiments of the present disclosure, the electroluminescent element array on the display substrate comprises a plurality of electroluminescent elements, correspondingly, the first electrode pattern of the electroluminescent element array may comprise a corresponding number of the first electrodes 210, the first electrodes 210 of each electroluminescent element are correspondingly connected to a pixel driving circuit 300 and make light emission display under the drive of the pixel driving circuit 300. One electroluminescent element and one pixel driving circuit 300 constitute one pixel unit. Furthermore, a plurality of display drive signal lines for controlling each pixel driving circuit 230 may also be formed on the display substrate. It is not difficult to understand that each second electrode 220 in the second electrode pattern functioning as a touch electrode does not necessarily fit to one pixel unit in size because the requirement for touch accuracy is lower than pixel resolution, that is, a plurality of pixel units may share one second electrode 220.

[0061] See FIG. 8, the structure of one pixel unit in the display substrate provided by the present disclosure may comprise: a base 100, a first electrode 210 formed on the base 100, a second electrode 220, and an electroluminescent layer 230 disposed between the first electrode 210 and the second electrode 220. The first electrode 210 and the second electrode 220 and the electroluminescent layer 230 disposed thereon jointly achieve electroluminescence. It is further comprised a pixel driving circuit 300 connected to the first electrode 210.

[0062] FIG. 9 is a schematic diagram of a connection relation between a pixel unit and a touch signal line in the display substrate according to the second embodiment of the present disclosure. FIG. 9 is a diagram showing connection relation between each second electrode 220 in the second electrode pattern and a touch signal line 400, second electrodes 220 in odd-numbered rows

($2n-1$, $2n+1$ and $2n+3$) are interlaced in location with second electrodes 220 in even-numbered rows ($2n$ and $2n+2$). In each odd-numbered row, the second electrodes 220 in the same row are connected to a touch signal line 400 in the same row direction. In even-numbered rows, the second electrodes 220 in the same column are connected to a touch signal line 400 in the same column direction. In specific application, when a finger touches any location, electric charges stored on second electrodes 220 (including second electrodes 220 connected to touch signal lines 400 in column direction and second electrodes 220 connected to touch signal lines 400 in row direction) adjacent to the location may change, and such change may be detected through touch signal lines 400 connecting these second electrodes 220, thereby determining a touch location. Odd-numbered rows and even-numbered rows are used for distinguishing two adjacent rows of second electrodes 220 for ease of description, not for limiting locations of rows of second electrodes 220, that is, the technical solutions of the present disclosure still hold true even though the foregoing odd-numbered rows and even-numbered rows in the description are exchanged.

[0063] Generally, the first electrode 210 here is the anode of an electroluminescent element 200, and the second electrode 220 is the cathode of the electroluminescent element 200. The electroluminescent element 200 may be OLED in FIG. 2.

[0064] It is not difficult to understand that FIG. 8 and FIG. 9 are merely schematic diagram of the display substrate according to the present disclosure, in practical application, the pixel driving circuit 300 likely comprises a plurality of transistors, and thus the schematic structures shown in FIG. 8 and FIG. 9 shall not constitute a limitation on the protection scope of the present disclosure.

[0065] In the embodiments of the present disclosure, the touch signal lines here may be simultaneously fabricated while various components (for example, capacitors, transistors and so on) in the pixel driving circuit are fabricated. Further, in some cases, the foregoing pixel driving circuit, the first electrode pattern and the electroluminescent layer 230 may be fabricated on a backplate, the second electrode pattern may be fabricated on a cover plate, and in such a case, the touch signal lines may be fabricated on the backplate.

[0066] A third embodiment of the present disclosure provides a method for driving the foregoing display substrate, and the method comprises a light emission phase which comprises a touch phase.

[0067] In the touch phase of the light emission phase, a touch drive signal is applied to second electrodes in the second electrode pattern through the touch signal line, and the touch driving compensation unit is controlled through the display signal line to make driving compensation on the voltage of the second energy storage end, so as to maintain that electric current generated by the driving unit does not vary with time.

[0068] By using the driving method, driving compensation is made on the voltage of the second energy storage end in a touch phase, so that driving current generated by the driving unit 310 does not vary with time. In this way, in the touch phase, luminance of a driven electroluminescent element does not vary with time, thereby avoiding affecting light emission display of the driven electroluminescent element.

[0069] Further, the driving method may also comprise: in a touch phase, a difference value between the voltage of a display drive signal applied to each display signal line and the voltage of the touch drive signal does not vary with time.

[0070] This may reduce transmission delay of a touch drive signal between a touch signal line and a second electrode, which is caused by capacitance between the second electrode and the touch signal line and each signal line. Specifically, in the touch phase, a display drive signal applied to each display signal line has a certain voltage fluctuation, the voltage fluctuation synchronously changes with the voltage of the touch drive signal applied to the second electrode, and an amplitude of the fluctuation the voltage is the same as variation of the voltage of the touch drive signal. In this way, a difference value between the voltage of a display drive signal and the voltage of the touch drive signal is a constant value, thereby avoiding capacitance between the second electrode and each signal line from changing, and reducing delay arisen therefrom.

[0071] The embodiments of the present disclosure further provide a display device which comprises the foregoing display substrate.

[0072] The display device here may be any product or component having display function, such electronic paper, a mobile phone, a tablet computer, a TV set, a display, a notebook computer, a digital photo frame, a navigation device and so on.

[0073] What is mentioned above merely refers to preferred embodiments of the present disclosure. It shall be pointed out that to those of ordinary skill in the art, various improvements and modifications may be made without departing from the technical principle of the present disclosure, and these improvements and modifications are also deemed to be within the protection scope of the present disclosure.

Claims

1. A pixel driving circuit, comprising a driving unit, a data voltage write unit, an energy storage unit, a threshold compensation unit and a touch driving compensation unit, wherein the energy storage unit comprises a first energy storage end and a second energy storage end, wherein the driving unit is connected to the first energy storage end, and is configured to generate a driving current for driving an electroluminescent el-

ement connected to the pixel driving circuit according to a difference value between a voltage of the first energy storage end and a threshold voltage of the driving unit,

wherein the data voltage write unit is connected to the driving unit, and is configured to write a data voltage into the driving unit,

wherein the energy storage unit is configured to maintain a voltage difference between the first energy storage end and the second energy storage end when the first energy storage end is floating,

wherein the threshold compensation unit is connected to the driving unit and the first energy storage end, and is configured to compensate the voltage of the first energy storage end, such that the voltage equals to a sum of the data voltage and the threshold voltage, and

wherein the touch driving compensation unit is connected to the second energy storage end, and is configured to compensate a voltage of the second energy storage end in a touch phase, so as to maintain that the driving current generated by the driving unit does not vary with time.

2. The pixel driving circuit according to claim 1, wherein the touch driving compensation unit comprises a first switching transistor, a compensation voltage input end and a first control signal input end, wherein a first electrode of the first switching transistor is connected to the compensation voltage input end, a second electrode of the first switching transistor is connected to the second energy storage end, and a control electrode of the first switching transistor is connected to the first control signal input end, and wherein the compensation voltage input end is configured to input a touch drive signal.
3. The pixel driving circuit according to claim 1, wherein the driving unit comprises a drive transistor, and a control electrode of the drive transistor is connected to the first energy storage end.
4. The pixel driving circuit according to claim 3, wherein the energy storage unit comprises a capacitor connected between the first energy storage end and the second energy storage end.
5. The pixel driving circuit according to claim 4, wherein the threshold compensation unit comprises a second switching transistor and a second control signal input end, a first electrode of the second switching transistor is connected to a second electrode of the drive transistor, a second electrode of the second switching transistor is connected to the first energy storage end, and a control electrode of the second switching transistor is connected to the second control signal input end, and wherein the data voltage write unit comprises a third

switching transistor, a data voltage writing end and a third control signal input end, a first electrode of the third switching transistor is connected to the data voltage writing end, a second electrode of the third switching transistor is connected to a first electrode of the drive transistor, and a control electrode of the third switching transistor is connected to the third control signal input end.

6. The pixel driving circuit according to claim 5, wherein the second control signal input end and the third control signal input end are the same control signal input end, and the electric levels for turning on the second switching transistor and the third switching transistor are the same.

7. The pixel driving circuit according to claim 4, further comprising a reset unit, wherein the reset unit is connected to the first energy storage end and the second energy storage end, and is configured to reset the first energy storage end and the second energy storage end.

8. The pixel driving circuit according to claim 7, wherein the reset unit comprises a fourth switching transistor, a fifth switching transistor, a fourth control signal input end, a fifth control signal input end and a reset voltage input end, wherein a first electrode of the fourth switching transistor is connected to the second energy storage end, a second electrode of the fourth switching transistor is connected to the reset voltage input end, a control electrode of the fourth switching transistor is connected to the fourth control signal input end, and wherein a first electrode of the fifth switching transistor is connected to the second energy storage end, a second electrode of the fifth switching transistor is connected to the first energy storage end, and a control electrode of the fifth switching transistor is connected to the fifth control signal input end.

9. The pixel driving circuit according to claim 4, further comprising a light emission control unit, wherein the light emission control unit is connected to the driving unit, and is configured to control the input of an electric current generated by the driving unit to the electroluminescent element.

10. The pixel driving circuit according to claim 9, wherein the light emission control unit comprises a sixth switching transistor, a seventh switching transistor, a work voltage input end and a sixth control signal input end, wherein a first electrode of the sixth switching transistor is connected to the work voltage input end, a second electrode of the sixth switching transistor is connected to the second electrode of the third switching transistor and the first electrode of the drive

transistor,

wherein a first electrode of the seventh switching transistor is connected to the first electrode of the second switching transistor and the second electrode of the drive transistor, a second electrode of the seventh switching transistor is connected to the electroluminescent element, and

wherein the electric levels for turning on the sixth switching transistor and the seventh switching transistor are the same, and the sixth control signal input end and the seventh control signal input end are the same control signal input end.

11. The pixel driving circuit according to any one of claims 4-10, wherein all the switching transistors and the drive transistor are P-type transistors, and the control electrode of each of the P-type transistors is a gate electrode, the first electrode is a source electrode, and the second electrode is a drain electrode.

12. A display substrate, comprising: a base, an electroluminescent element array formed on the base, a pixel driving circuit array for driving each electroluminescent element in the electroluminescent element array, and a plurality of display signal lines, wherein the pixel driving circuit array comprises a plurality of pixel driving circuits according to any one of claims 1-11, the plurality of display signal lines are respectively connected to the input ends in the pixel driving circuit, wherein the electroluminescent element array comprises a first electrode pattern, a second electrode pattern, and an electroluminescent layer disposed between the first electrode pattern and the second electrode pattern, the first electrode pattern comprises a plurality of first electrodes, wherein each of the first electrodes is connected to the corresponding pixel driving circuit, and wherein the display substrate further comprises a plurality of touch signal lines, the second electrode pattern comprises a plurality of second electrodes, and the second electrodes are connected to the touch signal lines and function as touch electrodes.

13. The display substrate according to claim 12, wherein the second electrodes in the second electrode pattern are divided into a plurality of rows, the second electrodes in odd-numbered rows and the second electrodes in even-numbered rows are disposed in a staggered manner in a column direction, the second electrodes in each odd-numbered row are connected to the same touch signal line, and the second electrodes in the even-numbered rows and in the same column are connected to the same touch signal line.

14. A method for driving the display substrate according to claim 12 or 13, comprising a light emission phase

which comprises a touch phase,
wherein in the touch phase of the light emission
phase, a touch drive signal is applied to the second
electrodes in the second electrode pattern through
the touch signal lines, and the touch driving compen- 5
sation unit is controlled through the display signal
lines to compensate the voltage of the second ener-
gy storage end, so as to maintain that the electric
current generated by the driving unit does not vary
with time. 10

15. The method according to claim 14, wherein in the
touch phase, a difference value between the voltage
of the display drive signal applied to each display
signal line and the voltage of the touch drive signal 15
does not vary with time.

16. A display device, comprising the display substrate
according to claim 12 or 13. 20

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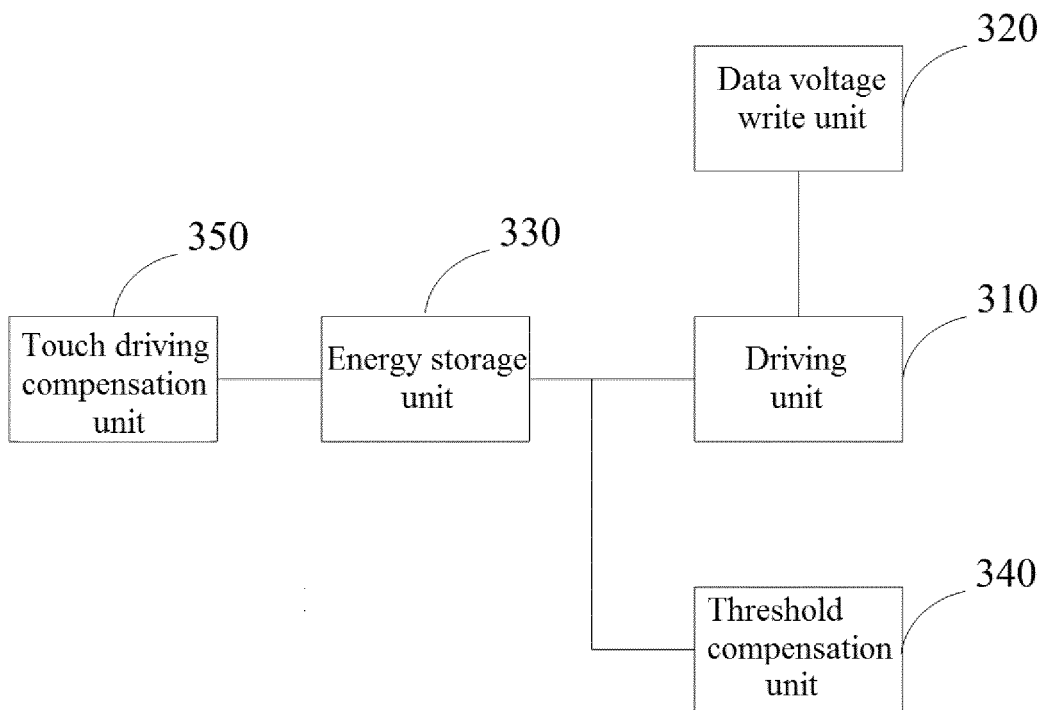


FIG. 1

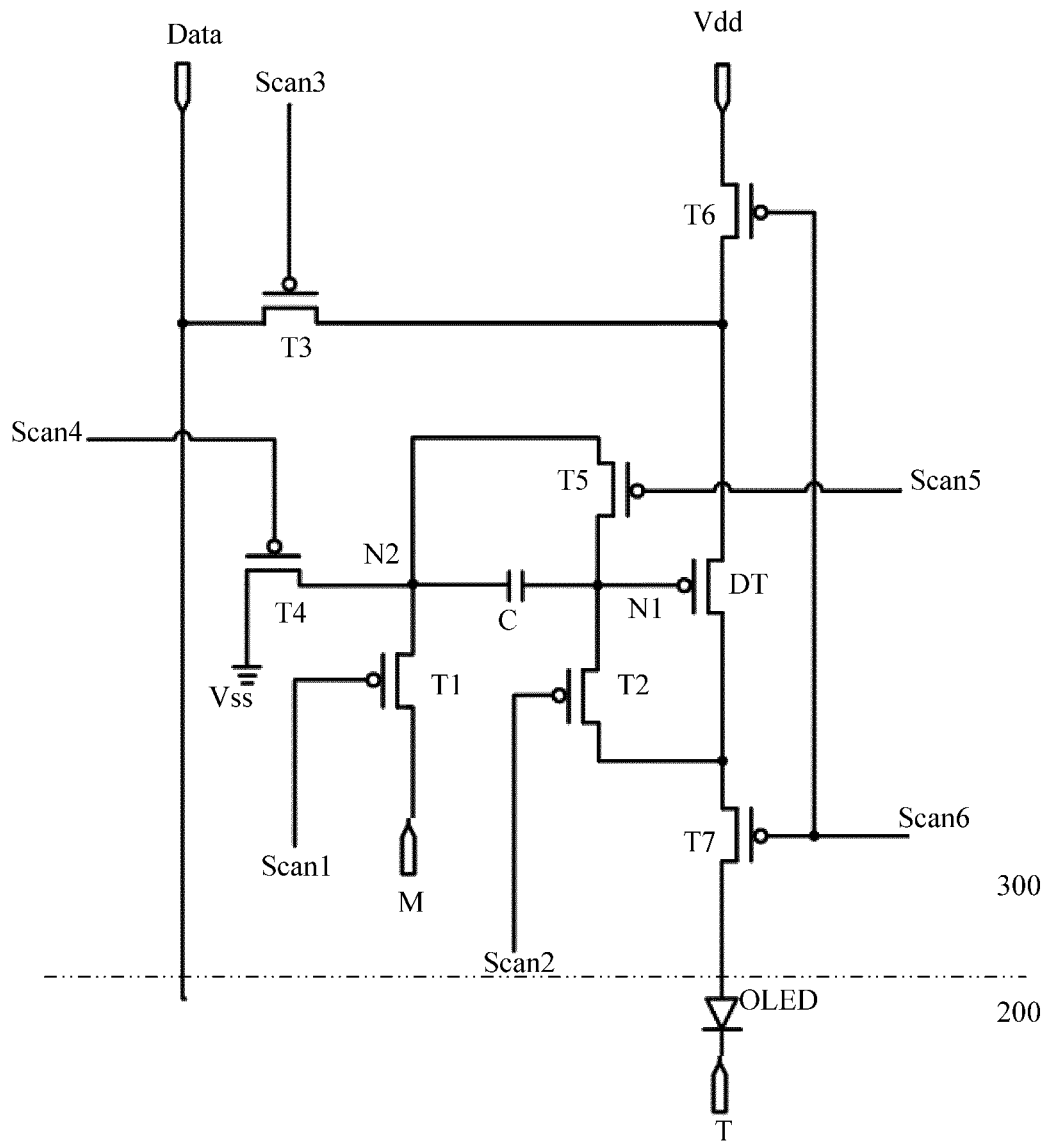


FIG. 2

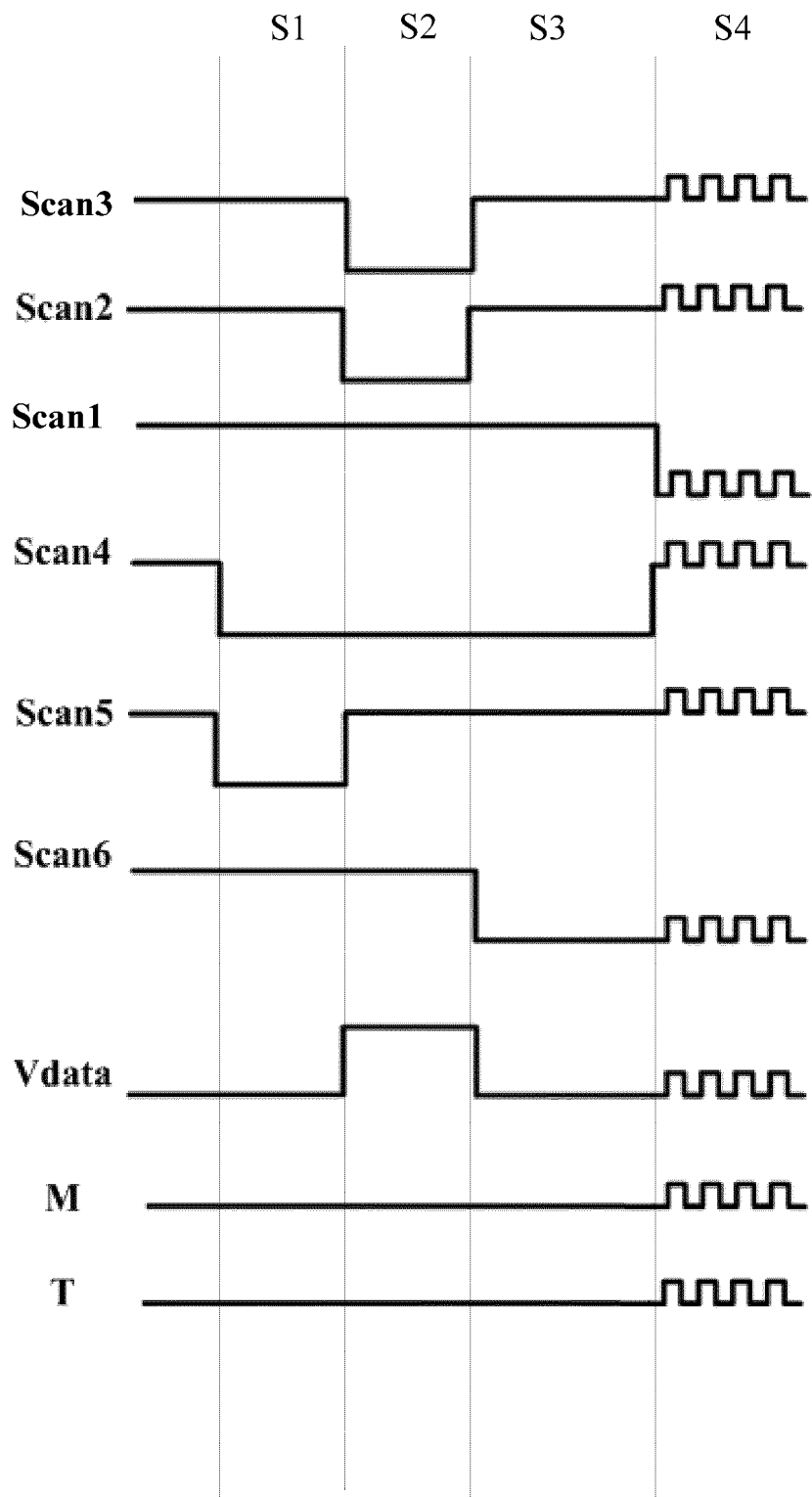


FIG. 3

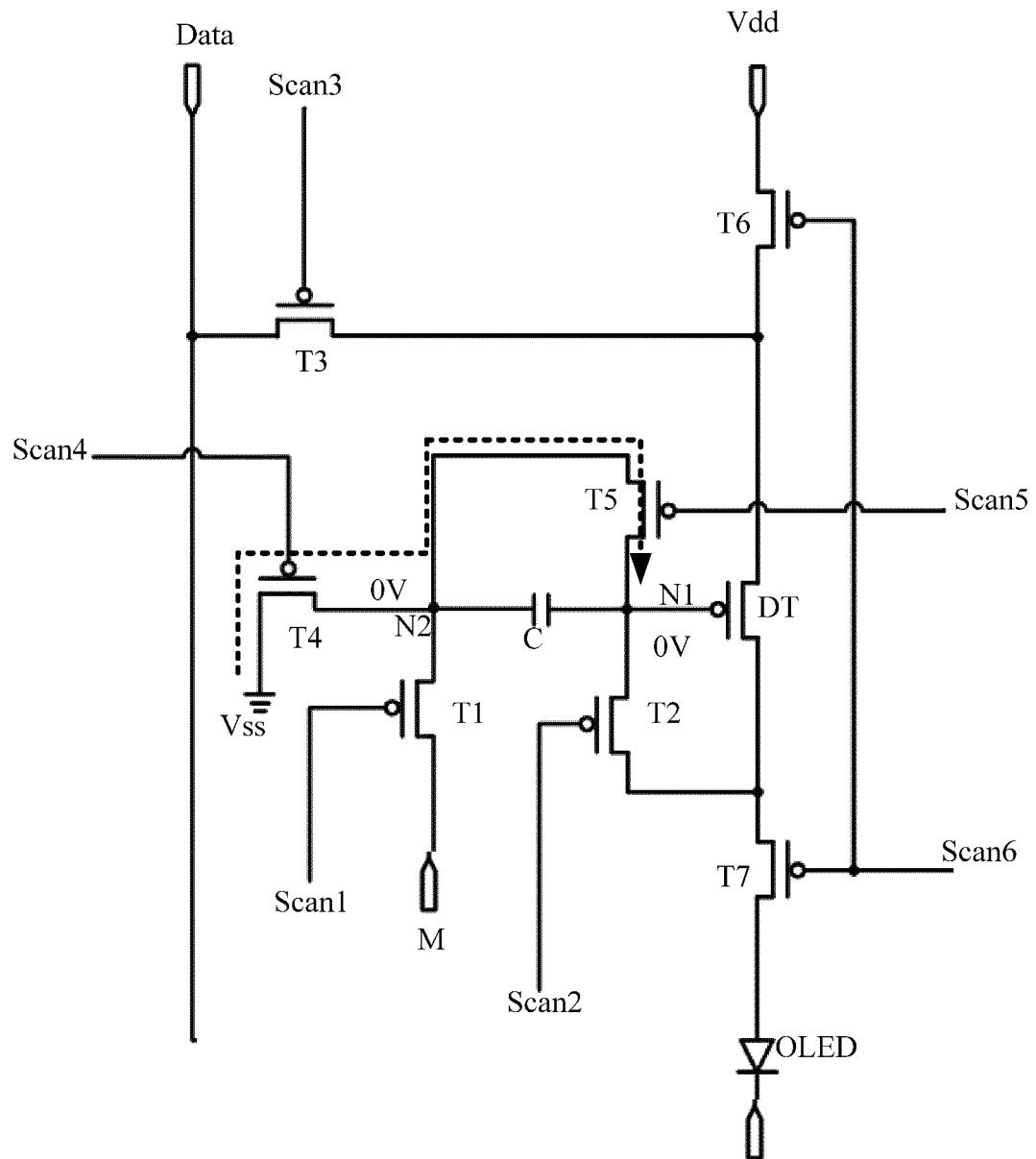


FIG. 4

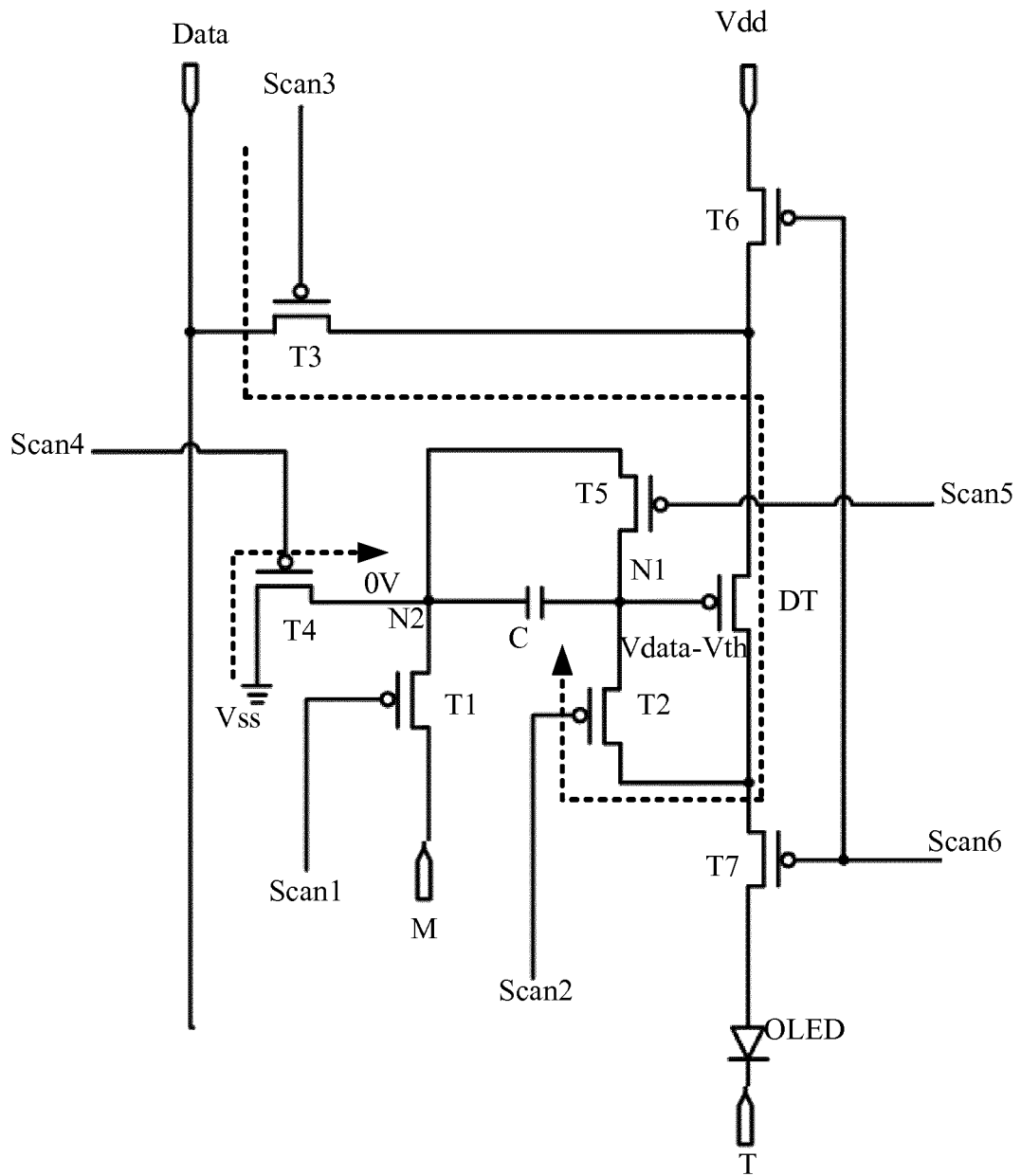


FIG. 5

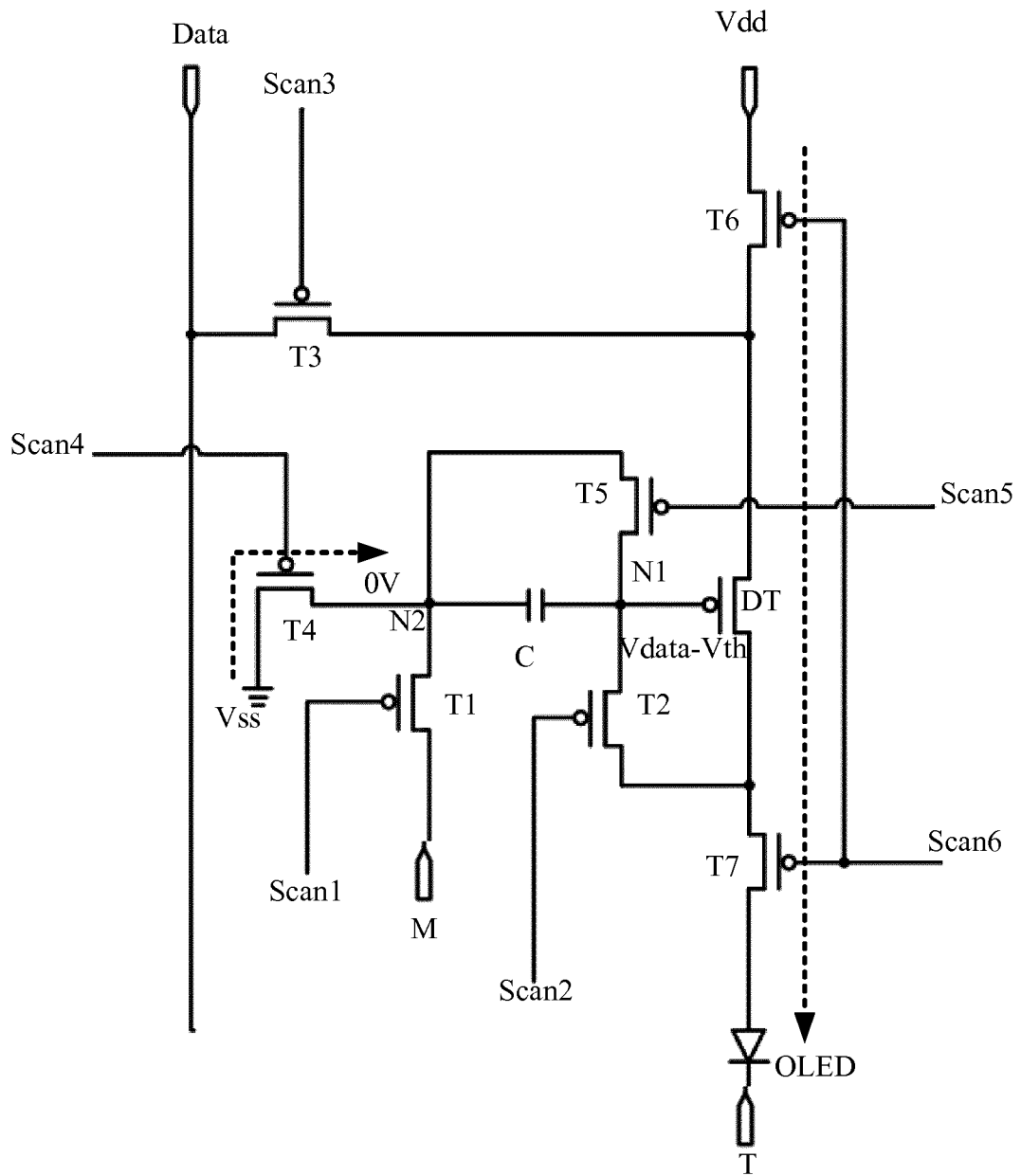


FIG. 6

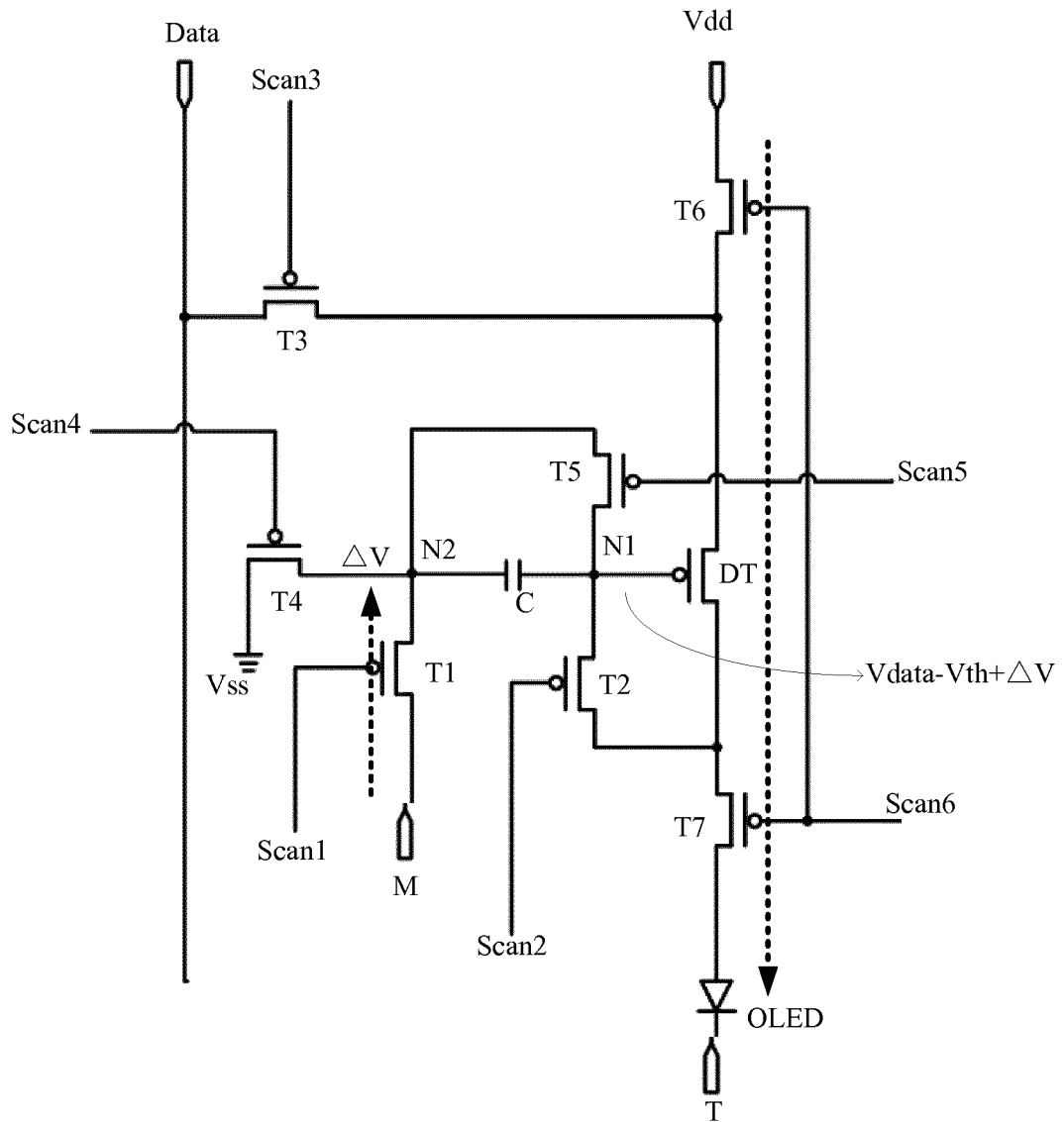


FIG. 7

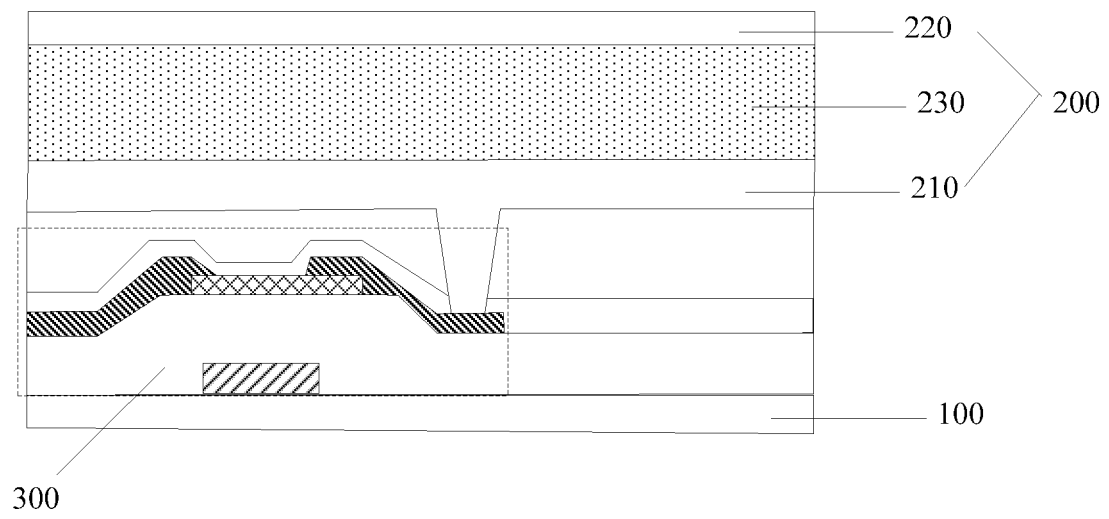


FIG. 8

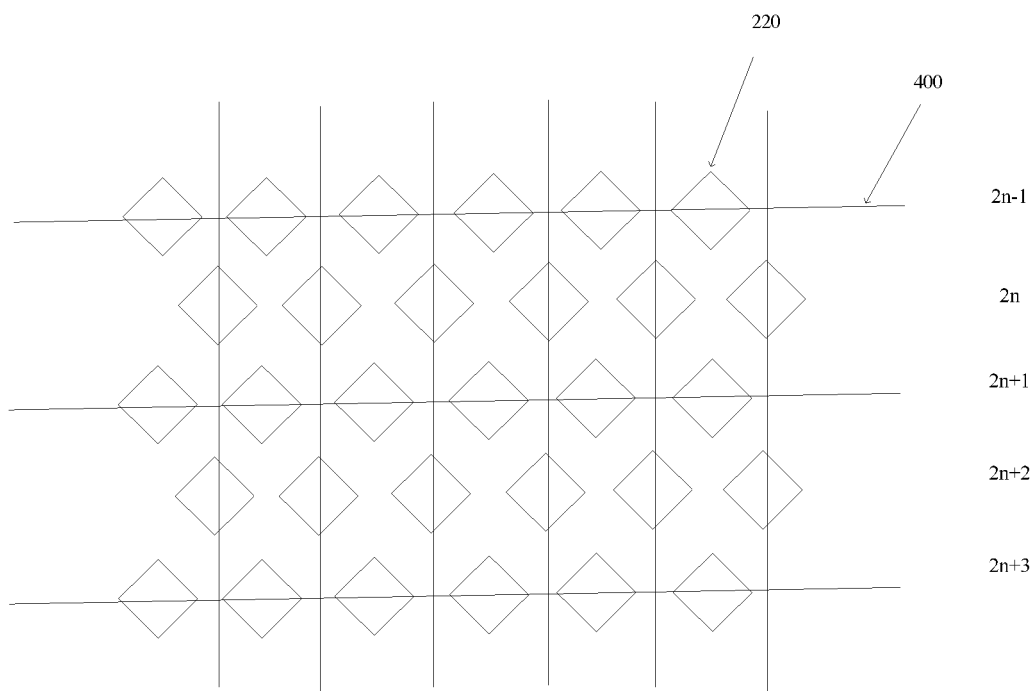


FIG. 9

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2015/098098

A. CLASSIFICATION OF SUBJECT MATTER

G09G 3/32 (2006.01) i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

G09G3/-

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

CNPAT, WPI, EPODOC, CNKI: YANG, Shengji; DONG, Xue; WANG, Haisheng; CHEN, Xiaochuan; LIU, Yingming; ZHAO, Weijie; XU, Rui; MENG, Chen; XUE, Jing; DONG, Ruijun; LI, Jing; energy storage, suspension joint, pixel, drive, compensation, energy, power, storage, voltage, threshold, first, second, write, store, suspension, joint, difference, sum

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
PX	CN 104933991 A (BOE TECHNOLOGY GROUP CO., LTD. et al.), 23 September 2015 (23.09.2015), claims 1-16, and description, paragraphs [0037]-[0085], and figures 1-9	1-16
A	CN 104575398 A (BOE TECHNOLOGY GROUP CO., LTD. et al.), 29 April 2015 (29.04.2015), claim 1, and description, paragraphs [0039]-[0043], and figures 1-2	1-16
A	CN 104217677 A (BOE TECHNOLOGY GROUP CO., LTD. et al.), 17 December 2014 (17.12.2014), the whole document	1-16
A	CN 104091563 A (BOE TECHNOLOGY GROUP CO., LTD. et al.), 08 October 2014 (08.10.2014), the whole document	1-16
A	KR 101411752 B1 (LG DISPLAY CO., LTD.), 01 July 2014 (01.07.2014), the whole document	1-16

☒ Further documents are listed in the continuation of Box C.☒ See patent family annex.

* Special categories of cited documents:

“A” document defining the general state of the art which is not considered to be of particular relevance

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“P” document published prior to the international filing date but later than the priority date claimed

“T” later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

“X” document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

“Y” document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

“&” document member of the same patent family

Date of the actual completion of the international search

04 March 2016 (04.03.2016)

Date of mailing of the international search report

24 March 2016 (24.03.2016)

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INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2015/098098

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2013194248 A1 (SAMSUNG MOBILE DISPLAY CO., LTD.), 01 August 2013 (01.08.2013), the whole document	1-16

Form PCT/ISA/210 (continuation of second sheet) (July 2009)

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/CN2015/098098

Patent Documents referred in the Report	Publication Date	Patent Family	Publication Date
CN 104933991 A	23 September 2015	None	
CN 104575398 A	29 April 2015	None	
CN 104217677 A	17 December 2014	WO 2016015392 A1	04 February 2016
CN 104091563 A	08 October 2014	WO 2015196553 A1	30 December 2015
KR 101411752 B1	01 July 2014	KR 20090095913 A	10 September 2009
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		US 9117407 B2	25 August 2015

Form PCT/ISA/210 (patent family annex) (July 2009)

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- CN 201510391775 [0001]

专利名称(译)	像素驱动电路，显示面板及其驱动方法，以及显示装置		
公开(公告)号	EP3321921A4	公开(公告)日	2019-02-13
申请号	EP2015892056	申请日	2015-12-21
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IPC分类号	G09G3/32		
CPC分类号	G06F3/0412 G06F3/04184 G06F3/044 G09G3/3233 G09G2300/0819 G09G2300/0842 G09G2300/0861 G09G2320/0219 G06F3/0418 G09G3/32 G09G2320/0233 G09G2354/00		
优先权	201510391775.0 2015-07-06 CN		
其他公开文献	EP3321921A1		
外部链接	Espacenet		

摘要(译)

本发明提供一种像素驱动电路，显示基板及其驱动方法，显示装置，其中，所述像素驱动电路包括：驱动单元，数据电压写入单元，储能单元，阈值补偿单元和触摸驱动补偿单元。能量存储单元包括第一能量存储端和第二能量存储端。触控驱动补偿单元连接至储能单元的第二储能端，以在触控阶段补偿第二储能端的电压，以保持驱动单元产生的驱动电流不随时间变化。本发明提供的像素驱动电路可以使被驱动的电致发光元件的亮度在触摸阶段不随时间变化，从而避免影响被驱动的电致发光元件的发光显示。

