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(54) ACTIVE MATRIX DISPLAY COMPENSATING APPARATUS

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G09G 3/30 (2006.01)

(52) **U.S. Cl.** **345/76**; 345/82

(58) **Field of Classification Search** 345/76–84, 345/6

See application file for complete search history.

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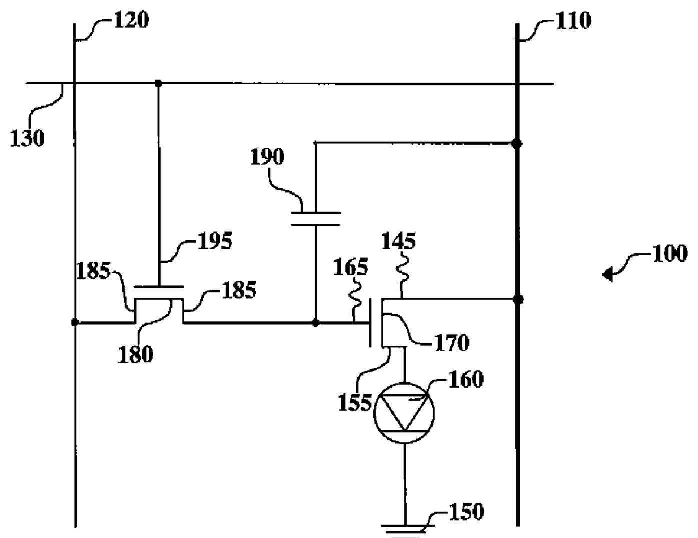
(57) **ABSTRACT**

An apparatus for determining an adjustment to a signal voltage for compensating for changes in the threshold voltage (Vth) for a drive transistor in a pixel drive circuit in an active matrix OLED display having at least one OLED light-emitting pixel, comprising: the pixel drive circuit having a data line, a power supply line, a drive transistor; the drive transistor being electrically connected to the power supply line and to the OLED light-emitting pixel; the switch transistor being electrically connected to the gate electrode of the drive transistor and to the data line; first means for applying a first voltage to the power supply line; second means for applying a second voltage to the power supply line opposite in polarity to the first voltage; third means for producing a threshold-voltage-related signal on the data line; and fourth means responsive to the threshold-voltage-related signal for calculating the adjustment to the signal voltage.

6 Claims, 6 Drawing Sheets



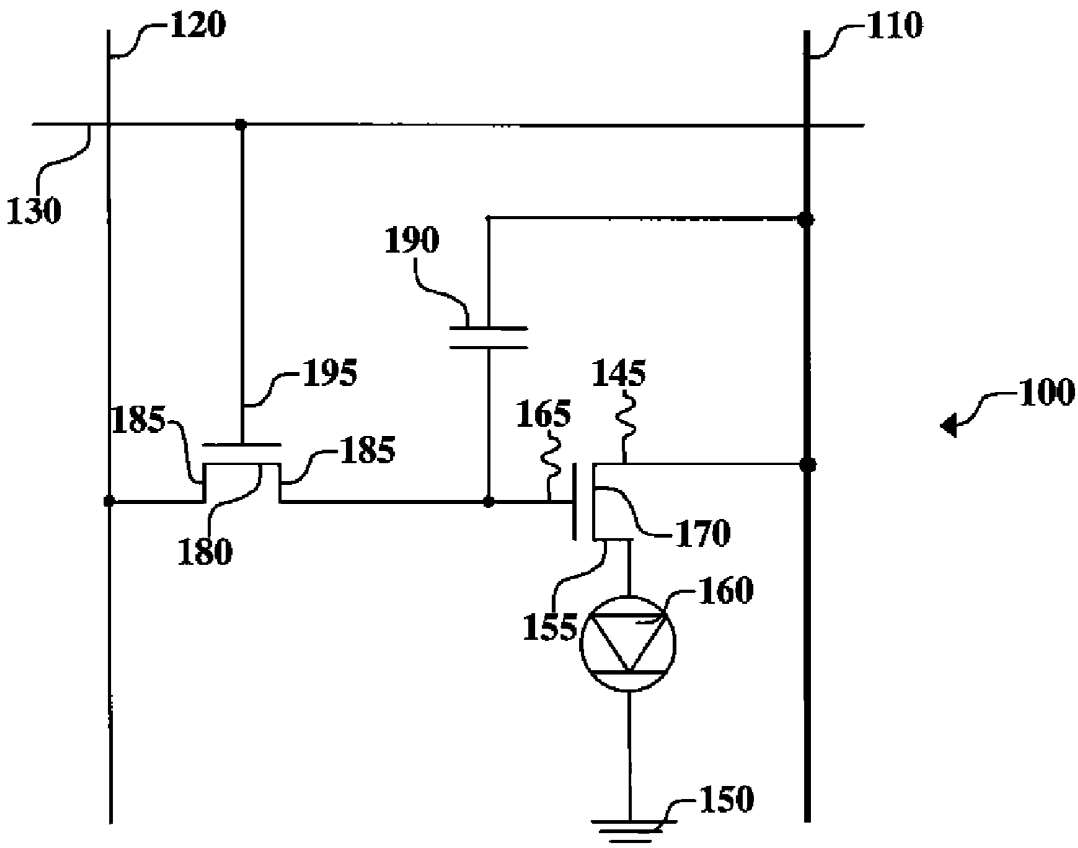


FIG. 1

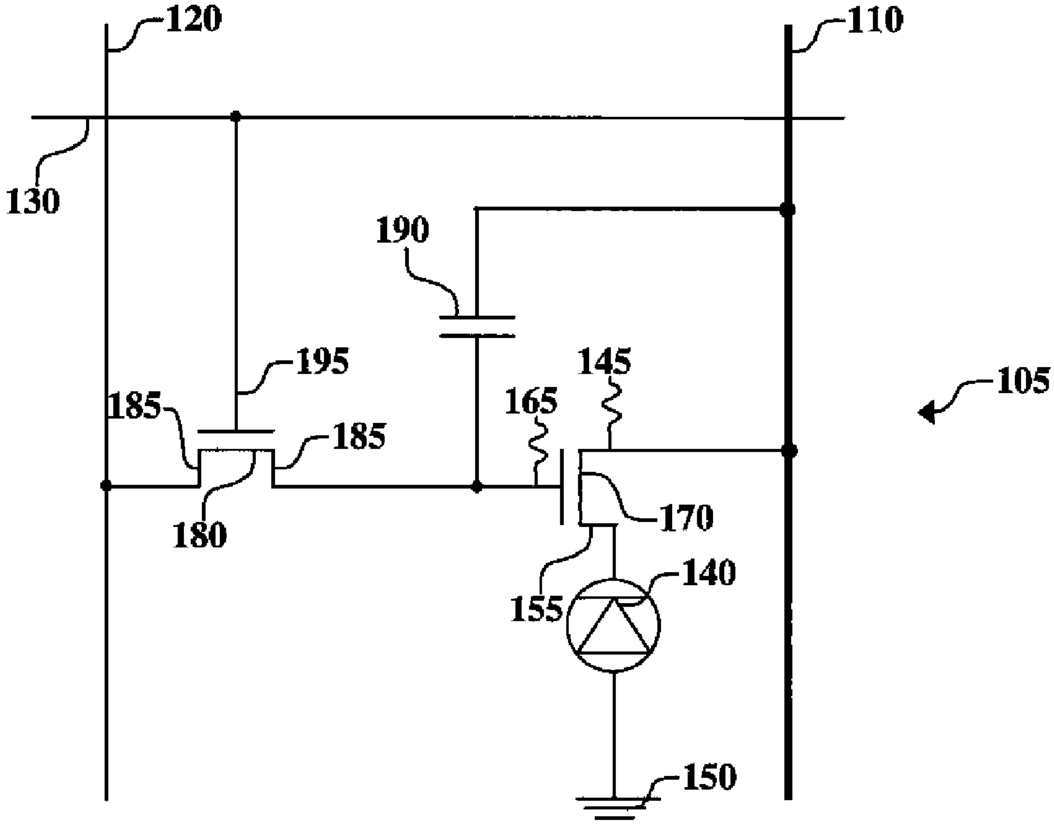


FIG. 2

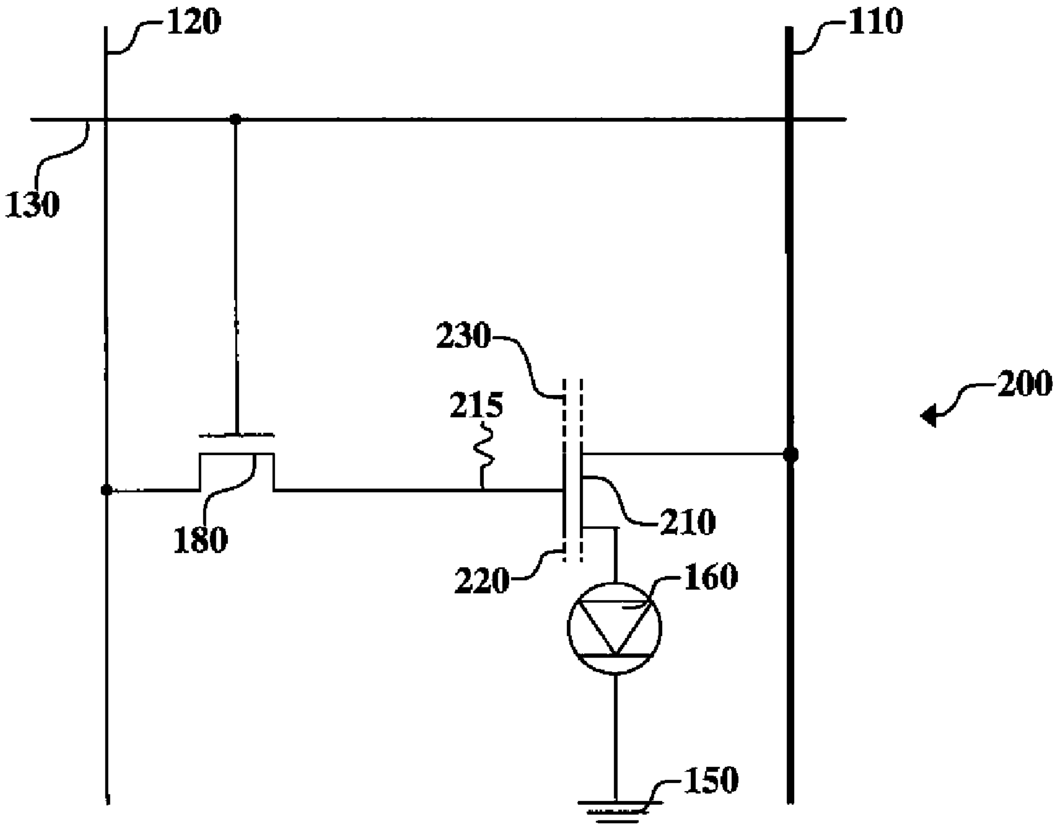


FIG. 3

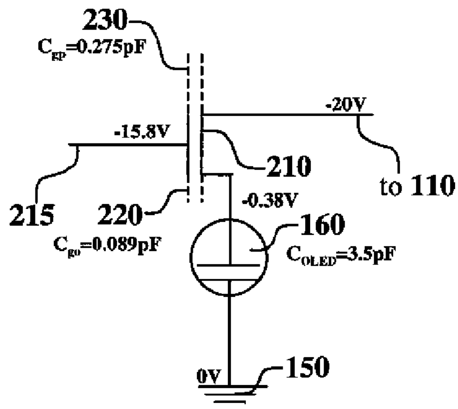


FIG. 4A

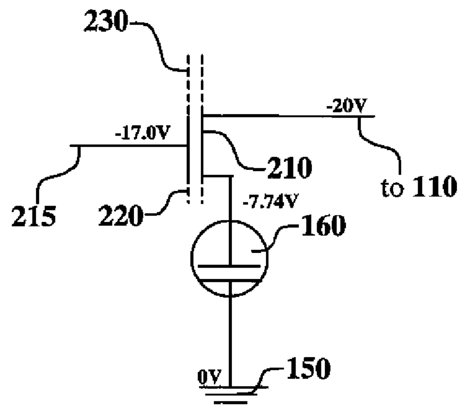


FIG. 4B

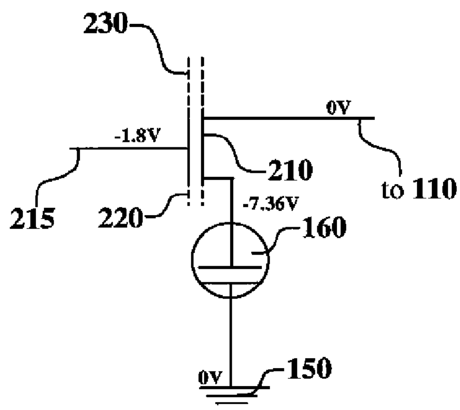


FIG. 4C

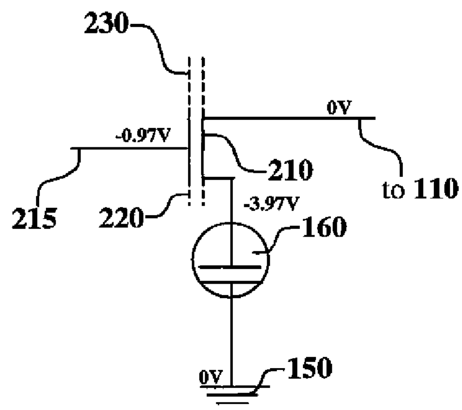


FIG. 4D

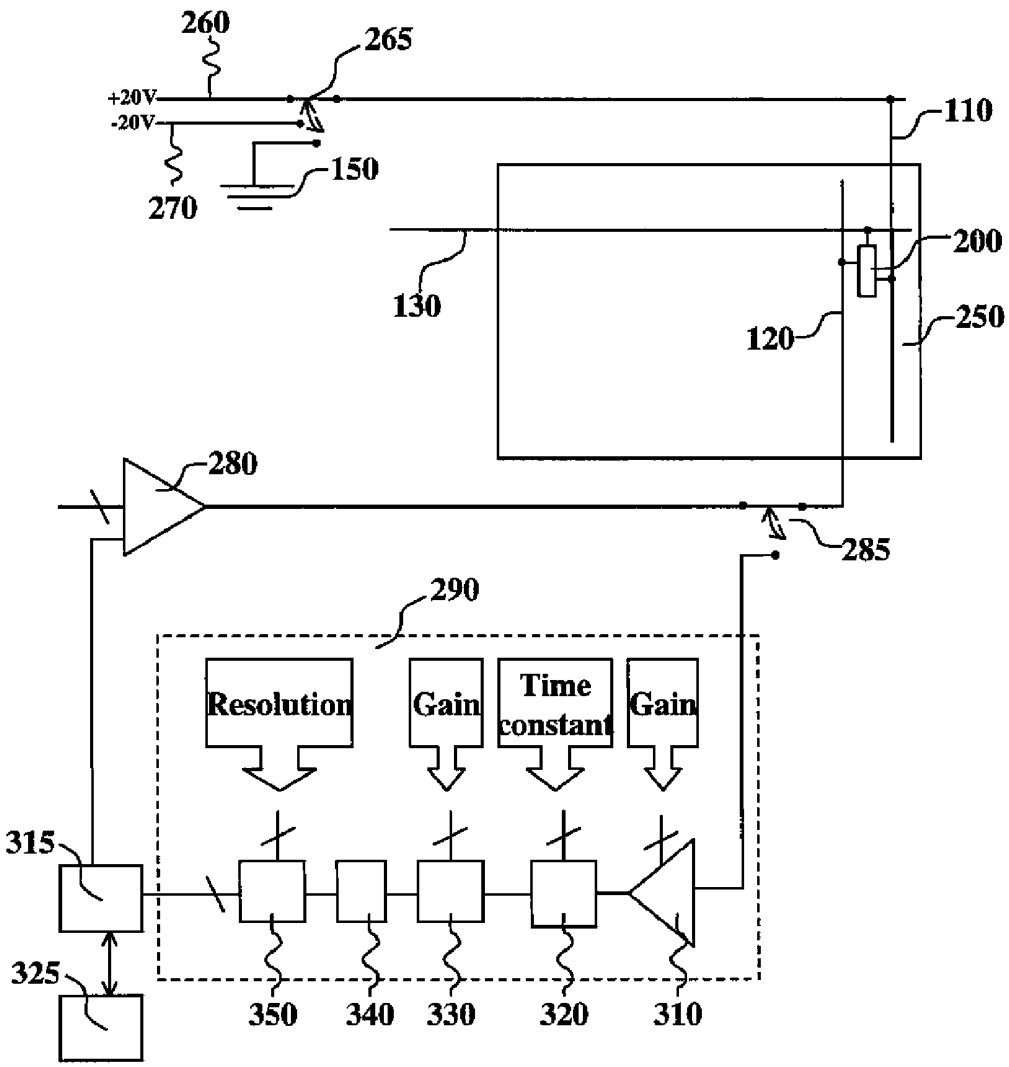

260
265
+20V
-20V
110
150
270
200
130
250
120
280
285
290
Resolution
Gain
Time constant
Gain
315
325
350
340
330
320
310

FIG. 5

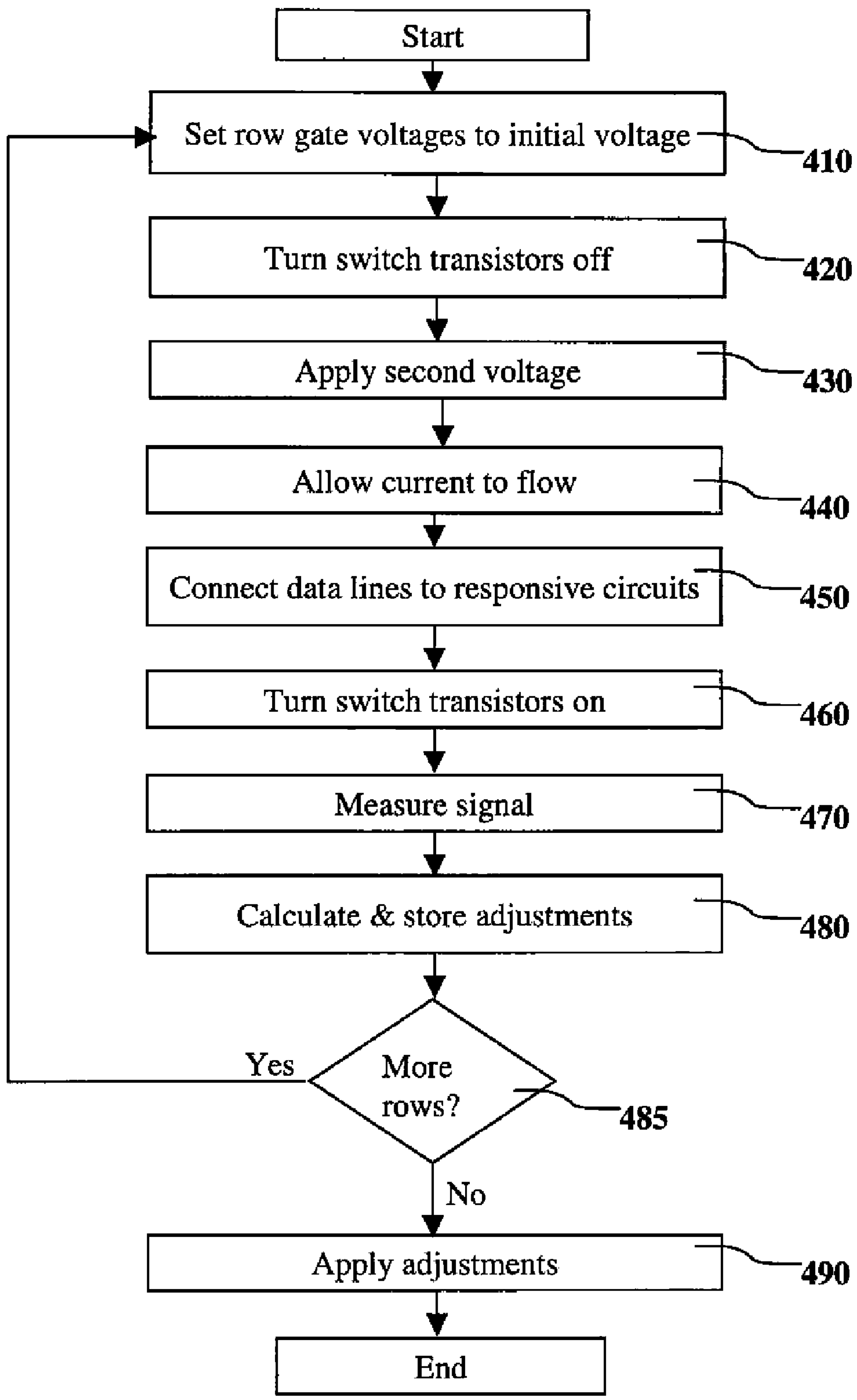

Start
Set row gate voltages to initial voltage
410
Turn switch transistors off
420
Apply second voltage
430
Allow current to flow
440
Connect data lines to responsive circuits
450
Turn switch transistors on
460
Measure signal
470
Calculate & store adjustments
480
Yes
More rows?
485
No
Apply adjustments
490
End

FIG. 6

ACTIVE MATRIX DISPLAY COMPENSATING APPARATUS

CROSS REFERENCE TO RELATED APPLICATIONS

The present application is related to U.S. Ser. No. 11/427,139, filed concurrently herewith, of John W. Hamer and Gary Parrett, entitled "Active Matrix Display Compensation".

FIELD OF THE INVENTION

The present invention relates to an active matrix-type display apparatus for driving display elements.

BACKGROUND OF THE INVENTION

In recent years, it has become necessary that image display devices have high-resolution and high picture quality, and it is desirable for such image display devices to have low power consumption and be thin, lightweight, and visible from wide angles. With such requirements, display devices (displays) have been developed where thin-film active elements (thin-film transistors, also referred to as TFTs) are formed on a glass substrate, with display elements then being formed on top.

In general, a substrate forming active elements is such that patterning and interconnects formed using metal are provided after forming a semiconductor film of amorphous silicon or polysilicon etc. Due to differences in the electrical characteristics of the active elements, the former requires ICs (Integrated Circuits) for drive use, and the latter is capable of forming circuits for drive use on the substrate. In liquid crystal displays (LCDs) currently widely used, the amorphous silicon type is widespread for large-type screens, while the polysilicon type is more common in medium and small screens.

Typically, organic EL elements are used in combination with TFTs and utilize a voltage/current control operation so that current is controlled. The current/voltage control operation refers to the operation of applying a signal voltage to a TFT gate terminal so as to control current between the source and drain. As a result, it is possible to adjust the intensity of light emitted from the organic EL element and to control the display to the desired gradation.

However, in this configuration, the intensity of light emitted by the organic EL element is extremely sensitive to the TFT characteristics. In particular, for amorphous silicon TFTs (referred to as a-Si), it is known that comparatively large differences in electrical characteristics occur with time between neighboring pixels, due to changes in transistor threshold voltage. This is a major cause of deterioration of the display quality of organic EL displays, in particular, screen uniformity. Uncompensated, this effect can lead to "burned-in" images on the screen.

Goh et al. (IEEE Electron Device Letters, Vol. 24, No. 9, pp. 583-585) have proposed a pixel circuit with a precharge cycle before data loading, to compensate for this effect. Compared to the standard OLED pixel circuit with a capacitor, a select transistor, a power transistor, and power, data, and select lines, Goh's circuit uses an additional control line and two additional switching transistors. Jung et al. (IMID '05 Digest, pp. 793-796) have proposed a similar circuit with an additional control line, an additional capacitor, and three additional transistors. While such circuits can be used to compensate for changes in the threshold voltage of the driving transistor, they add to the complexity of the display, thereby increasing the cost and the likelihood of defects in the manufactured product. Further, such circuitry generally comprises thin-film transistors (TFTs) and necessarily uses up a portion of the substrate area of the display. For bottom-emitting devices, the aperture ratio is important, and such additional circuitry reduces the aperture ratio, and can even make such bottom-emitting displays unusable. Thus, there exists a need to compensate for changes in the electrical characteristics of the pixel circuitry in an OLED display without reducing the aperture ratio of such a display.

SUMMARY OF THE INVENTION

It is therefore an object of the present invention to provide an apparatus and method of compensating for changes in the electrical characteristics of the pixel circuitry in an OLED display.

This object is achieved by an apparatus for determining an adjustment to a signal voltage for compensating for changes in the threshold voltage (V_{th}) for a drive transistor in a pixel drive circuit in an active matrix OLED display having at least one OLED light-emitting pixel, comprising:

a) the pixel drive circuit having a data line, a power supply line, a drive transistor having source, drain, and gate electrodes, and a switch transistor having source, drain, and gate electrodes;

b) the source or drain electrode of the drive transistor being electrically connected to the power supply line, and the other of the source or drain electrode being electrically connected to the OLED light-emitting pixel;

c) the source or the drain electrode of the switch transistor being electrically connected to the gate electrode of the drive transistor, and the other of the source or drain electrode being electrically connected to the data line;

d) first means for applying a first voltage to the power supply line which is either positive or negative for causing current to flow in a first direction through the drive transistor which causes the OLED light-emitting pixel to produce light in response to the signal voltage;

e) second means for applying a second voltage to the power supply line opposite in polarity to the first voltage so that current will flow through the drive transistor in a second direction opposite to the first direction until the potential on the gate electrode of the drive transistor causes the drive transistor to turn off;

f) third means for producing a threshold-voltage-related signal on the data line which is a function of the potential on the gate electrode of the drive transistor; and

g) fourth means responsive to the threshold-voltage-related signal for calculating the adjustment to the signal voltage.

Advantages

It is an advantage of the present invention that it can compensate for changes in the electrical characteristics of the thin-film transistors of an OLED display. It is a further advantage of this invention that it can so compensate without reducing the aperture ratio of a bottom-emitting OLED display and without increasing the complexity of the within-pixel circuits.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** shows a schematic diagram of an OLED pixel drive circuit well-known in the art;

FIG. **2** shows a schematic diagram of one embodiment of a common OLED pixel drive circuit that is useful in this invention;

FIG. **3** shows a schematic diagram of another embodiment of a common OLED pixel drive circuit that is useful in this invention;

FIGS. **4**A through **4**D show the stepwise results of the operations of this invention on a portion of an example pixel drive circuit;

FIG. **5** shows a schematic diagram of one embodiment of a circuit according to this invention for determining an error-correcting voltage for compensating for changes in the threshold voltages for a drive transistor in a pixel drive circuit in an active matrix OLED display; and

FIG. **6** shows a block diagram of one embodiment of a method according to this invention for determining an error-correcting voltage for compensating for changes in the threshold voltages for a drive transistor in a pixel drive circuit in an active matrix OLED display.

DETAILED DESCRIPTION OF THE INVENTION

Turning now to FIG. **1**, there is shown a schematic diagram of one embodiment of an OLED pixel drive circuit that can be used in this invention. Such pixel drive circuits are well known in the art in active matrix OLED displays. OLED pixel drive circuit **100** has a data line **120**, a power supply line **110**, a select line **130**, a drive transistor **170**, a switch transistor **180**, an OLED light-emitting pixel **160**, and a capacitor **190**. Drive transistor **170** has drain electrode **145**, source electrode **155**, and gate electrode **165**. In pixel drive circuit **100**, drain electrode **145** of drive transistor **170** is electrically connected to power supply line **110**, while source electrode **155** is electrically connected to OLED light-emitting pixel **160**. By electrically connected, it is meant that the elements are directly connected or connected via another component, e.g. a switch, a diode, another transistor, etc. It will be understood that embodiments are possible wherein the source and drain electrode connections are reversed. OLED light-emitting pixel **160** is a non-inverted OLED pixel, wherein the anode of the pixel is electrically connected to power line **110** and the cathode of the pixel is electrically connected to ground **150**. Switch transistor **180** has gate electrode **195**, as well as source and drain electrodes, together represented as source or drain electrodes **185** because such transistors are commonly bidirectional. Of the source and drain electrodes **185** of switch transistor **180**, one is electrically connected to the gate electrode **165** of drive transistor **170**, while the other is electrically connected to data line **120**. Gate electrode **195** is electrically connected to select line **130**. OLED light-emitting pixel **160** is powered by flow of current between power supply line **110** and ground **150**. In this embodiment, power supply line **110** has a positive potential, relative to ground **150**, for driving OLED light-emitting pixel **160**. The normal driving potential will herein be referred to as the first voltage and is positive for this embodiment. It will cause current to flow through drive transistor **170** and OLED light-emitting pixel **160** in a first direction, that is, electrons will flow from ground **150** to power line **110**, which will cause OLED light-emitting pixel **160** to produce light. The magnitude of the current—and therefore the intensity of the emitted light—is controlled by drive transistor **170**, and more exactly by the magnitude of the signal voltage on gate electrode **165** of drive transistor **170**. During a write cycle, select line **130** activates switch transistor **180** for writing and the signal voltage data on data line **120** is written to drive transistor **170** and stored on capacitor **190**, which is connected between gate electrode **165** and power supply line **110**.

Turning now to FIG. **2**, there is shown a schematic diagram of another embodiment of an OLED pixel drive circuit that can be used in this invention. Pixel drive circuit **105** is constructed much as pixel drive circuit **100** described above. However, OLED light-emitting pixel **140** is an inverted OLED pixel, wherein the cathode of the pixel is electrically connected to power line **110** and the anode of the pixel is electrically connected to ground **150**. In this embodiment, power supply line **110** must have a negative potential, relative to ground **150**, for driving OLED light-emitting pixel **160**. Therefore, the first voltage is negative relative to ground **150** for this embodiment and the first direction in which current flows so as to drive OLED light-emitting pixel **140** will be the reverse of that in FIG. **1**. It will be understood in the examples to follow that one can reverse the potentials and current directions if necessary for the structure and function of the OLED pixel drive circuits, and that such modifications are within the scope of this invention.

The above embodiments are constructed wherein the drive transistors and switch transistors are n-channel transistors. It will be understood by those skilled in the art that embodiments wherein the drive transistors and switch transistors are p-channel transistors, with appropriate well-known modifications to the circuits, can also be useful in this invention.

In practice in active-matrix displays, the capacitance is often not provided as a separate entity, but in a portion of the thin-film transistor sections that form the drive transistor. FIG. **3** shows a schematic diagram of one embodiment of a common OLED pixel drive circuit **200** of this type, which is useful in this invention. Drive transistor **210** also incorporates a capacitor **230** connected between gate electrode **215** and power line **110**. This will also be referred to as the gate-power capacitor, or C_{gp}. Drive transistor **210** generally inherently includes a smaller parasitic capacitor **230** connected between gate electrode **215** and OLED light-emitting pixel **160**. This will also be referred to as the gate-OLED capacitor, or C_{go}. In some embodiments, the relative magnitude of C_{gp} and C_{go} can be reversed. As in pixel drive circuit **100**, the first voltage is positive for normal operation of OLED light-emitting pixel **160**. If the potential is reversed (e.g. power supply line **110** has a negative voltage relative to ground **150**), OLED light-emitting pixel **160** will be in an inoperative condition and will function instead as a capacitor having a capacitance C_{OLED}. This potential, which is opposite in polarity to the first voltage, will herein be referred to as the second voltage. This will cause current to flow through drive transistor **210** in a second direction opposite to the above first direction. However, current flow in the second direction will only occur until the various capacitors in the circuit, including the OLED light-emitting pixel, become charged and cause the drive transistor to turn off. The use of this property of the pixel drive circuits described herein is an important feature of this invention, which will now be illustrated.

Turning now to FIGS. **4**A through **4**D, there are shown the stepwise results of the operations of this invention on a portion of an example pixel drive circuit **200**. In preparation for FIG. **4**A, a potential of zero volts is placed on power supply line **110** and on gate electrode **215**. It is not required for the practice of this invention that power supply line **110** or gate electrode **215** first be set to zero volts; however, doing so will make illustration of the use of this invention clearer. The switch transistor that electrically connects gate electrode **215** to data line **120** is turned off, so that gate electrode **215** is isolated. Then a second voltage of −20V is applied to power supply line **110**. With a second voltage, OLED light-emitting pixel **160** is in an inoperative condition and acts as a capacitor. In the example shown here, the OLED capacitance C_{OLED} is 3.5 pF, the gate-OLED capacitance C_{go} is 0.089 pF, and the gate-power capacitance C_{gp} is 0.275 pF. The voltages shown in FIG. **4**A are those expected with these capacitances before any current flows if the gate and power supply potentials are both initially zero. If either the gate or power supply potential—or both—is not zero, the resulting voltages will be different, but will still be a function of the capacitances.

Current will then flow through drive transistor **210** in a second direction, that is, electrons will flow from power line **110** to ground **150**, and charge the C_{OLED} capacitor. As the charge on C_{OLED} is increased, the potential between the source and drain electrodes of drive transistor **210** is reduced. Simultaneously, the potential on the gate electrode of drive transistor **210** (which is isolated by switch transistor **180**) will shift to maintain the ratio of the potential difference from the gate to source and drain in proportion to the inverse of the ratio of respective capacitances:

$$V_{gp}/V_{go}=C_{go}/C_{gp} \quad \text{(Eq. 1)}$$

The current flow will continue until the potential V_{gp} between gate electrode **215** of drive transistor **210** and power supply line **110** falls to the value of the drive transistor threshold voltage, which causes the drive transistor to turn off. By turn off, it is meant that the current flow through drive transistor **210** is substantially zero. However, it is known in the art that transistors can leak small amounts of current under threshold voltage or lower conditions; such transistors can be successfully used in this invention. For illustration purposes, we are assuming in this example that the threshold voltage V_{th} of drive transistor **210** is 3.0V. FIG. **4**B shows the resulting voltages stored on the capacitors at this point. These voltages are a function of the threshold voltage of the transistor. Thus, the gate voltage is a threshold-voltage-proportional signal, and can be related to the threshold voltage by Eq. 2, wherein PV_{DD2} represents the second voltage (e.g. −20V in this example) applied to power supply line **110**:

$$V_{gate}=PV_{DD2}+V_{th} \quad \text{(Eq. 2)}$$

After the voltages have equilibrated as shown in FIG. **4***b*, select line **130** activates switch transistor **180** to connect gate electrode **215** to data line **120**, wherein the gate electrode voltage will be changed by a transfer function, here represented by f(x). The transfer function depends on the characteristics of switch transistor **180**, the change in potential of select line **130**, the circuit layout, the capacitance and impedance of the external circuits connected to data line **120**, and the number of pixels on data line **120** that are switched. One skilled in the art can predict the transfer function based on the design, or can measure it. Thus, the voltage produced on data line **120** (V_{out}) is a threshold-voltage-related signal which is a function of the potential on the gate electrode of the drive transistor, given by:

$$V_{out}=f(V_{gate}) \quad \text{(Eq. 3)}$$

The transfer function f(x) can be inverted, represented by $f^{-1}(x)$. The threshold voltage is calculated from the measured voltage by:

$$V_{th}=f^{-1}(V_{out})-PV_{DD2} \quad \text{(Eq. 4)}$$

Alternatively, before activating switch transistor **180** and measuring the potentials, an additional step can be done wherein the potential of power supply line **110** can then be changed to a third voltage. This will redistribute the potentials based upon the capacitances, as shown in FIG. **4**C. If the voltage is chosen correctly, such as zero in this example, current will flow through drive transistor **210** in the direction used to cause the OLED to emit light. No light will be emitted, as the OLED remains in a reverse bias condition. The current will continue to flow until the gate-to-OLED potential difference is equal to the threshold voltage of the drive transistor for current flow in the direction used for light emission. FIG. **4**D shows the resulting voltages on the circuit at this point. The gate voltage can be related to the threshold voltage by:

$$V_{gate}=PV_{DD3}-\frac{V_{th}C_{gp}}{C_{go}} \quad \text{(Eq. 5)}$$

wherein PV_{DD3} represents the third voltage (e.g. zero in this example) applied to power supply line **110**. In this case the threshold voltage can be calculated from the measured voltage by:

$$V_{th}=\frac{-C_{go}(f^{-1}(V_{out})-PVDD_3)}{C_{gp}} \quad \text{(Eq. 6)}$$

This last step of reducing the reverse driving potential (FIGS. **4**C and **4**D) is useful in the case that the threshold voltage of the driving transistor **210** is different for forward and reverse operation.

As the threshold voltage of a transistor can change with usage, it can be necessary to calculate an adjustment for the threshold voltage. This is the difference between the currently-calculated threshold voltage and the initial threshold voltage:

$$\text{Adjustment}=V_{th}-V_{thi} \quad \text{(Eq. 7)}$$

where V_{thi} represents the initial threshold voltage of the transistor.

Turning now to FIG. **5**, and referring also to FIGS. **3** through **4**D, there is shown a schematic diagram of one embodiment of an apparatus of this invention for determining an adjustment to a signal voltage for compensating for changes in the threshold voltage for a drive transistor in a pixel drive circuit as described herein. Active matrix OLED display **250** has at least one OLED light-emitting pixel, each having a pixel drive circuit **200** as described above. In normal operation, voltage supply **260**, which is a positive power supply, applies a first voltage (also called PV_{DD1}) to power supply line **110** via switch **265** to cause current to flow in a first direction through the drive transistor as described above, which causes OLED light-emitting pixel **160** to produce light. The intensity of the emitted light, which is proportional to the current through drive transistor **170**, is responsive to the signal voltage set by data line **120**, which is electrically connected to digital-to-analog converter **280**. Digital-to-analog converter **280** converts a digital input representing the desired intensity of light emitted by a given pixel into an analog signal voltage, which select line **130**) allows to be written to the capacitors of the selected pixel circuit. Although not shown for clarity of illustration, it will be understood that OLED display **250** can include a plurality of pixel drive circuits **200** arranged in an array, and further can include multiple power supply lines, select lines, and data lines, as known in the art.

In order to determine an adjustment to a signal voltage for compensating for changes in the threshold voltages (V_{th}) for the drive transistors of OLED display **250**, it is necessary to apply a second voltage opposite in polarity to the first voltage to the power supply line and the pixel drive circuit and thus place the OLED in an inoperative condition, as described above. Voltage supply **270**, which is a negative power supply in this embodiment, applies a second voltage (PV_{DD2}) opposite in polarity to the first voltage to power supply line **110** via switch **265**. As described above, this causes current to flow through the drive transistor in a second direction opposite to the first direction of normal operation, until the potential on the gate electrode of the drive transistor causes the drive transistor to turn off. Switch **265** can also optionally switch the circuit to a third voltage state (PV_{DD3}), e.g. ground **150**. During the second and third voltage operations, data line **120** can become an output line providing a threshold-voltage-related signal that is a function of the potential on gate electrode **215** of drive transistor **210**. Switch **285** connects data line **120** during such data output to a correlated double sampling circuit **290** which is responsive to the threshold-voltage-related signal. In the case of multiple data lines **120**, each data line can have its own correlated double sampling circuit **290**, or there can be fewer correlated double sampling circuits, with multiplexing to allow sequential data sampling of all data lines. Correlated double sampling circuit **290** comprises integrator **310**, low pass filter **320**, correlated double sampling unit **330**, sample-and-hold element **340**, and analog-to-digital converter **350**. Correlated double sampling circuit **290** is known and is a commercially available integrated circuit for amplification and readout of small charge over long data wires. An example is ISC9717 from Indigo. The data from correlated double sampling circuit **290** goes to a processor **315**, which can store it in memory **325** as raw data, or can include computation circuitry for calculating the current threshold voltage for the drive transistor via Eq. 4 or Eq. 6, or via a lookup table. Processor **315** can calculate an adjustment to the signal voltage, via Eq. 7, from the difference between the current threshold voltage and the initial threshold voltage, which is the threshold voltage of drive transistor **210** before any aging takes place. The initial threshold voltage can be measured when pixel drive circuit **200** is new, and subsequently stored in memory. During operation of OLED display **250**, processor **315** can apply the adjustment to the signal voltage through digital-to-analog converter **280**, which can adjust the signal voltage, and thus apply the adjustment to data line **120**, through switch transistor **180** of pixel drive circuit **200**, to gate electrode **215** of drive transistor **210**. Processor **315** and memory **325** can be made of individual integrated circuits or encapsulated in a single package as an SiP (System in Package). Memory **325** can also be built into processor **315** as an SoC (System on Chip).

In practice, circuits such as correlated double sampling circuit **290** make two measurements for each pixel. The first measurement is made on data line **120** without a signal, e.g. with switch transistor **180** turned off, wherein correlated double sampling circuit **290** obtains the noise level of the data line. The second measurement is made after the potentials have equilibrated, as in FIG. **4**B or **4**D, and switch transistor **180** has been turned on, wherein correlated double sampling circuit **290** obtains a reading of a threshold-voltage-related signal on data line **120**.

Turning now to FIG. **6**, and referring also to FIGS. **3** through **5**, there is shown a block diagram of one embodiment of a method using the apparatus of this invention for determining an adjustment to a signal voltage for compensating for changes in the threshold voltage for a drive transistor in a pixel drive circuit in an active matrix OLED display, and for applying the adjustment. At the start, the gate voltages of an entire row of pixel drive circuits **200** are set to the initial voltage by setting all data lines **120** to the initial voltage and turning on switch transistor **180** by selecting the appropriate select line **130** (Step **410**). The initial gate voltage can conveniently be zero volts, or can be a different preselected voltage. Switch transistors **180** are then turned off (Step **420**). Then a second voltage opposite in polarity to the first driving voltage is applied to OLED light-emitting pixel **160** by connecting negative voltage supply **270** to power supply line **110** via switch **265** (Step **430**), thus placing the OLED in an inoperative condition. Then current is allowed to flow through the circuit (Step **440**) to charge the capacitors: OLED **160**, gate-OLED capacitor **220**, and gate-power capacitor **230**. Current flows until the potential difference across gate-power capacitor **230** equals the threshold voltage of drive transistor **210**, which causes the drive transistor to turn off. The resulting voltages are as shown in FIG. **4**B. Then data lines **120** are connected to the responsive circuits, e.g. correlated double sampling circuits **290** by switch **285** (Step **450**), and switch transistors **180** are turned on for the row of pixel drive circuits **200** by selecting the appropriate select line **130** (Step **460**). The threshold-voltage-related signal is then measured by correlated double sampling circuit **290** (Step **470**). The threshold voltage V_{th} is related to the threshold-voltage-related signal by Eq. 4 above. Using this equation, or a lookup table, processor **315** can calculate or find the threshold voltage and the adjustment to the signal voltage for each drive transistor **210** in the row of pixel drive circuits **200** and store one or both in memory **325** (Step **480**). If there are more rows of pixel drive circuits **200** in OLED display **250** (Step **485**), the process is repeated. If there are no more rows of pixel circuits, the determination of the threshold voltages is complete. Processor **315** can apply the adjustment to the signal voltage to digital-to-analog converter **280** to adjust the gate voltage on each drive transistor **210** to compensate for changes in the threshold voltage (Step **490**). Step **490** need not follow immediately after Step **485**. For example, Steps **410** to **485** can be done sequentially to all rows of pixel drive circuits **200** upon power-down of OLED display **250** and the adjustments stored in memory. Step **490** can then be done to all pixel drive circuits **200** the next time the display is powered on.

Those skilled in the art will understand that other embodiments are possible. For example, after Step **440**, the drive voltage can be set to another voltage, such as zero, by connecting ground **150** to power supply line **110** via switch **265**, after which current flows again to reach the state shown in FIG. **4**D. In this case, processor **315** can use Eq. 6 above to determine the threshold voltage and the adjustment to the signal voltage in Step **480**.

The invention has been described in detail with particular reference to certain preferred embodiments thereof, but it will be understood that variations and modifications can be effected within the spirit and scope of the invention.

PARTS LIST

100	pixel drive circuit
105	pixel drive circuit
110	power supply line
120	data line
130	select line
140	OLED light-emitting pixel
145	drain electrode
150	ground
155	source electrode
160	OLED light-emitting pixel
165	gate electrode
170	drive transistor

-continued

PARTS LIST	
180	switch transistor
185	source or drain electrode
190	capacitor
195	gate electrode
200	pixel drive circuit
210	drive transistor
215	gate electrode
220	capacitor
230	capacitor
250	OLED display
260	voltage supply
265	switch
270	voltage supply
280	digital-to-analog converter
285	switch
290	correlated double sampling circuit
310	integrator
315	processor
320	low pass filter
325	memory
330	correlated double sampling unit
340	sample-and-hold element
350	analog-to-digital converter
410	block
420	block
430	block
440	block
450	block
460	block
470	block
480	block
485	decision block
490	block

What is claimed is:

1. An apparatus for compensating for changes in the threshold voltage (Vth) of a drive transistor in a pixel drive circuit in an active matrix OLED display, comprising:

a) the active matrix OLED display having a data line, a power supply line, and the pixel drive circuit, the pixel drive circuit having an OLED light-emitting pixel, a capacitor, and two transistors, a drive transistor and a switch transistor, the drive transistor having source, drain, and gate electrodes, and the switch transistor having source, drain, and gate electrodes, wherein the capacitor is connected between the gate electrode of the drive transistor and the power supply line;

b) the source or drain electrode of the drive transistor being electrically connected to the power supply line, and the other of the source or drain electrode being electrically connected to the OLED light-emitting pixel;

c) the source or the drain electrode of the switch transistor being electrically connected to the gate electrode of the drive transistor, and the other of the source or drain electrode being electrically connected to the data line;

d) a first voltage supply for selectively applying a first voltage to the power supply line which is either positive

or negative for causing current to flow in a first direction through the drive transistor which causes the OLED light-emitting pixel to produce light in response to the signal voltage;

e) a second voltage supply for selectively applying a second voltage to the power supply line opposite in polarity to the first voltage so that current will flow through the drive transistor in a second direction opposite to the first direction, so that a first potential between the gate electrode and the power supply line shifts until the first potential causes the drive transistor to turn off, whereby the first potential is stored on the capacitor;

f) first means for producing a threshold-voltage-related signal on the data line which is a function of the first potential stored on the capacitor by activating the switch transistor, whereby the threshold-voltage-related signal is produced on the data line;

g) an analog-to-digital converter responsive to the threshold-voltage-related signal for producing first data corresponding to the threshold- voltage-related signal;

h) a memory for storing one or more value(s) of the first data;

i) second means for measuring a first value of the first data corresponding to an initial threshold voltage when the pixel drive circuit is new and storing the first value of the first data in the memory;

j) third means for measuring a second value of the first data corresponding to a current threshold voltage after the threshold voltage of the drive transistor has changed with usage; and

k) a processor responsive to the stored first value of the first data and to the second value of the first data for receiving a signal voltage and calculating an adjustment to the signal voltage using the first and second values of the first data and for applying the adjustment to the signal voltage through the switch transistor of the pixel drive circuit to the gate electrode of the drive transistor of the pixel drive circuit to compensate for changes in the threshold voltage of the drive transistor.

2. The apparatus of claim **1** wherein the OLED light-emitting pixel is a non-inverted OLED pixel and the first voltage is positive relative to a ground value.

3. The apparatus of claim **1** wherein the OLED light-emitting pixel is an inverted OLED pixel and the first voltage is negative relative to a ground value.

4. The apparatus of claim **1** wherein the drive transistor and switch transistor are n-type transistors.

5. The apparatus of claim **1** wherein the drive transistor and switch transistor are p-type transistors.

6. The apparatus of claim **1**, further including a correlated double sampling circuit responsive to the threshold-voltage-related signal.

* * * * *

专利名称(译)	有源矩阵显示补偿装置		
公开(公告)号	US7636074	公开(公告)日	2009-12-22
申请号	US11/427104	申请日	2006-06-28
[标]申请(专利权)人(译)	伊斯曼柯达公司		
申请(专利权)人(译)	伊士曼柯达公司		
当前申请(专利权)人(译)	全球OLED科技有限责任公司		
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发明人	HAMER, JOHN W. PARRETT, GARY		
IPC分类号	G09G3/30		
CPC分类号	G09G3/3233 G09G3/3291 G09G2300/0842 G09G2320/043 G09G2310/0254 G09G2310/0256 G09G2320/0295 G09G2300/0866		
代理机构(译)	OWENS , RAYMOND L.		
助理审查员(译)	LAM , NELSON		
其他公开文献	US20080001854A1		
外部链接	Espacenet USPTO		

摘要(译)

一种用于确定对信号电压的调整的装置，用于补偿具有至少一个OLED发光像素的有源矩阵OLED显示器中的像素驱动电路中的驱动晶体管的阈值电压（Vth）的变化，包括：像素驱动电路，具有数据线，电源线，驱动晶体管;驱动晶体管电连接到电源线和OLED发光像素;开关晶体管电连接到驱动晶体管的栅极和数据线;第一种用于向电源线施加第一电压的装置;第二装置，用于向与第一电压极性相反的电源线施加第二电压;第三种用于在数据线上产生阈值电压相关信号的装置;第四装置响应于阈值电压相关信号，用于计算对信号电压的调节。