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

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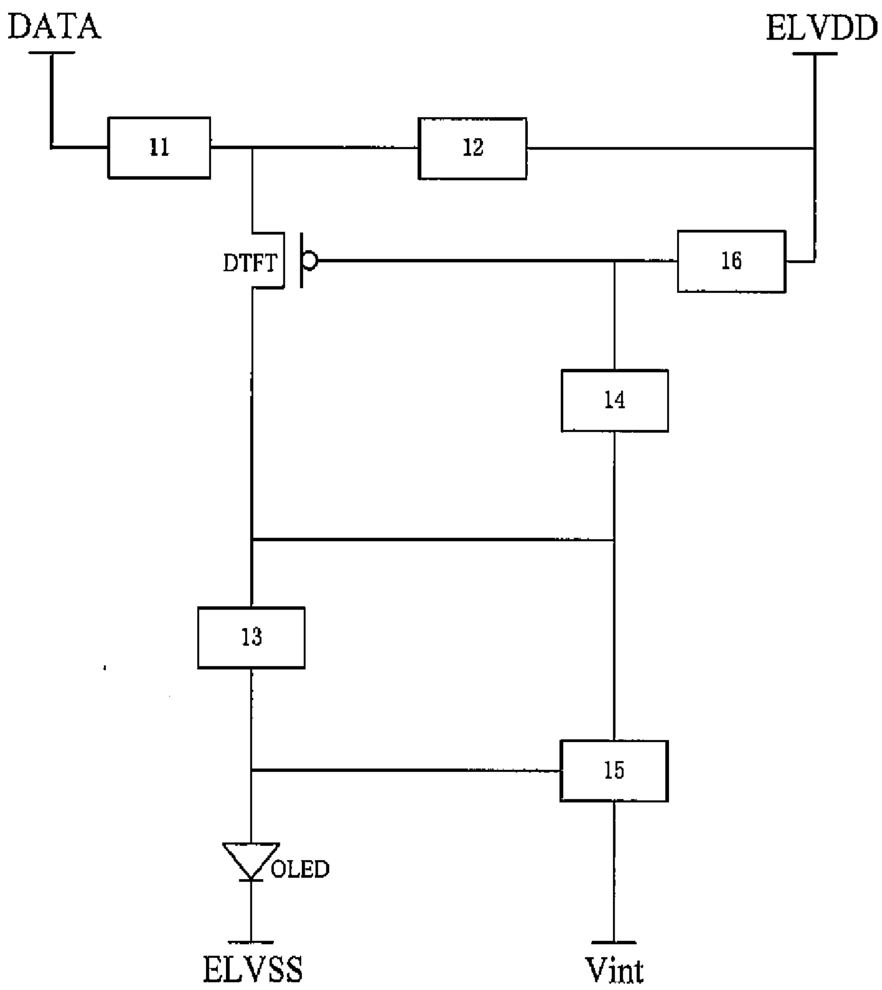
(57) **ABSTRACT**

There provides a display device, a pixel driving circuit and a driving method thereof. The pixel driving circuit includes an organic light emitting diode, a first, a second and a third switching transistor, a storage capacitor, a driving transistor, a compensation unit and a reset unit. The first switching transistor writes a data signal into the storage capacitor via the driving transistor and the compensation unit; the second switching transistor applies a driving voltage to the driving transistor; the third switching transistor applies a driving current output from the driving transistor to the organic light emitting diode; the compensation unit writes a threshold voltage of the driving transistor into the storage capacitor; the storage capacitor stores a written voltage signal and apply it to the driving transistor; and the reset unit resets the organic light emitting diode and the storage capacitor.



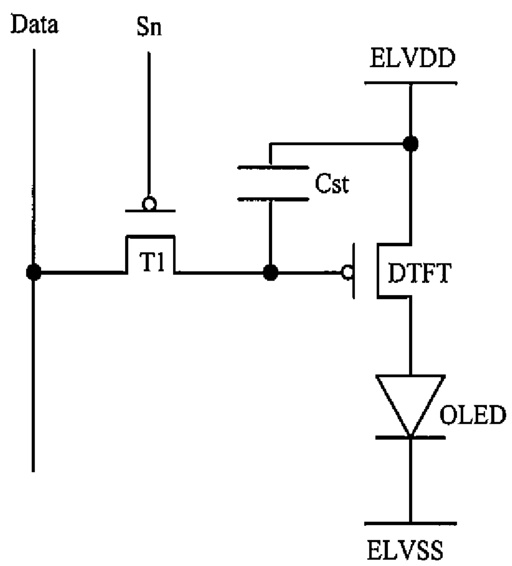


Fig. 1 (Prior Art)

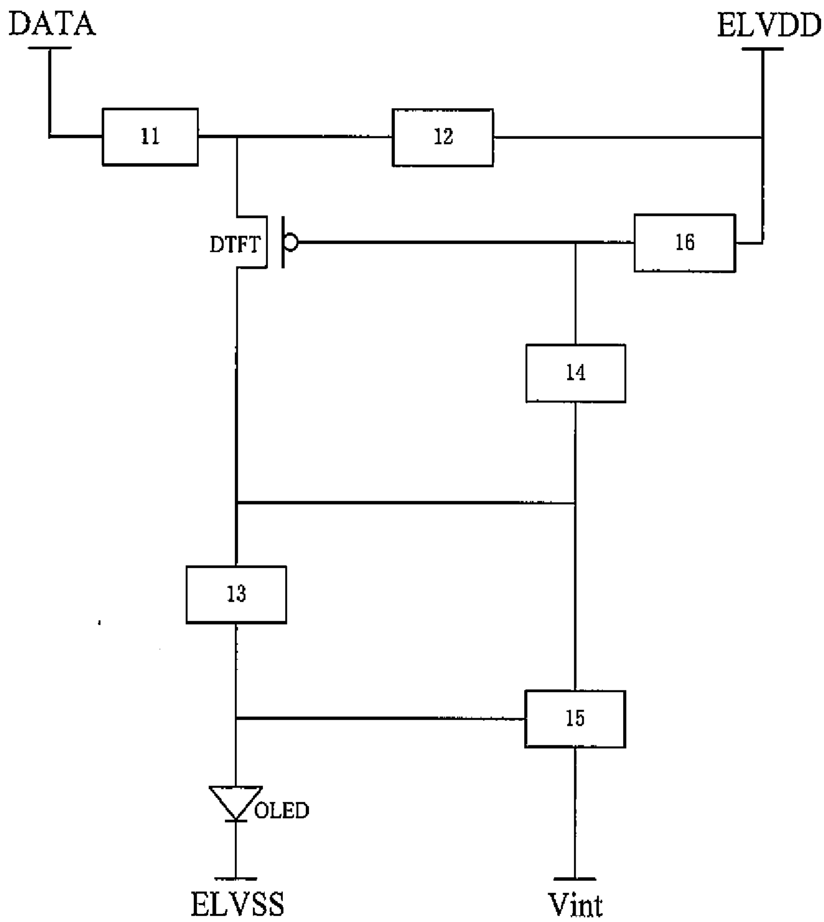


Fig. 2

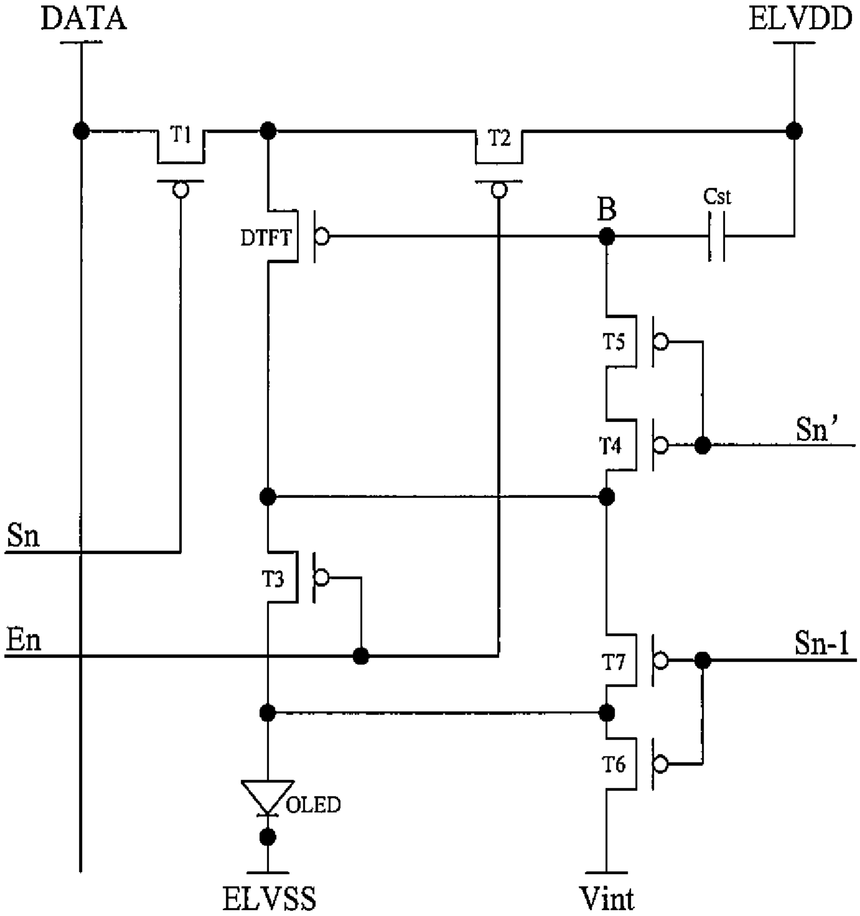

DATA
ELVDD
T1
T2
Cst
B
DTFT
T5
T4
Sn'
Sn
T3
En
T7
Sn-1
T6
OLED
ELVSS
Vint

Fig. 3

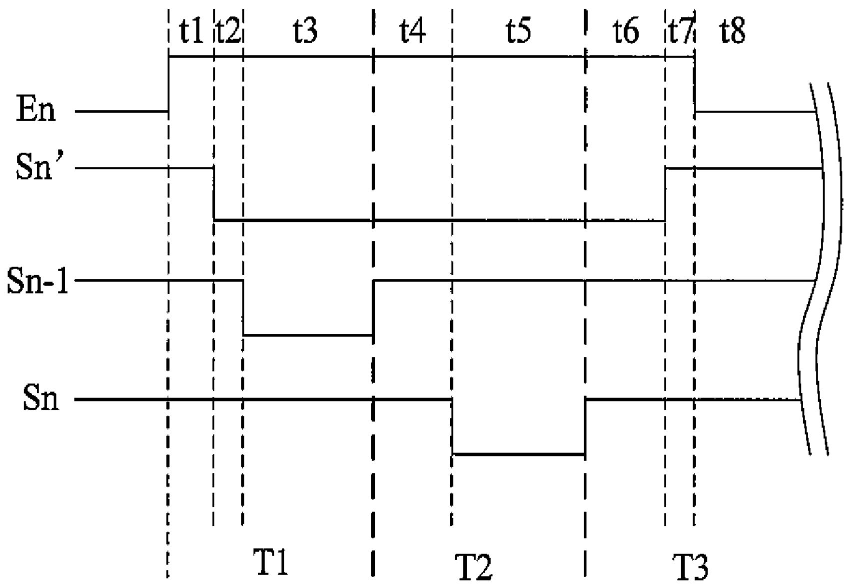


Fig. 4

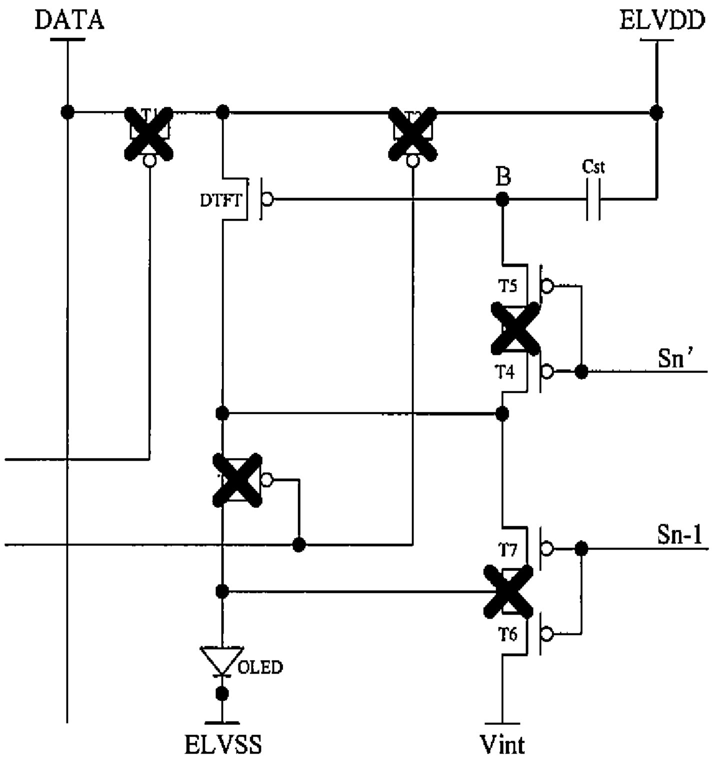


Fig. 5

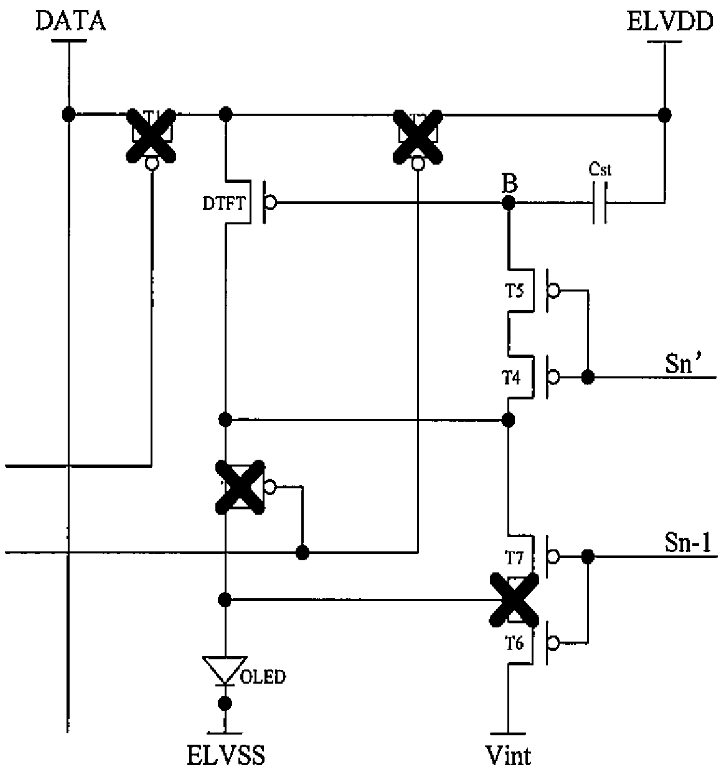


Fig. 6

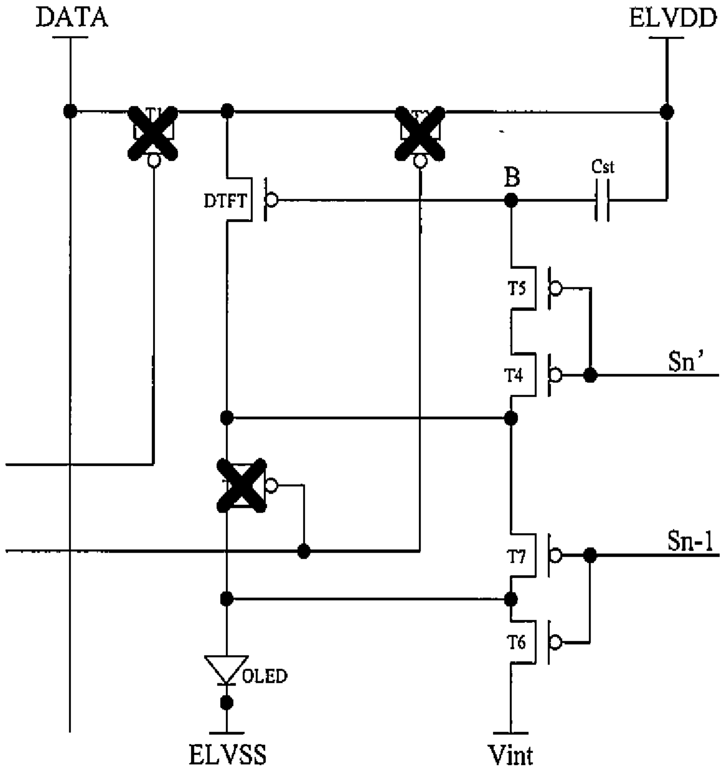


Fig. 7

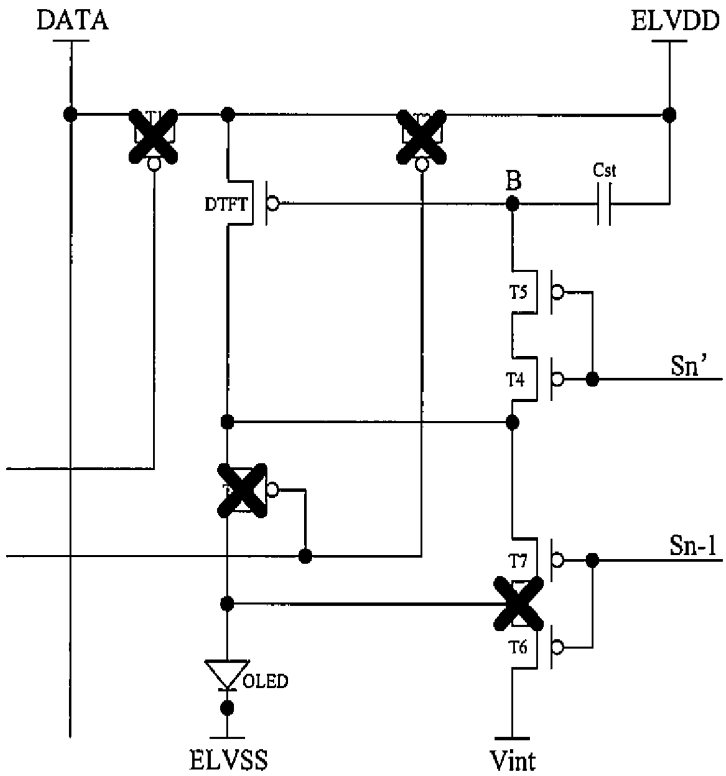


Fig. 8

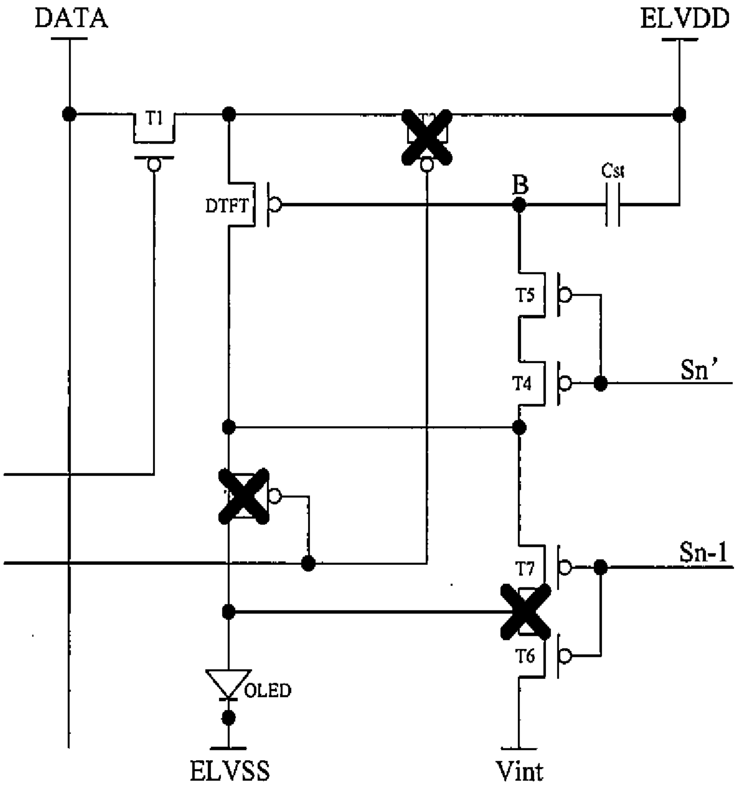


Fig. 9

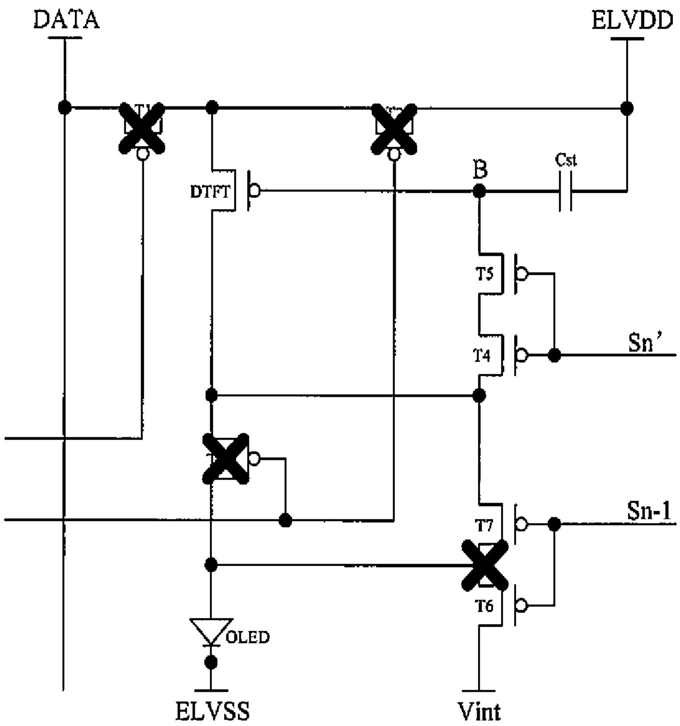


Fig. 10

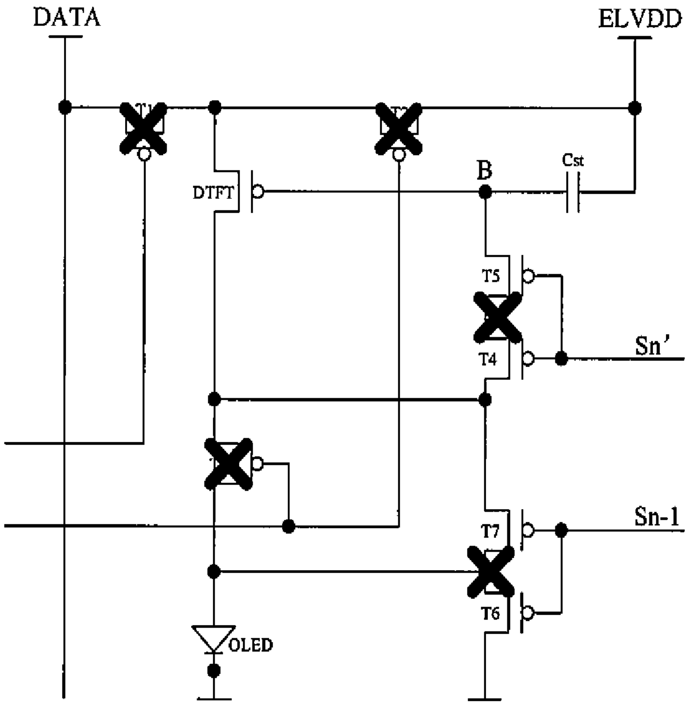


Fig. 11

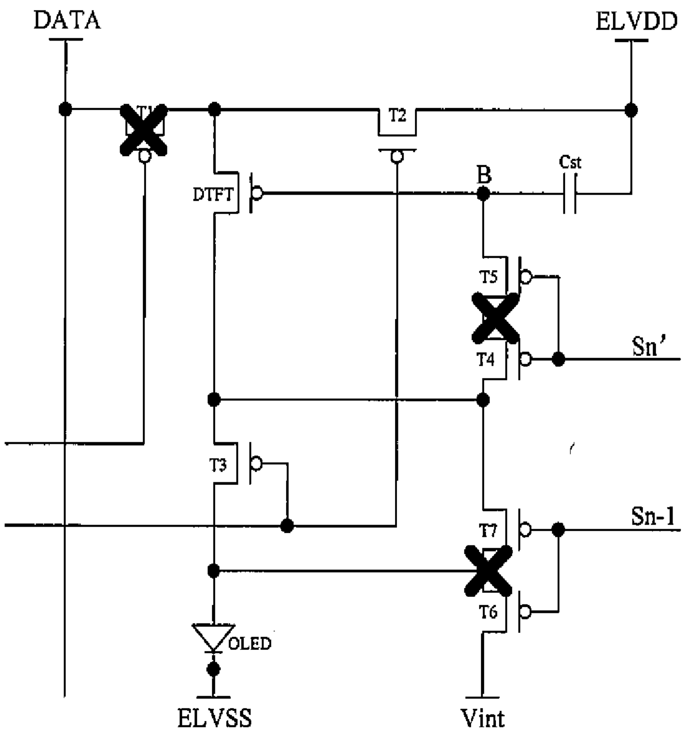


Fig. 12

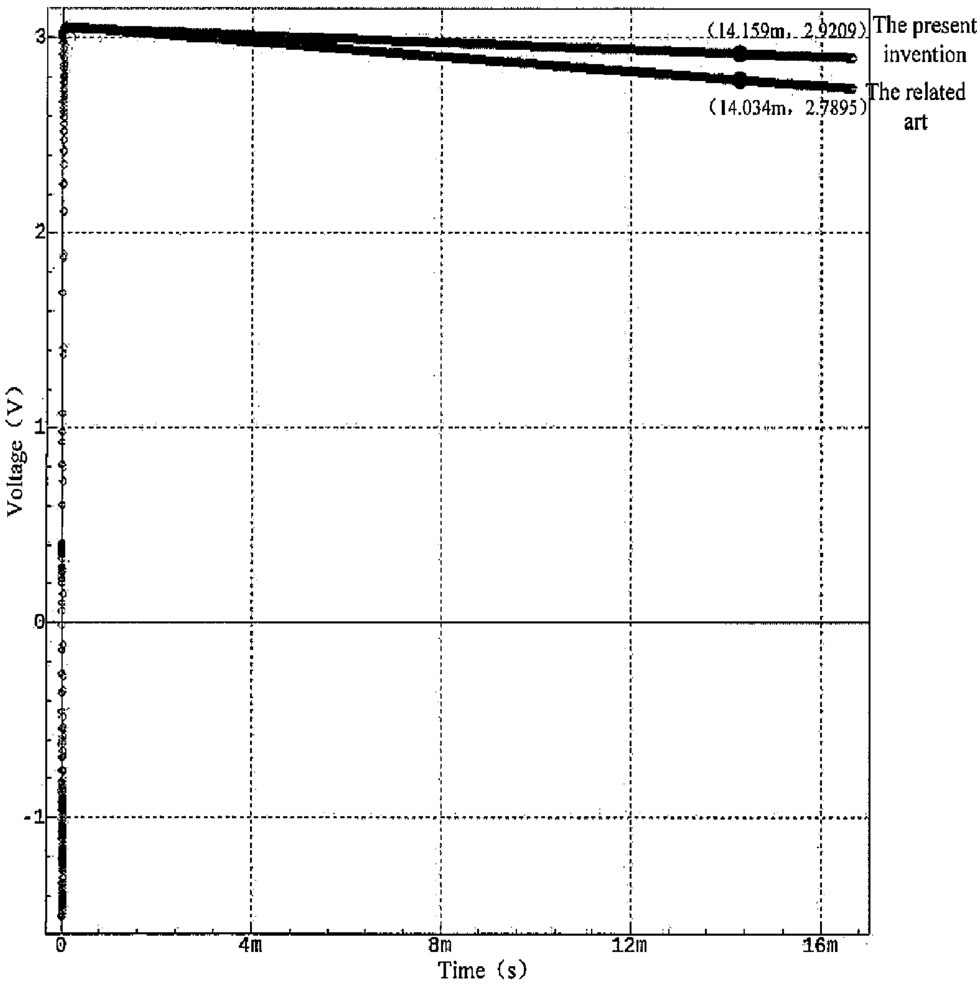

(14.159m, 2.9209)
The present invention
The related art
(14.034m, 2.7895)
Voltage (V)
Time (s)
3
2
1
0
-1
0
4m
8m
12m
16m

Fig. 13

DISPLAY DEVICE, PIXEL DRIVING CIRCUIT AND DRIVING METHOD THEROF

CROSS REFERENCE TO RELATED DISCLOSURES

[0001] The present application claims priority under 35 U.S.C. §119 to Chinese Patent Application No. 201410848357.5, filed on Dec. 29, 2014, the entire content of which are incorporated herein by reference.

TECHNICAL FIELD

[0002] The present disclosure generally relates to the field of display technology, particularly to a pixel driving circuit, a driving method of the pixel driving circuit and a display device including the pixel driving circuit.

BACKGROUND

[0003] Compared with LCD (Liquid Crystal Display) panels in the conventional technology, OLED (Organic Light Emitting Diode) display panels have advantages of faster response, better color purity and brightness, higher contrast, wider view angle, etc. Therefore, OLED display panels are gaining increasingly widespread attention from developers for the display technology.

[0004] A pixel unit in an OLED display panel mainly includes an organic light emitting diode and a pixel unit driving circuit for driving the organic light emitting diode. A conventional 2T1C pixel unit driving circuit is as illustrated in FIG. **1**: it includes a first switching transistor T**1**, a driving transistor DTFT and a storage capacitor Cst. Wherein the first switching transistor T**1** is controlled by a first scan signal Sn output by a scan line (Scan Line), for controlling the writing of a data signal Data from a data line (Data Line). The driving transistor DTFT is configured to control the organic light emitting diode OLED to emit light, and the storage capacitor Cst is configured to provide a sustaining voltage for a gate of the driving transistor DTFT.

[0005] The organic light emitting diode OLED can emit light, which is driven by a driving current generated by the driving transistor DTFT operating in a saturation state. Wherein the driving current I_{OLED} can be expressed as:

$$I_{OLED} = \frac{1}{2}\mu_n \cdot C_{OX} \cdot \frac{W}{L} \cdot (ELVDD - Vdata - Vth)^2$$

[0006] Wherein $\mu_n \cdot C_{OX} \cdot W/L$ is a constant relevant to a production process and design, for example, μ_n is a carrier mobility, C_{OX} is a capacitance of a gate oxide layer, W/L is a width-to-length ratio of the transistor, Vdata is a voltage of the data signal Data, ELVDD is a driving voltage for driving the transistor DTFT, which is shared by all the pixel units, and Vth is a threshold voltage of the driving transistor DTFT.

[0007] However, due to technical limitations, the uniformity of the threshold voltage Vth is usually poor, and drift of the threshold voltage Vth may also occur in practical usage. From the above equation, if Vthes are different among different pixel units, differences will occur in the driving currents, which may result in non-uniform brightness. If the threshold voltage Vthes of the driving transistors drift over time, the currents may change from time to time, which may influence the displaying effect.

SUMMARY

[0008] An object of the present disclosure is to provide a pixel driving circuit, a driving method of the pixel driving circuit and a display device including the pixel driving circuit, to overcome, at least to a certain degree, one or more problems due to the technical limitations and disadvantages in the related art.

[0009] Other features and advantages of the present disclosure will be apparent from the following detailed description, or partially learned through practice of the present disclosure.

[0010] According to a first aspect of embodiments of the present disclosure, there provides a pixel driving circuit, including an organic light emitting diode, a first, a second and a third switching transistor, a storage capacitor, a driving transistor, a compensation unit and a reset unit, wherein:

[0011] the first switching transistor is configured to write a data signal into the storage capacitor via the driving transistor and the compensation unit in response to a first scan signal;

[0012] the second switching transistor is configured to apply a driving voltage to the driving transistor in response to a light emitting control signal;

[0013] the third switching transistor is configured to apply a driving current output from the driving transistor to the organic light emitting diode to cause it to emit light, in response to the light emitting control signal;

[0014] the compensation unit is configured to write a threshold voltage of the driving transistor into the storage capacitor in response to an enable signal;

[0015] the storage capacitor is configured to store the written data signal and the threshold voltage and apply the written data signal and the threshold voltage to a gate of the driving transistor; and

[0016] the reset unit is configured to reset the organic light emitting diode and the storage capacitor with an initial voltage, in response to a reset signal.

[0017] In an exemplary embodiment of the present disclosure,

[0018] a gate of the first switching transistor receives the first scan signal, a source thereof receives the data signal, and a drain thereof is connected to a source of the driving transistor;

[0019] a gate of the second switching transistor receives the light emitting control signal, a source thereof is connected to the driving voltage, and a drain thereof is connected to a source of the driving transistor;

[0020] a gate of the third switching transistor receives the light emitting control signal, a source thereof is connected to a drain of the driving transistor, and a drain thereof is connected to a first terminal of the organic light emitting diode;

[0021] a first terminal of the compensation unit is connected to the drain of the driving transistor, a second terminal thereof is connected to the storage capacitor, and a control terminal thereof receives the enable signal;

[0022] a first terminal of the storage capacitor is connected to the gate of the driving transistor, and a second terminal thereof is connected to the driving voltage; and

[0023] a first terminal of the reset unit is connected to the initial voltage, a second terminal thereof is connected to the first terminal of the organic light emitting diode, a third terminal thereof is connected with the first terminal of the compensation unit, and a control terminal thereof receives the reset signal.

[0024] In an exemplary embodiment of the present disclosure,

[0025] the reset unit includes a first reset transistor and a second reset transistor;

[0026] a gate of the first reset transistor receives the reset signal, a source thereof is connected to the initial voltage, and a drain thereof is connected to a source the second reset transistor and the first terminal of the organic light emitting diode; and

[0027] a gate of the second reset transistor receives the reset signal, and a drain thereof is connected to the first terminal of the compensation unit.

[0028] In an exemplary embodiment of the present disclosure,

[0029] the compensation unit includes a first compensation transistor and a second compensation transistor;

[0030] a gate of the first compensation transistor receives the enable signal, a source thereof is connected to the drain of the driving transistor, and a drain thereof is connected to a source of the second compensation transistor; and

[0031] a gate of the second compensation transistor receives the enable signal, and a drain thereof is connected to the first terminal of the storage capacitor.

[0032] In an exemplary embodiment of the present disclosure,

[0033] the reset signal is a second scan signal;

[0034] the first scan signal is provided by a scan line; and

[0035] the second scan signal is provided by a previous scan line to the scan line.

[0036] In an exemplary embodiment of the present disclosure,

[0037] all of the transistors are P type thin film transistors;

[0038] the driving voltage connected to the source of the second switching transistor is a high level driving voltage;

[0039] the drain of the third switching transistor is connected to an anode of the organic light emitting diode; and

[0040] a cathode of the organic light emitting diode is connected to a low level voltage.

[0041] In an exemplary embodiment of the present disclosure,

[0042] all of the transistors is an N type thin film transistor;

[0043] the driving voltage connected to the source of the second switching transistor is a low level driving voltage;

[0044] the drain of the third switching transistor is connected to a cathode of the organic light emitting diode; and

[0045] an anode of the organic light emitting diode is connected to a high level voltage.

[0046] According a second aspect of the present disclosure, there provides a driving method of a pixel driving circuit, wherein the pixel driving circuit is any one of pixel driving circuits according to the first aspect of the present disclosure, and the driving method includes:

[0047] turning on the compensation unit and the reset unit respectively by using the enable signal and the reset signal, thereby causing the initial voltage to reset the organic light emitting diode via the reset unit and to reset the storage capacitor via the reset unit and the compensation unit respectively;

[0048] turning on the first switching transistor and the compensation unit respectively by using the first scan signal and the enable signal, thereby causing the data signal and the threshold voltage to be written into the storage capacitor; and

[0049] turning on the second and the third switching transistor by using the light emitting control signal, thereby turning on the driving transistor by using the data signal and the threshold voltage written into the storage capacitor, and causing the driving voltage drive to drive the organic light emitting diode to emit light via the second and the third switching transistor and the driving transistor.

[0050] According a third aspect of the present disclosure, there provides a display device, including:

[0051] a plurality of data lines for providing data signals;

[0052] a plurality of scan lines for supplying scan signals, wherein the scan signals include a first scan signal and a second scan signal which are provided successively; and

[0053] a plurality of pixel driving circuits, electrically connected to the data lines and the scan lines, each of the plurality of pixel driving circuit includes an organic light emitting diode, a first, a second and a third switching transistor, a storage capacitor, a driving transistor, a compensation unit and a reset unit, wherein:

[0054] the first switching transistor is configured to write one of the data signals into the storage capacitor via the driving transistor and the compensation unit in response to the first scan signal;

[0055] the second switching transistor is configured to apply a driving voltage to the driving transistor in response to a light emitting control signal;

[0056] the third switching transistor is configured to apply a driving current output from the driving transistor to the organic light emitting diode to cause it to emit light, in response to the light emitting control signal;

[0057] the compensation unit is configured to write a threshold voltage of the driving transistor into the storage capacitor in response to an enable signal;

[0058] the storage capacitor is configured to store the written one data signal and the threshold voltage and apply the written one data signal and the threshold voltage to a gate of the driving transistor; and

[0059] the reset unit is configured to reset the organic light emitting diode and the storage capacitor with an initial voltage, in response to a reset signal.

[0060] In an exemplary embodiment of the present disclosure,

[0061] a gate of the first switching transistor receives the first scan signal, a source thereof receives the one data signal, and a drain thereof is connected to a source of the driving transistor;

[0062] a gate of the second switching transistor receives the light emitting control signal, a source thereof is connected to the driving voltage, and a drain thereof is connected to a source of the driving transistor;

[0063] a gate of the third switching transistor receives the light emitting control signal, a source thereof is connected to a drain of the driving transistor, and a drain thereof is connected to a first terminal of the organic light emitting diode;

[0064] a first terminal of the compensation unit is connected to the drain of the driving transistor, a second terminal thereof is connected to the storage capacitor, and a control terminal thereof receives the enable signal;

[0065] a first terminal of the storage capacitor is connected to the gate of the driving transistor, and a second terminal thereof is connected to the driving voltage; and

[0066] a first terminal of the reset unit is connected to the initial voltage, a second terminal thereof is connected to the first terminal of the organic light emitting diode, a third terminal thereof is connected with the first terminal of the compensation unit, and a control terminal thereof receives the reset signal.

[0067] In an exemplary embodiment of the present disclosure,

[0068] the reset unit includes a first reset transistor and a second reset transistor;

[0069] a gate of the first reset transistor receives the reset signal, a source thereof is connected to the initial voltage, and a drain thereof is connected to a source the second reset transistor and the first terminal of the organic light emitting diode; and

[0070] a gate of the second reset transistor receives the reset signal, and a drain thereof is connected to the first terminal of the compensation unit.

[0071] In an exemplary embodiment of the present disclosure,

[0072] the compensation unit includes a first compensation transistor and a second compensation transistor;

[0073] a gate of the first compensation transistor receives the enable signal, a source thereof is connected to the drain of the driving transistor, and a drain thereof is connected to a source of the second compensation transistor; and

[0074] a gate of the second compensation transistor receives the enable signal, and a drain thereof is connected to the first terminal of the storage capacitor.

[0075] In an exemplary embodiment of the present disclosure,

[0076] the reset signal is the second scan signal;

[0077] the first scan signal is provided by one scan line of the plurality of scan lines;

[0078] and

[0079] the second scan signal is provided by a previous scan line to the one scan line.

[0080] In an exemplary embodiment of the present disclosure,

[0081] all of the transistors are P type thin film transistors;

[0082] the driving voltage connected to the source of the second switching transistor is a high level driving voltage;

[0083] the drain of the third switching transistor is connected to an anode of the organic light emitting diode; and

[0084] a cathode of the organic light emitting diode is connected to a low level voltage.

[0085] In an exemplary embodiment of the present disclosure,

[0086] all of the transistors is an N type thin film transistor;

[0087] the driving voltage connected to the source of the second switching transistor is a low level driving voltage;

[0088] the drain of the third switching transistor is connected to a cathode of the organic light emitting diode; and

[0089] an anode of the organic light emitting diode is connected to a high level voltage.

[0090] In the pixel driving circuits provided by exemplary embodiments of the present disclosure, firstly, the level of the gate of the driving transistor is reset via the preset unit, thereby to eliminate the influence of the residual voltage signal of the previous frame; then, the threshold voltage and the data signal of the driving transistor are pre-stored in the storage capacitor via the compensation unit during the process that data is written into the storage capacitor, thereby to effectively compensate for the drift of the threshold voltage. In this way, the uniformity and stability of the driving currents may be ensured, and thus the brightness of the OLED display panel may be made more uniform.

BRIEF DESCRIPTION OF THE DRAWINGS

[0091] By referring to the exemplary embodiments thereof described in detail with the accompanying drawings, the above and other features and advantages of the present disclosure will become more apparent.

[0092] FIG. **1** is a schematic diagram of a pixel driving circuit in the related art;

[0093] FIG. **2** is a schematic diagram of connection of modules in a pixel driving circuit according to an exemplary embodiment of the present disclosure;

[0094] FIG. **3** is a schematic diagram of a pixel driving circuit according to an exemplary embodiment of the present disclosure;

[0095] FIG. **4** is a timing sequence diagram of the pixel driving circuit illustrated in FIG. **3**;

[0096] FIGS. **5** to **7** are diagrams of equivalent circuits in a reset stage of the pixel driving circuit illustrated in FIG. **3**;

[0097] FIGS. **8** to **9** are diagrams of equivalent circuits in a charging stage of the pixel driving circuit illustrated in FIG. **3**;

[0098] FIGS. **10** to **12** are diagrams of equivalent circuits in a displaying stage of the pixel driving circuit illustrated in FIG. **3**; and

[0099] FIG. **13** is a schematic diagram of a simulation result of leakage of a storage capacitor of the pixel driving circuit according to the exemplary embodiment.

[0100] Reference numerals are defined as follows:

[0101] **11**, T**1** first switching transistor

[0102] **12**, T**2** second switching transistor

[0103] **13**, T**3** third switching transistor

[0104] **14** compensation unit

[0105] T**4** first compensation transistor

[0106] T**5** second compensation transistor

[0107] **15** reset unit

[0108] T**6** first reset transistor

[0109] T**7** second reset transistor

[0110] **16**, Cst storage capacitor

[0111] OLED organic light emitting diode

[0112] DTFT driver transistor

[0113] ELVDD driving voltage

[0114] ELVSS low level voltage

[0115] Data data signal

[0116] Sn first scan signal

[0117] Sn−1 second scan signal

[0118] Sn' enable signal

[0119] En light emitting control signal

[0120] Vint initial voltage

DETAILED DESCRIPTION

[0121] Now exemplary embodiments will be described more fully with reference to the accompanying drawings. However, the exemplary embodiments may be embodied in various forms, and should not be construed as limited to the embodiments set forth herein. Rather, these embodiments are provided so that this disclosure will be thorough and complete, and fully convey the concept of the exemplary embodiments to those skilled in the art. In the drawings, the same reference numerals denote the same or similar structure, and therefore a detailed description thereof will be omitted.

[0122] Moreover, the described features, structures or characteristics may be combined in any suitable manner in one or more embodiments. In the following description, numerous specific details are provided in order that the embodiments of the present disclosure could be fully understood. However, those skilled in the art will recognize that the solution of the present disclosure may be practiced without one or more of the specific details, or may take other methods, devices, connections and the like. In these cases, known structures, methods or operations are not shown or described in detail to avoid obscuring aspects of the present disclosure.

[0123] In the present exemplary embodiment, firstly, there provides a pixel driving circuit. As illustrated in FIG. **2**, the pixel driving circuit mainly includes an organic light emitting diode OLED, a first switching transistor **11**, a second switching transistor **12**, a third switching transistor **13**, a compensation unit **14**, a reset unit **15**, a storage capacitor **16** and a driving transistor DTFT, etc.

[0124] Wherein a first terminal of the first switching transistor **11** is connected to a data line, to receive a data signal Data, and a second terminal thereof is connected to a source of the driving transistor DTFT, to write the data signal Data into the storage capacitor **16** via the driving transistor DTFT and the compensation unit **14** in response to a first scan signal. A first terminal of the second switching transistor **12** is connected to a driving voltage, and a second terminal thereof is connected to the source of the driving transistor DTFT, to apply the driving voltage to the source of the driving transistor DTFT in response to a light emitting control signal. A first terminal of the third switching transistor **13** is connected to a drain of the driving transistor DTFT, and a second terminal thereof is connected to a first terminal of the organic light emitting diode OLED, to apply a driving current output from the drain of the driving transistor DTFT to the light emitting diode OLED to cause it to emit light, in response to the light emitting control signal. A first end of the compensation unit **14** is connected to the drain of the driving transistor DTFT, and a second terminal thereof is connected to a first terminal of the storage capacitor **16**, to pre-store a threshold voltage of the driving transistor DTFT to the storage capacitor **16**. The first terminal of the storage capacitor **16** is connected to a gate of the driving transistor DTFT, and a second terminal thereof is connected to the driving voltage. The storage capacitor **16** is configured to store a written voltage signal, and provide it to the gate of the driving transistor DTFT. A first terminal of the reset unit **15** is connected to an initial signal, a second terminal thereof is connected to the second terminal of the third switching transistor **13**, and a third terminal thereof is connected to the first terminal of the compensation unit **14**, to reset the organic light emitting diode OLED in response to a reset signal and write an initial voltage Vint into the storage capacitor **16** via the compensation unit **14** to reset the storage capacitor **16**, so as to eliminate the influence of the residual voltage signal of the previous frame in the storage capacitor **16**.

[0125] Hereinafter, the driving method of the pixel driving circuit is briefly described. The method may include the following steps.

[0126] In a reset stage: the reset unit **15** and the compensation unit **14** are turned on, and the first to the third switching transistors **11-13** are turned off, by using the first scan signal, the light emitting control signal, an enable signal and the reset signal. The initial voltage Vint resets the organic light emitting diode OLED via the reset unit **15**, and the initial voltage Vint is written into the storage capacitor **16** via the reset unit **15** and the compensation unit **14** to reset the storage capacitor **16**, so as to eliminate the influence of the residual voltage signal of the previous frame.

[0127] In a charging stage: the first switching transistor **11** and the compensation unit **14** are turned on, and the second and the third switching transistors **12-13** and the reset unit **15** are turned off, by using the first scan signal, the light emitting control signal, the enable signal and the reset signal. The data signal Data and the threshold voltage of the driving transistor DTFT are written into the storage capacitor **16**.

[0128] In a displaying stage: the second and the third switching transistors **12-13** are turned on, and the first switching transistor **11**, the compensation unit **14** and the reset unit **15** are turned off, by using the first scan signal, the light emitting control signal, the enable signal and the reset signal. The driving transistor DTFT is turned on by using the voltage signal stored in the storage capacitor **16**, to drive the organic light emitting diode OLED to emit light.

[0129] In the above pixel driving circuit, firstly the reset unit **15** resets the level of the gate of the driving transistor DTFT, and writes the initial voltage Vint into the storage capacitor **16** to reset the storage capacitor **16**, thereby the influence of the previous frame of voltage signal is eliminated. Then, the compensation unit **14** pre-stores the threshold voltage of the driving transistor DTFT and the data signal Data to the storage capacitor **16** when data is written to the storage capacitor **16**, thereby the drift of the threshold voltage may be effectively compensated, and the uniformity and stability of the driving currents may be ensured, and thus the brightness of the OLED display panel may be made more uniform.

[0130] As illustrated in FIG. **3**, it shows a specific implementation of the above pixel driving circuit. Wherein the compensation unit may include a first compensation transistor T**4** and a second compensation transistor T**5**. The reset unit may include a first reset transistor T**6** and a second reset transistor T**7**. A gate of the first switching transistor T**1** is connected to a first scan line, a source thereof receives the data signal Data, and a drain thereof is connected to the source of the driving transistor DTFT. The first switching transistor T**1** may be turned on or off under a control of a first scan signal Sn output from the first scan line. A gate of the second switching transistor T**2** receives a light emitting control signal En, a source thereof is connected to the driving voltage, and a drain thereof is connected to the source of the driving transistor DTFT. A gate of the third switching transistor T**3** receives the light emitting control signal En, a source thereof is connected to the drain of the driving transistor DTFT, and a drain thereof is connected to the first terminal of the organic light emitting diode OLED. The second switching transistor T**2** and the third switching transistor T**3** may be turned on or off under a control of the light emitting control signal En. A gate of the first compensation transistor T**4** receives an enable signal Sn', a source thereof is connected to the drain of the driving transistor DTFT, and a drain thereof is connected to a source of the second compensation transistor T**5**. A gate of the second compensation transistor T**5** receives the enable signal Sn', and a drain thereof is connected to the first terminal of the storage capacitor **16**. The first compensation transistor T**4** and the second compensation transistor T**5** may be turned on or off under a control of the enable signal Sn'. The first terminal of the storage capacitor **16** is connected to the gate of said driving transistor DTFT, the second terminal thereof is connected to the driving voltage. A gate of the first reset transistor T**6** receives the reset signal, a source thereof is connected to the initial voltage Vint, and a drain thereof is connected to a source of the second reset transistor T**7** and the first terminal of the organic light emitting diode OLED. A gate of the second reset transistor T7 receives the reset signal, and a drain thereof is connected to the source of the first compensation transistor T4. The first reset transistor T6 and the second reset transistor T7 be turned on or off under a control of the reset signal.

[0131] In an exemplary embodiment of the present disclosure, the above reset signal may be a second scan signal Sn−1. The second scan signal Sn−1 is provided by a second scan line, and the second scan line is a previous row of scan line to the first scan line. In this way, the overall amount of control signals and control lines may be reduced.

[0132] It should be noted that, although in the above exemplary embodiment, in order to improve the switching speed, the compensation unit includes a first compensation transistor T4 and a second compensation transistor T5, in other exemplary embodiments, the compensation unit may only include one transistor. For example, the compensation unit includes a compensation transistor. In this case, a gate of the compensation transistor receives the enable signal Sn', a source thereof is connected to the drain of the driving transistor DTFT, and a drain thereof is connected to the first terminal of the storage capacitor **16**, and so on.

[0133] An additional advantage of the pixel driving circuit of the present embodiment lies in that, each of the transistors is of a single channel type, i.e., a P type thin film transistor. Entirely P type thin film transistors may provide the advantage of, for example, a strong suppression against noise. For example, they are turned on at a low level which may be easily implemented in charging management. For example, an N type thin film transistor is subject influence of ground bounce, while a P type thin film transistor is only subject to influence of IR Drop of the driving voltage line, which generally may be eliminated more easily. For example, for a P type thin film transistor, the production process is simple, and the cost is low. For example, stability of a P type thin film transistor is better than other advantages. Therefore, with entirely P type thin film transistors, not only complexity of the production process and production cost is reduced, but also the product quality may be improved. As illustrated in FIG. **3**, in case where each of the transistors are a P type thin film transistor, a source of the second switching transistor T**2** is connected to a high level driving voltage ELVDD, a drain of the third switching transistor T3 is connected to an anode of the organic light emitting diode OLED, and a cathode of the organic light emitting diode OLED is connected a low level voltage ELVSS.

[0134] However, those skilled in the art would anticipate that the pixel driving circuit provided by the present disclosure may be easily modified into a pixel driving circuit of entirely N type thin film transistors. The structural difference from that of the circuit composed of P type thin film transistors mainly lies in that, in a case where all the transistors are N type thin film transistors, the point corresponding to the source of the second switching transistor T**2** is connected to a low level driving voltage, the point corresponding to the drain of the switching transistor T**3** is connected to the cathode of the organic light emitting diode OLED, and the anode of the organic light emitting diode OLED is connected to a high level voltage. However, the pixel driving circuit provided by the present disclosure may be easily modified into a CMOS (Complementary Metal Oxide Semiconductor) circuit, and so on, which is not limited to the pixel driving circuit according to the present embodiment and will not be repeated herein.

[0135] Hereinafter, a driving method of the pixel driving circuit in FIG. **3** will be described by referring to the timing sequence diagram of FIG. **4**. As illustrated in FIG. **4**, the driving method mainly includes a reset stage T1, a charging stage T2 and a displaying stage T3. In order to avoid input noise due to simultaneous transitions of signals, the reset stage T1 may be divided into timing sections t**1**-t**3**, the charging stage T2 may be divided into timing sections t**4**-t**6**, and the displaying stage may be divided into timing sections t**6**-t**8**. FIGS. **5**-**12** show equivalent circuits corresponding to the above timing sections.

[0136] For example, as illustrated in FIGS. **4** and **5**, in the timing section t**1** of the reset stage, the first scan signal Sn, the second scan signal Sn−1, the light emitting control signal En and the enable signal Sn' are at a high level, and all of the transistors are turned off.

[0137] As illustrated in FIGS. **4** and **6**, in the timing section t**2** of the reset stage, the first scan signal Sn, the second scan signal Sn−1 and the light emitting control signal En are at a high level, and the enable signal Sn' are at a low level. The first compensation transistor T**4** and the second compensation transistor T**5** are turned on, and the first switching transistor the second switching transistor T**2**, the third switching transistor T**3**, the first reset transistor T**6**, the second reset transistor T**7** are turned off. This timing section is a preparation for the reset in the next timing section.

[0138] As illustrated in FIGS. **4** and **7**, in the timing section t**3** of the reset stage, the first scan signal Sn and the light emitting control signal En are at a high level, and the second scan signal Sn−1 and the enable signal Sn' are at a low level. The first compensation transistor T**4**, the second compensation transistor T**5**, the first reset transistor T**6** and the second reset transistor T**7** are turned on, and the first switching transistor T**1**, the second switching transistor T**2** and the third switching transistor T**3** are turned off. In this timing section, the initial voltage Vint is applied to the first terminal of the organic light emitting diode OLED via the first reset transistor T**6**, to reset the organic light emitting diode OLED. Further, the initial voltage Vint is applied to the first terminal of the storage capacitor **16** via the first reset transistor T**6**, the second reset transistor T**7**, the first compensation transistor T**4** and the second compensation transistor T**5**, so that a voltage at the gate of the driving transistor DTFT V_B=Vint, so as to eliminate the influence of the residual voltage signal of the previous frame.

[0139] As illustrated in FIGS. **4** and **8**, in the timing section t**4** of the charging stage, the first scan signal Sn, the second scan signal Sn−1 and the light emitting control signal En are at a high level, and the enable signal Sn' is at a low level. The first compensation transistor T**4** and the second compensation transistor T**5** are turned on, and the first switching transistor T**1**, the second switching transistor T**2**, the third switching transistor T**3**, the first reset transistor T**6** and the second reset transistor T**7** are turned off. In this timing section, the voltage of the gate of the driving transistor DTFT is sustained constant.

[0140] As illustrated in FIGS. **4** and **9**, in the timing section t**5** of the charging stage, the second scan signal Sn−1 and the light emitting control signal En are at a high level, and the first scan signal Sn and the enable signal Sn' are at a low level. The first switching transistor T**1** and the first compensation transistor T**4** and the second compensation transistor T**5** are turned on, and the second switching transistor T**2**, the third switching transistor T**3**, the first reset transistor T**6** and the second reset transistor T7 are turned off. In this timing segment, since the driving transistor DTFT forms a diode connection (i.e., in a saturate state), the data signal Data is written into the storage capacitor **16** via the first switching transistor T1, the diode connection formed by the driving transistor DTFT, the first compensation transistor T4 and the second compensation transistor T5, to charge the storage capacitor **16**, so that a voltage at point B rises to Vdata+Vth (Vdata is level of the data signal Data, and Vth is the threshold voltage of the driving transistor DTFT).

[0141] As illustrated in FIGS. **4** and **10**, in the timing section t**6** of the charging stage, the first scan signal Sn, the second scan signal Sn−1 and the light emitting control signal En are at a high level, and the enable signal Sn' is at a low level. The first compensation transistor T**4** and the second compensation transistor T**5** are turned on, and the first switching transistor T**1**, the second switching transistor T**2**, the third switching transistor T**3**, the first reset transistor T**6** and the second reset transistor T**7** are turned off. In this timing section, the voltage of the gate of the driving transistor DTFT is sustained constant.

[0142] As illustrated in FIGS. **4** and **11**, in the timing section t**7** of the displaying stage, the first scan signal Sn, the second scan signal Sn−1, the light emitting control signal En and the enable signal Sn' are at a high level. The first switching transistor T**1**, the second switching transistor T**2**, the third switching transistor T**3**, the first compensation transistor T**4**, the second compensation transistor T**5**, the first reset transistor T**6** and the second reset transistor T**7** are all turned off. In this timing section, the driving transistor DTFT dose not form a diode connection, and the voltage at the gate is sustained constant as Vdata+Vth.

[0143] As illustrated in FIGS. **4** and **12**, in the timing section t**8** of the displaying stage, the first scan signal Sn, the second scan signal Sn−1 and the enable signal Sn' are at a high level, and the light emitting control signal En is at a low level. The second switching transistor T**2** and the third switching transistor T**3** are turned on, and the first switching transistor T**1**, the first compensation transistor T**4**, the second compensation transistor T**5**, the first reset transistor T**6** and the second reset transistor T**7** are turned off. In this timing section, the voltage at the first terminal of the storage capacitor **16**, i.e. the gate voltage V_g of the driving transistor DTFT is:

$$V_g = Vth + V\text{data}$$

[0144] If the source voltage of the driving transistor DTFT is V_s=ELVDD, a gate-source voltage thereof V_{gs} is:

$$V_{gs} = V_g - V_s = Vth + V\text{data} - ELVDD$$

[0145] At this time, the driving transistor DTFT is in a linear state, and provides a stable driving current to the organic light emitting diode OLED. The driving current of the organic light emitting diode OLED is:

$$\begin{aligned} I_{oled} &= \frac{1}{2}\mu_n \cdot C_{OX} \cdot \frac{W}{L} \cdot (V_{gs} - Vth)^2 \\ &= \frac{1}{2}\mu_n \cdot C_{OX} \cdot \frac{W}{L} \cdot (Vth + Vdata - ELVDD - Vth)^2 \\ &= \frac{1}{2}\mu_n \cdot C_{OX} \cdot \frac{W}{L} \cdot (Vdata - ELVDD)^2 \end{aligned}$$

[0146] Where $\mu_n \cdot C_{OX} \cdot W/L$ is a constant relevant to the production process and design. Finally, the driving current passes through the third switching transistor T**3** to drive the organic light emitting diode OLED to emit light.

[0147] It can be seen from the above that, in the present exemplary embodiment, since the driving current is irrelevant to the threshold voltage Vth of the driving transistor DTFT, the drift of the threshold voltage of the driving transistor DTFT will not influence the drain current, i.e. a driving current I_{oled} of the organic light emitting diode OLED. Accordingly, in the present exemplary embodiment, by effectively compensating for the drift of the threshold voltage, the uniformity and stability of the driving currents may be ensured, and thus the brightness of the OLED display panel may be made more uniform.

[0148] Further, since in the present exemplary embodiment, a path for the leakage current of the storage capacitor is only via the compensation unit, while in the related art, the pixel driving circuit with a compensation function for the threshold voltage generally have more paths for the leakage current, the pixel driving circuit according to the present exemplary embodiment has another technical effect of reducing the leakage current of the storage capacitor. For example, as illustrated in FIG. **13**, a simulation result of the pixel driving circuit according to the present exemplary embodiment shows, the leakage current of the storage capacitor of the pixel driving circuit according to the present exemplary embodiment is significantly small. In this way, the pixel driving circuit according to the present exemplary embodiment may also improve the stability of the gate voltage of the driving transistor supplied by the storage capacitor, thus further improve the uniformity and contrast of the displayed screen, and make the black screen more stable.

[0149] Further, the present exemplary embodiment also provides a display device. The display device includes a plurality of data lines for providing data signals; a plurality of scan lines for supplying scan signals; and a plurality of pixel driving circuits, electrically connected to the data lines and the scan lines. Each of the pixel driving circuits may be any of the pixel driving circuits according to the present exemplary embodiment described above. Since in the pixel driving circuits, the drift of the threshold voltage of the driving transistor is compensated, the organic light emitting diode may display stably, the uniformity of the brightness of the display device may be improved, and thus the display quality may be significantly improved.

[0150] Although the present disclosure has been described with reference to the above relevant embodiments, they are only exemplary. It should be noted that, the scope of the present disclosure are not limited within the disclosed embodiments. Rather, various variations and modifications made without departing from the spirit and scope of the present disclosure all fall into the protection scope of the present disclosure.

What is claimed is:

1. A pixel driving circuit, comprising:

an organic light emitting diode;

a storage capacitor;

a driving transistor;

a compensation unit configured to write a threshold voltage of the driving transistor into the storage capacitor in response to an enable signal;

a first switching transistor configured to write a data signal into the storage capacitor via the driving transistor and the compensation unit in response to a first scan signal;

a second switching transistor configured to apply a driving voltage to the driving transistor in response to a light emitting control signal;

a third switching transistor configured to apply a driving current output from the driving transistor to the organic light emitting diode to cause it to emit light, in response to the light emitting control signal; and

a reset unit is configured to reset the organic light emitting diode and the storage capacitor with an initial voltage, in response to a reset signal,

wherein the storage capacitor is configured to store the written data signal and the threshold voltage and apply the written data signal and the threshold voltage to a gate of the driving transistor.

2. The pixel driving circuit according to claim **1**, wherein:

the first switching transistor has a gate that receives the first scan signal, a source that receives the data signal, and a drain that is connected to a source of the driving transistor;

the second switching transistor has a gate that receives the light emitting control signal, a source that is connected to the driving voltage, and a drain that is connected to a source of the driving transistor;

the third switching transistor has a gate that receives the light emitting control signal, a source that is connected to a drain of the driving transistor, and a drain that is connected to a first terminal of the organic light emitting diode;

the compensation unit has a first terminal that is connected to the drain of the driving transistor, a second terminal that is connected to the storage capacitor, and a control terminal that receives the enable signal;

the storage capacitor has a first terminal that is connected to the gate of the driving transistor, and a second terminal that is connected to the driving voltage; and

the reset unit has a first terminal that is connected to the initial voltage, a second terminal that is connected to the first terminal of the organic light emitting diode, a third terminal that is connected with the first terminal of the compensation unit, and a control terminal that receives the reset signal.

3. The pixel driving circuit according to claim **2**, wherein:

the reset unit comprises a first reset transistor and a second reset transistor;

the first reset transistor has a gate that receives the reset signal, a source that is connected to the initial voltage, and a drain that is connected to a source of the second reset transistor and the first terminal of the organic light emitting diode; and

the second reset transistor has a gate that receives the reset signal, and a drain that is connected to the first terminal of the compensation unit.

4. The pixel driving circuit according to claim **2**, wherein:

the compensation unit comprises a first compensation transistor and a second compensation transistor;

the first compensation transistor has a gate that receives the enable signal, a source that is connected to the drain of the driving transistor, and a drain that is connected to a source of the second compensation transistor; and

the second compensation transistor has a gate that receives the enable signal, and a drain that is connected to the first terminal of the storage capacitor.

5. The pixel driving circuit according to claim **2**, wherein:

the reset signal is a second scan signal;

the first scan signal is provided by a scan line; and

the second scan signal is provided by a previous scan line to the scan line.

6. The pixel driving circuit according to claim **3**, wherein:

all of the transistors are P type thin film transistors;

the driving voltage connected to the source of the second switching transistor is a high level driving voltage;

the drain of the third switching transistor is connected to an anode of the organic light emitting diode; and

the organic light emitting diode has a cathode that is connected to a low level voltage.

7. The pixel driving circuit according to claim **3**, wherein:

all of the transistors is an N type thin film transistor;

the driving voltage connected to the source of the second switching transistor is a low level driving voltage;

the drain of the third switching transistor is connected to a cathode of the organic light emitting diode; and

the organic light emitting diode has an anode that is connected to a high level voltage.

8. A method for driving a pixel driving circuit according to claim **1**, and the driving method comprises:

turning on the compensation unit and the reset unit respectively by using the enable signal and the reset signal, thereby causing the initial voltage to reset the organic light emitting diode via the reset unit and to reset the storage capacitor via the reset unit and the compensation unit respectively;

turning on the first switching transistor and the compensation unit respectively by using the first scan signal and the enable signal, thereby causing the data signal and the threshold voltage to be written into the storage capacitor; and

turning on the second and the third switching transistor by using the light emitting control signal, thereby turning on the driving transistor by using the data signal and the threshold voltage written into the storage capacitor, and causing the driving voltage drive to drive the organic light emitting diode to emit light via the second and the third switching transistor and the driving transistor.

9. A display device, comprising:

a plurality of data lines that provides data signals;

a plurality of scan lines that supplies scan signals comprising a first scan signal and a second scan signal which are provided successively; and

a plurality of pixel driving circuits, electrically connected to the data lines and the scan lines, each of the plurality of pixel driving circuit comprising:

an organic light emitting diode;

a storage capacitor;

a driving transistor;

a compensation unit configured to write a threshold voltage of the driving transistor into the storage capacitor in response to an enable signal;

a first switching transistor configured to write a data signal into the storage capacitor via the driving transistor and the compensation unit in response to a first scan signal;

a second switching transistor configured to apply a driving voltage to the driving transistor in response to a light emitting control signal;

a third switching transistor configured to apply a driving current output from the driving transistor to the organic light emitting diode to cause it to emit light, in response to the light emitting control signal; and

a reset unit is configured to reset the organic light emitting diode and the storage capacitor with an initial voltage, in response to a reset signal,

wherein the storage capacitor is configured to store the written data signal and the threshold voltage and apply the written data signal and the threshold voltage to a gate of the driving transistor.

10. The display device according to claim **9**, wherein:

the first switching transistor has a gate that receives the first scan signal, a source that receives the one data signal, and a drain that is connected to a source of the driving transistor;

the second switching transistor has a gate that receives the light emitting control signal, a source that is connected to the driving voltage, and a drain that is connected to a source of the driving transistor;

the third switching transistor has a gate that receives the light emitting control signal, a source that is connected to a drain of the driving transistor, and a drain that is connected to a first terminal of the organic light emitting diode;

the compensation unit has a first terminal that is connected to the drain of the driving transistor, a second terminal that is connected to the storage capacitor, and a control terminal that receives the enable signal;

the storage capacitor has a first terminal that is connected to the gate of the driving transistor, and a second terminal that is connected to the driving voltage; and

the reset unit has a first terminal that is connected to the initial voltage, a second terminal that is connected to the first terminal of the organic light emitting diode, a third terminal that is connected with the first terminal of the compensation unit, and a control terminal that receives the reset signal.

11. The pixel driving circuit according to claim **10**, wherein:

the reset unit comprises a first reset transistor and a second reset transistor;

the first reset transistor has a gate that receives the reset signal, a source that is connected to the initial voltage, and a drain that is connected to a source of the second reset transistor and the first terminal of the organic light emitting diode; and

the second reset transistor has a gate that receives the reset signal, and a drain that is connected to the first terminal of the compensation unit.

12. The pixel driving circuit according to claim **10**, wherein:

the compensation unit comprises a first compensation transistor and a second compensation transistor;

the first compensation transistor has a gate that receives the enable signal, a source that is connected to the drain of the driving transistor, and a drain that is connected to a source of the second compensation transistor; and

the second compensation transistor has a gate that receives the enable signal, and a drain that is connected to the first terminal of the storage capacitor.

13. The pixel driving circuit according to claim **10**, wherein:

the reset signal is the second scan signal;

the first scan signal is provided by one scan line of the plurality of scan lines; and

the second scan signal is provided by a previous scan line to the one scan line.

14. The pixel driving circuit according to claim **11**, wherein:

all of the transistors are P type thin film transistors;

the driving voltage connected to the source of the second switching transistor is a high level driving voltage;

the drain of the third switching transistor is connected to an anode of the organic light emitting diode; and

the organic light emitting diode has a cathode that is connected to a low level voltage.

15. The pixel driving circuit according to claim **11**, wherein:

all of the transistors is an N type thin film transistor;

the driving voltage connected to the source of the second switching transistor is a low level driving voltage;

the drain of the third switching transistor is connected to a cathode of the organic light emitting diode; and

the organic light emitting diode has an anode that is connected to a high level voltage.

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摘要(译)

提供一种显示装置，像素驱动电路及其驱动方法。像素驱动电路包括有机发光二极管，第一，第二和第三开关晶体管，存储电容器，驱动晶体管，补偿单元和复位单元。第一开关晶体管通过驱动晶体管和补偿单元将数据信号写入存储电容器;第二开关晶体管将驱动电压施加到驱动晶体管;第三开关晶体管将驱动晶体管输出的驱动电流施加到有机发光二极管;补偿单元将驱动晶体管的阈值电压写入存储电容器;存储电容器存储写入的电压信号并将其施加到驱动晶体管;并且复位单元复位有机发光二极管和存储电容器。