US 20050067971A1

(19) United States
(12) Patent Application Publication (10) Pub. No.: US 2005/0067971 A1
Kane (43) Pub. Date: Mar. 31, 2005

(54) **PIXEL CIRCUIT FOR AN ACTIVE MATRIX ORGANIC LIGHT-EMITTING DIODE DISPLAY**

(76) Inventor: **Michael Gillis Kane**, Skillman, NJ (US)

Correspondence Address:
**DANN, DORFMAN, HERRELL & SKILLMAN, P.C.**
**SARNOFF CORPORATION**
**1601 MARKET STREET, SUITE 720**
**PHILADELPHIA, PA 19103 (US)**

(21) Appl. No.: **10/953,087**

(22) Filed: **Sep. 29, 2004**

**Related U.S. Application Data**

(60) Provisional application No. 60/507,060, filed on Sep. 29, 2003.

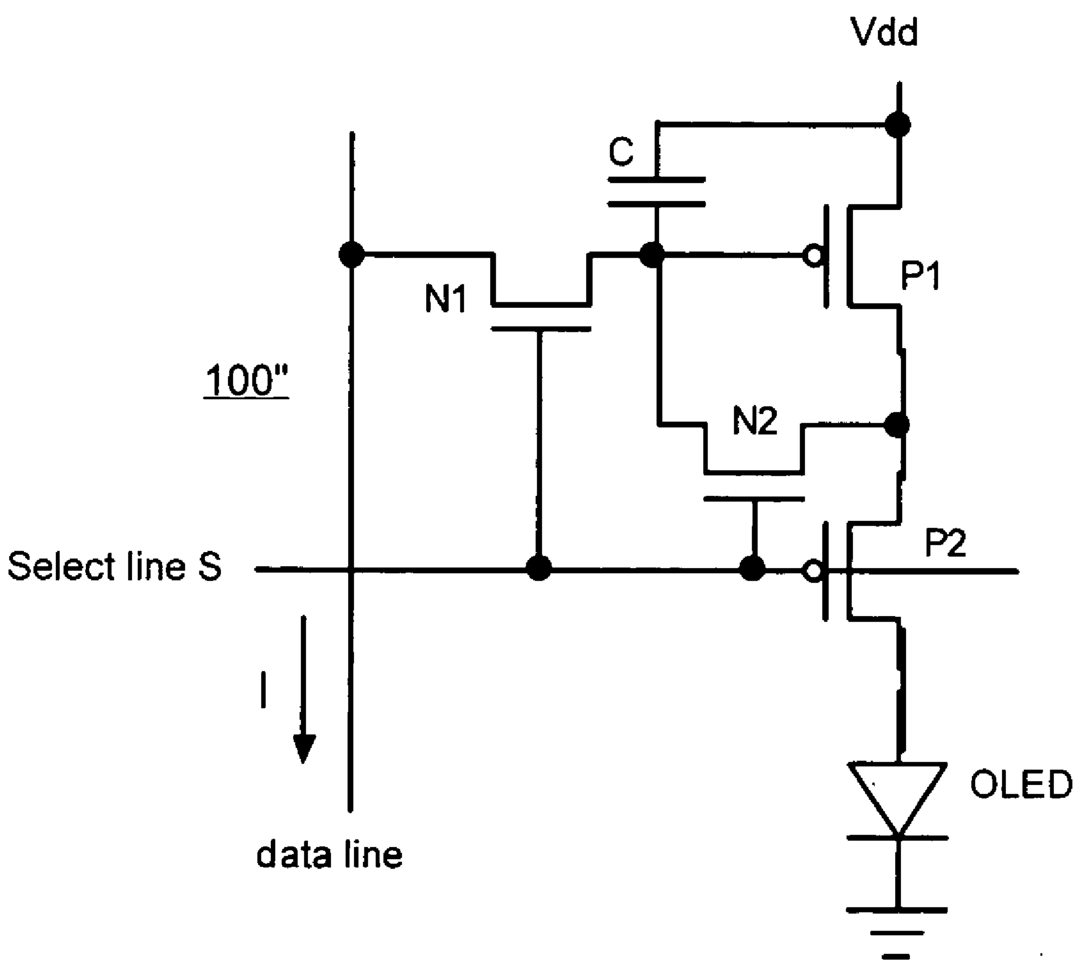
**Publication Classification**

(51) Int. Cl.[7] .................................................. **G09G 3/10**

(52) U.S. Cl. ................................ **315/169.3**; 315/169.1

(57) **ABSTRACT**

A pixel circuit for an OLED element comprises first, second, third and fourth transistors wherein controllable conduction paths of the first and second transistors are connected for receiving a data signal current, and the control electrodes thereof are connected for receiving a select signal for being enabled thereby. The third and/or fourth transistors are connected for establishing a current in the OLED element responsive to the data signal current and the select signal. Capacitance may be provided by at least one of the transistors or by additional capacitance.



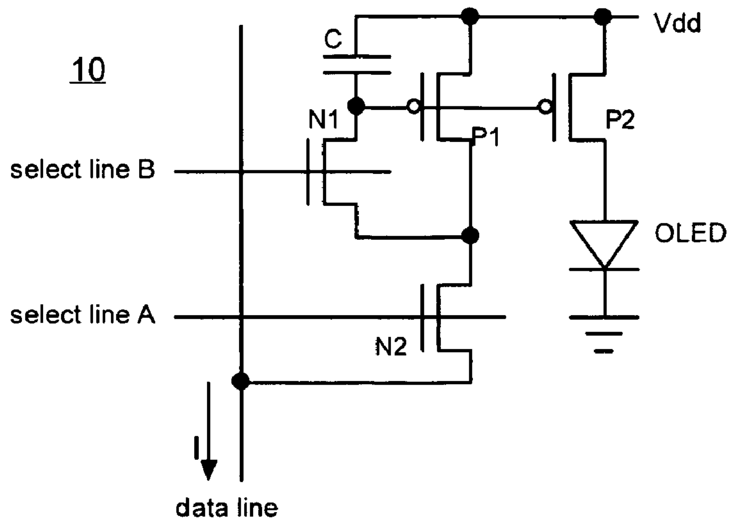



FIGURE 1 (PRIOR ART)

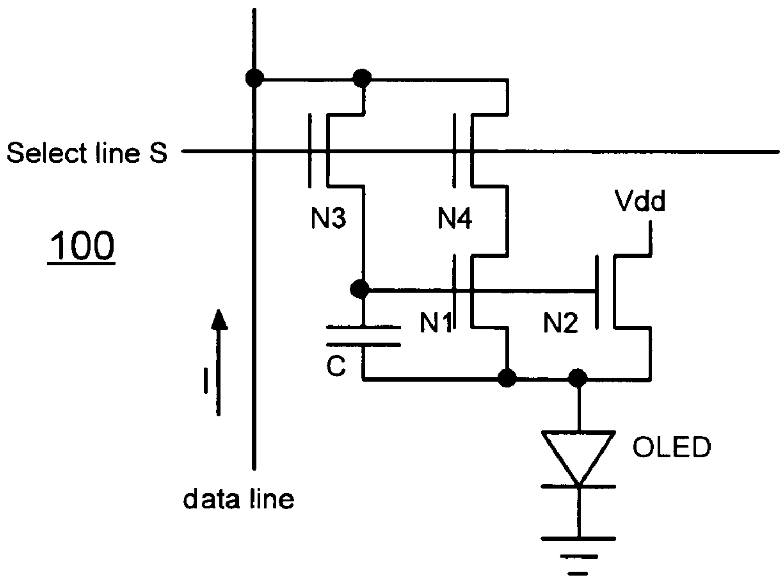



FIGURE 2

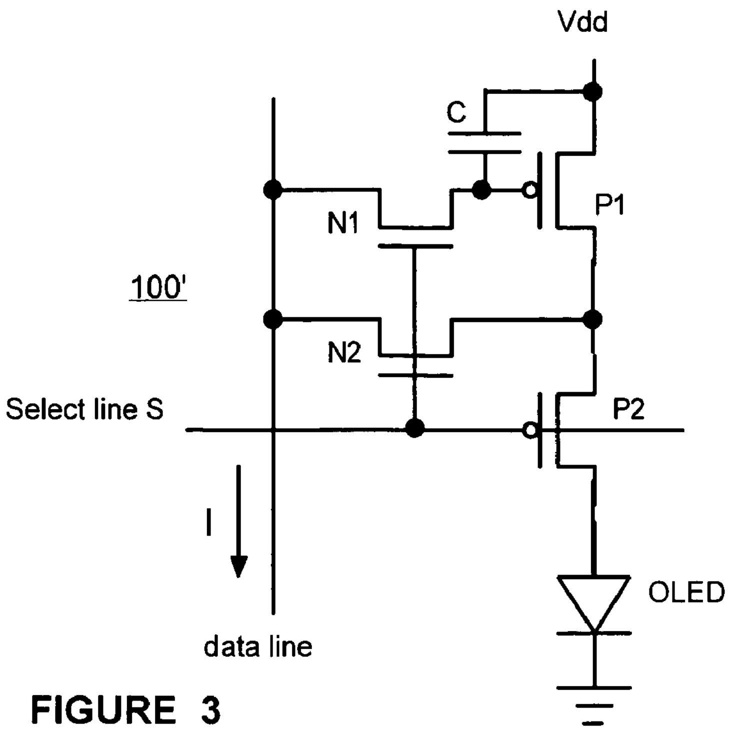



FIGURE 3

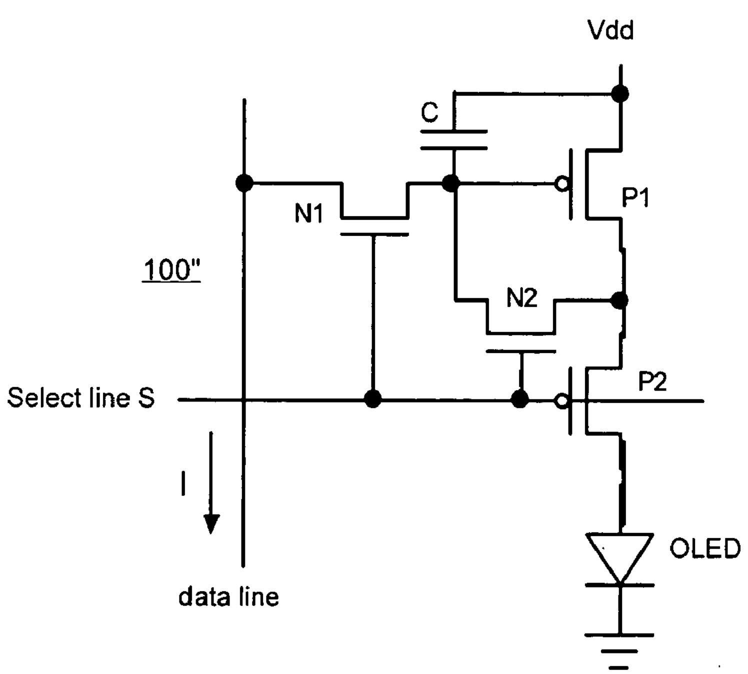



FIGURE 4

## PIXEL CIRCUIT FOR AN ACTIVE MATRIX ORGANIC LIGHT-EMITTING DIODE DISPLAY

**[0001]** This Application claims the benefit of U.S. Provisional Application Ser. No. 60/507,060 filed Sep. 29, 2003.

**[0002]** The present invention relates to a pixel circuit, and in particular to a pixel circuit suitable for an active matrix display.

**[0003]** Passive matrix organic light-emitting diode (OLED) displays suffer from a limitation in the number of lines (i.e. rows) in a display due to activation of one line at a time thereby to require a high current flow needed to provide moderate average current to each line. An active-matrix OLED (AMOLED) display substantially mitigates these problems because the OLED pixels can operate all the time. Analog data is written into the AMOLED pixel array one row at a time, but the OLEDs thereof are operated at essentially 100% duty cycle. This is accomplished by providing an analog memory circuit for each pixel using active devices, i.e. transistors.

**[0004]** Many existing AMOLED pixels and drive schemes apply to voltage-programmed displays. A voltage-programmed display is one in which the analog data that is applied to the display is applied as a voltage. The alternative is a current-programmed display, wherein the analog data is applied to the display as a current.

**[0005]** All active-matrix liquid-crystal displays (AMLCDs) are voltage-programmed, because the liquid-crystal is a voltage-sensitive element. It is like a capacitor whose electro-optic properties are sensitive to the voltage across it. But an OLED is different. The brightness of an OLED element depends primarily on the current through it, and only secondarily on the voltage that is applied in order to produce that current. In an AMOLED display there are transistors in each pixel circuit, and the programming of the pixel circuit to drive the desired current through the OLED is accomplished by applying a voltage to the transistors in the pixel circuit (for a voltage-programmed pixel), or by applying a current to the transistors in the pixel circuit (in a current-programmed pixel). Of course, the configuration of the transistors in the pixel will be different in the two cases.

**[0006]** In a voltage-programmed display, the data applied to the data lines, i.e. columns, is a voltage, not a current, and it is much faster to charge the large capacitance associated with the column to its steady-state voltage from a voltage source than from a current source. (Even with current programming, the column capacitance must be charged to its steady-state voltage before the pixel can be considered programmed, because until the capacitance is charged, some of the programming current is being diverted to charge the column capacitance rather than to program the pixel.) The main disadvantage of current-programmed AMOLED pixels is the difficulty of charging the column within a line time.

**[0007]** On the other hand, in a voltage-programmed display pixel the analog data is applied as a voltage, but it must be converted to a current that will be driven through the OLED element. This voltage-to-current conversion is performed by a transistor relying on its transconductance, a small-signal quantity $g_m = \Delta I / \Delta V$ that represents the ratio of current-output to voltage-input at a given bias level, so that

ductance depends on such factors as the mobility of the transistor and the gate capacitance, which can vary across the display thereby creating nonuniformity within a display, and from display to display, requiring each display module to be individually adjusted at the factory. In addition, voltage programmed pixels can also have sensitivity to transistor threshold voltage, which varies across the display and from display to display, which also produces similar display nonuniformity.

**[0008]** In a current-programmed pixel, however, non-uniformity in the transconductance of the transistor does not necessarily produce non-uniformity in the display. The analog data signal is applied as a current, and this value of current (or some fixed multiple of it) is applied to the OLED element and so transistor non-uniformities are not a problem. However, certain prior-art current-programmed pixels can have a secondary problem with transistor nonuniformities because of mismatch between the two transistors forming a current mirror in the pixel circuit.

**[0009]** **FIG. 1** is an electrical circuit schematic diagram of a prior art pixel circuit **10** which operates as follows. When the pixel is to be programmed, both select lines A and B are pulsed high. A programming current I is drawn from the data line by the column driver circuit. Since all other pixels in this column are unselected, the current I flows through transistors **P1** and **N2** (once the column and pixel have been charged to a stable voltage). Since transistor **N1** is on at this time, transistor **P1** self-biases to a gate-to-source voltage that sets its drain current to equal the programming current I. Then select lines A and B are turned off, and the voltage on the gate of transistor **P1** is stored there with the help of capacitor C. Since transistor **P2** is matched to transistor **P1**, and they share the same gate-to-source voltage, and assuming transistor **P2** is kept in saturation, the OLED drive current is now set to the same value as the programming current I, or a fixed multiple thereof, depending on the size ratios of transistors **P1** and **P2**. (This configuration of two transistors is known as a current mirror, because the current flowing through transistor **P1** is "mirrored" by that flowing through transistor **P2**.) This current through the OLED element continues to flow while transistors **N1** and **N2** are off. The overall brightness of the display can be scaled down by pulsing select line B prior to the time for programming the pixel again, one frame time later. This turns on transistor **N1** without turning on transistor **N2**, so that transistor **P1** self-biases to zero current, and the current through transistor **P2** and the OLED drops to zero as well for the rest of the frame time.

**[0010]** To reduce the disadvantage of longer charging time of a current-programmed OLED display driven from a fixed current source, the column charging time may be reduced by using a programming current I that is larger than the desired OLED current. The ratio of the channel width of transistor **P1** to that of transistor **P2** in the current mirror (e.g., the "width ratio" of **P1** to **P2**) may be used to scale the programming current down to the appropriate level. Thus, transistor **P1** might be five times wider than transistor **P2**, and the programming current I is set by the driver chip to be five times higher than the desired OLED current, so that five times the program current is available to charge the data line capacitance.

two p-channel devices, which can not be made using an amorphous-silicon (a-Si) thin-film transistor (TFT) technology. Amorphous silicon TFT processing is more readily available and is lower in cost than polysilicon TFT processing, but a-Si TFTs are only available as n-channel devices. The p-channel devices in this prior art pixel circuit **10** cannot simply be replaced with n-channel devices, with appropriate circuit changes, because this will place the OLED (whose anode is accessible to the transistors) in the source of the n-channel transistor, and the prior art circuit **10** will not work.

**[0012]** Accordingly, it would be desirable to have a pixel circuit that may utilize only n-channel transistors so as to be compatible with a-Si TFT processing, e.g., by permitting the OLED to be in the source of the current mirror transistors, as well as compatible with polysilicon processing. It would also be desirable to have an improved pixel circuit that may utilize n-channel transistors and p-channel transistors that can be fabricated with polysilicon processing.

**[0013]** To this end, a pixel circuit for an OLED element comprises first, second, third and fourth transistors wherein controllable conduction paths of the first and second transistors are connected for receiving a data signal current, and the control electrodes thereof are connected for receiving a select signal for being enabled thereby. The third and/or fourth transistors are connected for establishing a current in the OLED element responsive to the data signal current and the select signal. Capacitance may be provided by at least one of the transistors or by additional capacitance.

## BRIEF DESCRIPTION OF THE DRAWING

**[0014]** The detailed description of the preferred embodiment(s) will be more easily and better understood when read in conjunction with the FIGURES of the Drawing which include:

**[0015]** **FIG. 1** is an electrical circuit schematic diagram of a prior art pixel circuit;

**[0016]** **FIG. 2** is an electrical circuit schematic diagram of an example embodiment of a pixel circuit;

**[0017]** **FIG. 3** is an electrical circuit schematic diagram of an example embodiment of a pixel circuit; and

**[0018]** **FIG. 4** is an electrical circuit schematic diagram of an example embodiment of a pixel circuit.

**[0019]** In the Drawing, where an element or feature is shown in more than one drawing figure, the same alphanumeric designation may be used to designate such element or feature in each figure, and where a closely related or modified element is shown in a figure, the same alphanumerical designation primed. Similarly, similar elements or features may be designated by like alphanumeric designations in different figures of the Drawing. It is noted that, according to common practice, the various features of the drawing are not to scale, and the dimensions of the various features are arbitrarily expanded or reduced for clarity, and any value stated in any Figure is given by way of example only.

## DESCRIPTION OF THE PREFERRED EMBODIMENT(S)

polarity, e.g., only n-channel transistors, which could be provided using amorphous silicon thin-film transistor (a-Si TFT) technology, e.g., as used in conventional AMLCD displays. Alternatively, even though polysilicon processes can produce both n-channel and p-channel transistors, it might be desirable to simplify the polysilcon transistor process by fabricating transistors of only one polarity. Other pixels described herein use transistors of both polarities, i.e. both n-channel and p-channel transistors, which could be provided using conventional CMOS processes, such as a low-temperature polysilicon CMOS process.

**[0021]** A current mirror circuit provides a current through the OLED pixel element that is a predetermined multiple of the programming current, wherein the multiplier may be unity or may be greater or less than unity. Good matching is required of the two transistors in the current mirror, so that the OLED current is a well-defined function of the programming current. However, in polysilicon it is difficult to get two transistors to match, even if they are next to each other, because the random grain structure of the polysilicon material produces "random" device variations. As a result, the OLED element current may have a "random" component, and the display can be nonuniform.

**[0022]** The pixels described herein address this need for matching in two different ways: (a) by using a current mirror formed of n-channel transistors, which are compatible with amorphous silicon processing and therefore do not manifest the random nonuniformities of polysilicon transistors, or (b) by utilizing the same transistor to both receive the programming current and, after programming, to drive current through the OLED element, so that no matching problem arises.

**[0023]** Plural pixel circuits described are typically arranged in rows or lines of a scanned display. The time taken to scan each row (line) is referred to as the line time or select interval, and the time taken to scan all rows (lines) of a display is referred to as the frame time. Each pixel circuit is programed to provide a current that is a scaled value of a programming or data current applied thereto during a line time which is a portion of the frame time in a scanned display. Each pixel is typically "refreshed" or reprogrammed during the line time and the line time is 1/N of the frame time where there are N lines in the display.

**[0024]** **FIG. 2** is an electrical circuit schematic diagram of an example embodiment of a pixel circuit **100**. An AMOLED pixel employs a current-programmed current mirror **N1**, **N2** in which the OLED element is in the source of the mirror transistors **N1**, **N2**. The circuit **100** shown uses n-channel transistors, although one skilled in the art could translate the circuit into an implementation with p-channel transistors. However, because OLED technology typically makes the anode of the OLED elements accessible to the transistors, n-channel transistor technology is more natural. Circuit **100** is thus compatible with a-Si TFT processing.

**[0025]** Operation of circuit **100** is as follows. When the row is selected, the select line S is pulsed high, turning on transistors **N3** and **N4**, and a programming or data current I is driven down the row by the column driver circuit via the data line conductor. After the column line and pixel capacitances are charged, this data current I flows through tran-

DOCKET ALARM

# Explore Litigation Insights

Docket Alarm provides insights to develop a more informed litigation strategy and the peace of mind of knowing you're on top of things.

## Real-Time Litigation Alerts

Keep your litigation team up-to-date with **real-time alerts** and advanced team management tools built for the enterprise, all while greatly reducing PACER spend.

Our comprehensive service means we can handle Federal, State, and Administrative courts across the country.

## Advanced Docket Research

With over 230 million records, Docket Alarm's cloud-native docket research platform finds what other services can't. Coverage includes Federal, State, plus PTAB, TTAB, ITC and NLRB decisions, all in one place.

Identify arguments that have been successful in the past with full text, pinpoint searching. Link to case law cited within any court document via Fastcase.

## Analytics At Your Fingertips

Learn what happened the last time a particular judge, opposing counsel or company faced cases similar to yours.

Advanced out-of-the-box PTAB and TTAB analytics are always at your fingertips.

## API

Docket Alarm offers a powerful API (application programming interface) to developers that want to integrate case filings into their apps.

**LAW FIRMS**

Build custom dashboards for your attorneys and clients with live data direct from the court.

Automate many repetitive legal tasks like conflict checks, document management, and marketing.

**FINANCIAL INSTITUTIONS**

Litigation and bankruptcy checks for companies and debtors.

**E-DISCOVERY AND LEGAL VENDORS**

Sync your system to PACER to automate legal marketing.

**WHAT WILL YOU BUILD?** | **sales@docketalarm.com** | **1-866-77-FASTCASE**

fastcase® Smarter legal research.