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(54) **ACTIVE MATRIX ORGANIC LIGHT EMITTING DIODE DISPLAY**
ORGANISCHE LICHTEMITTIERENDE DIODENANZEIGE MIT AKTIVER MATRIX
ECRAN A DIODES ELECTROLUMINESCENTES ORGANIQUES A MATRICE ACTIVE

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Description

BACKGROUND OF THE INVENTION

Technical Field

[0001] The present invention relates generally to the field of flat panel displays, and more specifically, but not exclusively, to an improved Active Matrix Organic Light Emitting Diode (AM OLED) display and method of wide dynamic range dimming in such a display for commercial and military applications, such as, for example, cockpit displays, avionics displays, or hand-held military communication device displays.

Description of Related Art

[0002] AM OLED displays are an emerging flat panel display technology, which has already produced such new products as passive matrix-addressed displays that can be used for cell-phones and automobile audio systems. AM OLED displays are most likely to replace backlit AM Liquid Crystal Displays (LCDs) because AM OLED displays are more power efficient, rugged, weigh less, cost less, and have much better image quality than existing AM LCDs. As such, the market for AM OLED-based displays is estimated to reach about $1.7B per year by 2006.

[0003] Cockpit display applications are relatively demanding for existing display technologies, because of the stringent requirements imposed with respect to image quality and the need for superior operational performance within a broad range of environments, such as high temperature, humidity, and ambient lighting environments. For the better part of the past ten years, AM LCDs have replaced Cathode Ray Tube (CRT) displays in cockpit applications, because of the advantages of AM LCDs over CRT displays in terms of lower weight, flatter form factor, less power consumption, the use of large active areas with relatively small bezels, higher reliability, higher luminance, greater luminance uniformity, wider dimming range, and better sunlight readability. As such, AM LCDs have been the displays of choice for cockpit and avionics display applications for a number of years.

[0004] A significant problem that exists with AM LCDs for display applications (e.g., cockpit, avionics and hand-held device displays) is that the backlighting of the AM LCDs adds a significant amount of weight and volume to these types of displays. However, an advantage of this backlighting feature of AM LCDs is that it provides a highly controllable function for (independently) dimming the display in order to achieve optimum performance over a range of ambient lighting conditions. Some critical display applications (e.g., avionics and certain military device displays) require wide dynamic ranges of dimming (e.g., > 2000:1) for the display to be viewed comfortably in both daytime (bright) and night-time (dark) viewing conditions. Currently, this dimming function can be accomplished with AM LCDs by dimming the display backlight (through a large dynamic range), while maintaining the AM LCD's optimized driving conditions.

[0005] The weight and volume problems that exist with AM LCDs for avionics or hand-held device applications, for example, can be alleviated with AM OLED displays. Compared to AM LCDs, AM OLED displays offer such significant advantages as wider viewing angles, lower power consumption, lighter weight, superior response time, superior image quality, and lower cost. However, a drawback of the existing AM OLED displays is that they are not easily dimmable (i.e., their brightness adjusted) to the desired luminance levels, except by changing the driving conditions of the AM OLED displays, or by varying the anode (V_{DD}) and/or cathode (V_K) voltages.

[0006] Generally, the existing AM OLED displays' grayscale driving conditions are optimized for "normal" daytime (bright ambient) viewing conditions. However, changing either the grayscale driving conditions or the V_{DD}/V_K voltages of AM OLED displays to achieve lower display luminance levels for night (dark ambient) conditions using a conventional AM OLED display results in luminance and color non-uniformities across the surfaces of these displays.

[0007] As such, an important requirement imposed on AM OLED displays in such critical applications as cockpit displays, avionics displays, or military hand-held device displays is that such displays have to be capable of adjusting their luminance (brightness) over a wide dynamic range (e.g., >2000:1) without affecting the color balance and/or the uniformity of the luminance and chromaticity across the surface of the display as the display is being dimmed. The drive methods used for existing AM OLED displays achieve the desired luminance by adjusting the grayscale data voltage (or current) or V_{DD}/V_K voltage(s). However, these existing methods of adjusting the luminance of AM OLED displays create numerous problems for wide dynamic range display dimming applications, such as: (1) it is a relatively difficult problem to achieve the desired wide dynamic range dimming requirements with the existing driving methods using 8-bit data (column) drivers currently available for AM OLED displays; (2) when the grayscale data voltages (or currents) or the V_{DD}/V_K voltages, which are optimized for "normal" daylight operation, are changed (e.g., reduced) for night-time (low luminance) operation, typically the display color balance is changed due to the different transfer characteristics (luminance versus voltage) for the Red, Green and Blue (R, G, B) AM OLED display materials used; and (3) operation of the existing AM OLED displays at the low luminance levels associated with night-time viewing conditions results in significant non-uniformities in the luminance and chromaticity across the surface of the displays due to increased variations in the Thin-Film Transistor (TFT) and OLED performance in the low luminance (gray-level) regime.

[0008] As such, to illustrate these problems with existing AM OLED displays, **Figure 1** depicts an electrical schematic diagram of a typical AM OLED sub-pixel circuit **100** (labeled "Prior Art"), which is currently used in a conventional method for dimming an AM OLED display. Referring to **Figure 1,** conventional sub-pixel circuit **100** includes a first TFT **102,** a second TFT **104,** a storage capacitor **106,** and an OLED pixel **108.** As shown, transistor **102** is a scan transistor, and transistor **104** is a drive transistor. The gate terminal **110** of the scan transistor **102** is connected to the row (scan/row enable) address bus of the display involved, and the drain terminal **112** of scan transistor **102** is connected to the column (data) address bus of the display. The source of scan transistor **102** is connected to the node **107** at the storage capacitor **106** and the gate terminal of the drive transistor **104.** During the row addressing time period of the display operation, scan transistor **102** charges the node **107** at the storage capacitor **106** and the gate terminal of the drive transistor 104 to the data voltage (signal), V_{DATA}. After the row addressing time period, scan transistor **102** is switched off, and the OLED pixel **108** is electrically isolated from the data bus. During the remainder of the frame time, the power supply voltage, V_{DD}, which is connected to the drain terminal **114** of the drive transistor **104,** provides the current for driving the OLED pixel **108.**

[0009] The grayscale from this conventional method in the AM OLED display circuit **100** depicted in **Figure 1** is achieved by varying the data voltages (signals) on the data bus. In addition, the brightness (maximum luminance) of the display is adjusted (for display dimming) directly by changing the data voltages (signals) or V_{DD}/V_K voltages. However, as discussed earlier, it can be seen from Figure 1 that a significant problem with these conventional methods of adjusting the luminance of an AM OLED display is that because the dimming is performed by changing the data voltage (or current), or by changing the power supply (V_{DD} and/or V_k) voltages to adjust the grayscale, wide dynamic range dimming (e.g., > 2000: 1) cannot be achieved with suitable uniformity. Nevertheless, as described in detail below, the present invention provides an improved AM OLED display and method of adjusting luminance with superior dimming capability (e.g., wide dynamic range > 2000 : 1) that resolves the problems encountered with existing AM OLED displays and other prior art displays.

[0010] US-A-2003/0063078 discloses an organic electroluminescent (EL) display device that includes display pixels forming a display screen, scanning lines disposed along rows of the display pixels, signal lines disposed along columns of the display pixels, and a power supply section which supplies a power-supply voltage to the display pixels. Each of the display pixels includes a luminous element, a pixel switch and a driving element. Each luminous element is connected to the power supply section via a dimmer switch portion. In one embodiment, three transistors, a capacitor and an organic EL element are used.

[0011] US-A-2004/0041525 discloses an organic electro-luminescence device and method and apparatus for driving the same, using multiple transistors. A cell drive voltage source applies a drive voltage to the electro-luminescence cell, and a cathode terminal of the electro-luminescence cell is selectively connected to a common voltage source and a ground voltage source to have a reverse bias voltage applied. In one embodiment, four transistors, a capacitor and an OLED are used.

[0012] EP-A-1,197,943 discloses a driving circuit for an organic electroluminescent element, electronic equipment, and electro-optical device. Pixels are reverse-biased on the basis of a group of predetermined pixels at a time. In one embodiment, multiple transistors and capacitors are used.

SUMMARY OF THE INVENTION

[0013] The invention is set forth in claim 1.

[0014] The present invention in its various aspects is as set out in the appended claims, and it provides an improved AM OLED pixel circuit of wide dynamic range dimming for AM OLED displays that maintains color balance throughout the dimming range, and also maintains the uniformity of the luminance and chromaticity of the display at low gray-levels as the display is dimmed to lower luminance values. As such, the present invention enables AM OLED displays to meet the stringent color/dimming specifications required for existing and future avionics, cockpit, and hand-held military device display applications. Essentially, the present invention provides an improved AM OLED pixel circuit of dynamic range dimming that uses Pulse Width Modulation (PWM) of the OLED pixel current to achieve the desired display luminance (brightness).

[0015] Two example embodiments of the invention are provided for externally (e.g., outside an AM OLED glass display) PW modulating the common cathode voltage (V_k) or common power supply voltage (V_{DD}) so as to modulate the OLED current in order to achieve the desired display luminance. Three additional example embodiments of the invention are provided that incorporate additional transistor switches in the pixel circuit in order to modulate the OLED current during the frame time. Unlike the conventional methods, the three additional (internal) example embodiments allow modulation of each row of pixels sequentially during the frame time, which eliminates any propensity for display flicker. Thus, by PW modulating the OLED current, in combination with data voltage (or current) modulation, the present invention achieves wide dynamic range dimming while maintaining the color balance and the luminance and chromaticity uniformity required over the surface of the display involved.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] The novel features believed characteristic of the invention are set forth in the appended claims. The invention itself, however, as well as a preferred mode of use, further objectives and advantages thereof, will best be understood by reference to the following detailed description of an illustrative embodiment when read in conjunction with the accompanying drawings, wherein:

Figure 1 depicts an electrical schematic diagram of a prior art AM OLED sub-pixel circuit, which is currently used in a conventional method for dimming an AM OLED display;

Figure 2A depicts a pictorial representation of an example cockpit or avionics display environment, which may be used as an environment to implement one or more embodiments of the present invention;

Figure 2B depicts a pictorial representation of an example cockpit or avionics display, in which one or more embodiments of the present invention may be implemented;

Figure 3 depicts an electrical schematic diagram of a comparative example AM OLED sub-pixel circuit;

Figure 4 depicts an electrical schematic diagram of a comparative example AM OLED sub-pixel circuit;

Figure 5 depicts an electrical schematic diagram of a comparative example AM OLED sub-pixel circuit;

Figure 6 depicts an electrical schematic diagram of a comparative example AM OLED sub-pixel circuit;

Figure 7 depicts an electrical schematic diagram of an example AM OLED sub-pixel circuit, which can be used to implement an embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0017] With reference now to the figures, **Figure 2A** depicts a pictorial representation of an example cockpit or avionics display environment **200A,** which may be used as an environment to implement one or more embodiments of the present invention. **Figure 2B** depicts a pictorial representation of an example cockpit or avionics display **200B** (e.g., from within the example environment **200A)** including an example display **202B,** in which one or more embodiments of the present invention may be implemented. As such, although **Figures 2A** and **2B** depict an exemplary environment and avionics or cockpit display, the present invention is not intended to be so limited and can be implemented in any suitable display requiring, for example, wide dynamic range dimming (e.g., military or commercial hand-held device with flat panel display, etc.).

[0018] **Figure 3** depicts an electrical schematic diagram of a comparative example AM OLED sub-pixel circuit **300.** As such, AM OLED sub-pixel circuit **300** can be used in a preferred method for dynamically dimming an AM OLED display using, for example, an external (to the display) PWM scheme. Referring now to **Figure 3,** AM OLED sub-pixel circuit **300** includes a first TFT **302,** a second TFT **304,** a storage capacitor **306,** an OLED pixel **308,** and a transistor **310,** represented here by a Field Effect Transistor (FET). As shown, transistor **302** is a scan transistor, and transistor **304** is a drive transistor. The gate terminal **312** of the scan transistor **302** is connected to the row (scan/row enable) address bus of the display involved, and the drain terminal **314** of scan transistor **302** is connected to the column (data) address bus of the display. The source of scan transistor **302** is connected to the node **307** at the storage capacitor **306** and the gate terminal of the drive transistor **304.** The source of drive transistor **304** is connected to a terminal of OLED pixel **308.** The second terminal **318** of OLED pixel **308** is connected to one (e.g. drain) terminal of transistor **310.** The other (e.g. source) terminal of transistor **310** is connected to a common cathode terminal, V_K **320.**

[0019] For this example, an AM OLED display incorporating AM OLED pixel circuit **300** can include a plurality of (e.g., two or more) common cathode terminals, V_K **320.** One such common cathode terminal, V_K **320,** can be used to cover a top half of the display rows on the display involved, and another common cathode terminal, V_K **320,** can be used to cover a bottom half of the display rows on the display involved. For example, a display can include 480 rows and 640 columns. Each of the common cathode terminals, V_K **320,** in such an AM OLED display can be switched to the cathode voltage through the transistor **310** controlled by a PWM signal generator **322.** An example frequency for a PWM signal from generator **322** is 60 Hz.

[0020] During the row addressing time period of the display operation, scan transistor **302** charges the node **307** at the storage capacitor **306** and the gate terminal of the drive transistor **304** to the data voltage (signal), V_{DATA}. After the row addressing time period, scan transistor **302** is switched off, and the OLED pixel **308** is electrically isolated from the data bus.

[0021] For this example, the common cathode voltage, V_K **320,** is PW modulated by the signal applied from PWM signal generator **322,** which functions to apply a reverse bias across the row(s) of OLED pixels (e.g., OLED pixel **308)** associated with this common cathode terminal, V_K **320,** which in turn, switches "off" the OLED pixels (e.g., OLED pixel **308)** associated with this common cathode terminal, V_K **320,** in order to control the brightness or luminance during the frame time of the display involved. Thus, in accordance with this example, an AM OLED pixel circuit and method are provided for achieving wide dynamic range dimming while maintaining the color balance and the luminance and chromaticity uniformity required over the surface of the display involved. In this case, an external transistor **310** can be used to modulate the cathode power supply, V_K **320,** of the OLED pixel

308 in order to dynamically dim the display. Thus, by PW modulating the common cathode voltage, V_K **320,** the luminance or brightness of the display is averaged over a suitable period of time. Therefore, using the PWM method allows significantly more uniform dimming of OLED displays than currently provided for the existing OLED displays.

[0022] **Figure 4** depicts an electrical schematic diagram of a comparative example AM OLED sub-pixel circuit **400.** As such, AM OLED sub-pixel circuit **400** can be used in a preferred method for dynamically dimming an AM OLED display using, for example, an external (to the display) PWM scheme. Referring now to **Figure 4,** AM OLED sub-pixel circuit **400** includes a first TFT **402,** a storage capacitor **404,** a second TFT **408,** an OLED pixel **410,** and a transistor **406** represented here by a P-channel FET. In this case, an external (to the display involved) transistor 406 can be used to PW modulate the positive power supply, V_{DD} **418,** of the OLED pixel **410,** in order to turn "off" the voltage across the OLED pixels (e.g., OLED pixel **410)** associated with the common power supply voltage, V_{DD} **418,** and thus to control the brightness of the display. Also, in this case, the reference voltage, V_{SC} **416,** for storage capacitor **404,** can be removed from the V_{DD} line to prevent coupling the PW modulated V_{DD} to the gate voltage, V_{GS2}, at the node **426** between the gate terminal of transistor **408** and storage capacitor **404.**

[0023] As shown, for this example, transistor **402** is a scan transistor, and transistor **408** is a drive transistor. The gate terminal **412** of the scan transistor **402** is connected to the row (scan/row enable) address bus of the display involved, and the drain terminal **414** of scan transistor **402** is connected to the column (data) address bus of the display. The source of scan transistor **402** is connected to the node **426** at the storage capacitor **404** and the gate terminal of the drive transistor **408.** The source of drive transistor **408** is connected to a terminal of OLED pixel **410.** The drain of drive transistor **408** is connected to one (e.g. the drain) terminal **422** of the transistor **406,** and the other (e.g. the source) terminal of transistor **406** is connected to the common power supply voltage, V_{DD} **418.** The second terminal of OLED pixel **410** is connected to a common cathode terminal, V_K **424.**

[0024] For this example, an AM OLED display incorporating AM OLED sub-pixel circuit **400** can include a plurality of (e.g., two or more) common power supply voltage terminals, V_{DD} **418.** Each one of the common power supply voltages (e.g., V_{DD} **418** in **Figure 4)** provides the positive power supply voltage for the particular OLED sub-pixel involved (e.g., OLED **410)** within the overall display. The control (e.g. gate) terminal of transistor **406** in such a display is connected to a PWM signal generator **420.**

[0025] During the row addressing time period of the display operation, scan transistor **412** charges the node **426** at the storage capacitor **404** and the gate terminal of the drive transistor **408** to the data voltage (signal), V_{DATA}. After the row addressing time period, scan transistor **412** is switched off, and the OLED pixel **410** is electrically isolated from the data bus. Then, in order to adjust the luminance (e.g., brightness) of the display (e.g., OLED pixel **410),** the PW modulated signal from PWM signal generator **420** is applied to the gate of the switch transistor **406,** which PW modulates the common power supply voltage, V_{DD} **418,** to turn "off" the voltage across the plurality of OLED pixels (e.g., OLED pixel **410)** associated with the common power supply voltage, V_{DD} **418,** and thus control the brightness of the overall display. Again, using the PWM method, the dimming of the display can be achieved with optimum uniformity.

[0026] **Figure 5** depicts an electrical schematic diagram of a compaarative example AM OLED sub-pixel circuit **500.** As such, AM OLED sub-pixel circuit **500** can be used in a preferred method for dynamically dimming an AM OLED display using, for example, an internal (to the display) PWM scheme. Referring now to **Figure 5,** AM OLED sub-pixel circuit **500** includes a first TFT **502,** a storage capacitor **504,** a second TFT 506, a third TFT **508,** and an OLED pixel **510.** In this case, a third TFT **508** (internal to the display involved) can be used at each sub-pixel in the display to PW modulate the current, I_{OLED} **518,** of the OLED pixel **510,** in order to turn "off" the OLED pixel (e.g., OLED pixel **510)** so that it does not emit light, and thus control the brightness of the overall display.

[0027] As shown, for this example, transistor **502** is a scan transistor, and transistor **506** is a drive transistor. The gate terminal **512** of the scan transistor **502** is connected to the row (scan/row enable) address bus of the display involved, and the drain terminal **514** of scan transistor **502** is connected to the column (data) address bus of the display. The source of scan transistor **502** is connected to the node **507** at the storage capacitor **504** and the gate terminal of the drive transistor 506. The source of drive transistor **506** is connected to the drain of the third TFT **508,** and the source of third TFT **508** is connected to a terminal of OLED pixel **510.** The drain of drive transistor **506** is connected to the common power supply voltage, V_{DD} **516.** The second terminal of OLED pixel **510** is connected to a common cathode terminal, V_K **522.**

[0028] For this example, an AM OLED display incorporating AM OLED sub-pixel circuit **500** can include a plurality of (e.g., two or more) PWM voltage signal generators, V_{PWM} **520.** Thus, by pixel switching or PWM of the third TFT **508,** the third TFT **508** controls the OLED current I_{OLED} **518** and switches "off" the OLED pixel involved (e.g., OLED pixel **510** in **Figure** 5) so that the OLED pixel involved does not emit light.

[0029] Specifically, the gate terminal of the switching TFT **508,** in each of the pixels in a given row in the display, is connected to a row bus that is addressable from outside the display, as is the row-enable bus. The PW modulated signal, Vp_{WM}, from the PWM voltage signal generator **520,** is applied to each row in order to switch "off" the current flow to the OLED pixel **510** and turn the pixel "off". The "on" time of each of the rows is modulated to control the brightness of the display. A significant amount of modulation (e.g., dimming) can be achieved using such an internal modulation scheme.

[0030] For example, in a 1000 line (rows) display, the brightness of the display can be modulated (dimmed) by a factor of 1000:1 by the preset PWM method alone, and allowing the desired wide dynamic range dimming (e.g., > 2000:1) to be accomplished using gray-levels with higher luminance values. Thus, it significantly improves the uniformity of the luminance and chromaticity across the surface of the display as it is being dimmed, as compared to the conventional dimming methods used for AM OLED displays.

[0031] As such, the PWM voltage signal generator **520** can be commonly connected to all of the pixels in the display, or each row of pixels can be provided with an independent PWM signal generator (e.g., such as PWM voltage signal generator **520).** Incidentally, an advantage of providing each row of pixels with a separate PWM voltage (e.g., V_{PWM} **520),** is that the display flicker can be significantly minimized in comparison to other approaches.

[0032] During the row addressing time period of the display operation, scan transistor **502** charges the node **507** at the storage capacitor **504** and the gate terminal of the drive transistor **506** to the data voltage (signal), V_{DATA}. After the row addressing time period, scan transistor **502** is switched off, and the OLED pixel **510** is electrically isolated from the data bus. Then, in order to adjust the luminance (e.g., brightness) of the display (e.g., OLED pixel **510),** the PW modulated signal, V_{PWM}, from PWM voltage signal generator **520** is applied to the gate of the third TFT **508,** which PW modulates the OLED current, I_{OLED} **518,** to turn "off" the subject OLED pixels (e.g., OLED pixel **510),** and thus control the brightness of the overall display. Again, using the PWM method of the present invention, the dimming of the display can be achieved with optimum uniformity.

[0033] **Figure 6** depicts an electrical schematic diagram of a comparative example AM OLED sub-pixel circuit **600.** As such, AM OLED sub-pixel circuit **600** can be used in a preferred method for dynamically dimming an AM OLED display using, for example, an internal (to the display) PWM scheme. Referring now to **Figure 6,** AM OLED sub-pixel circuit **600** includes a first TFT **602,** a storage capacitor **604,** a second TFT **606,** a third TFT **608,** and an OLED pixel **610.** In this case, a third TFT **608** (internal to the display involved) can be used at each sub-pixel in the display to PW modulate the current through the OLED pixel involved in order to turn "off" that OLED pixel (e.g., OLED pixel **610)** so that it does not emit light, and thus control the brightness of the overall display.

[0034] As shown, for this example, transistor **602** is a scan transistor, and transistor **606** is a drive transistor. The gate terminal **612** of the scan transistor **602** is connected to the row (scan/row enable) address bus of the display involved, and the drain terminal **614** of scan transistor **602** is connected to the column (data) address bus of the display. The source of scan transistor **602** is connected to the node **620** at the storage capacitor **604,** the drain of third TFT **608,** and the gate terminal of the drive transistor **606.** The source of the drive transistor **606** is connected to the source of the third TFT **608** and one terminal of OLED pixel **610.** The drain terminal of drive transistor **606** is connected to the common power supply voltage, V_{DD} **618.** The second terminal of OLED pixel **610** is connected to a common cathode terminal, V_K **622.**

[0035] For this example, an AM OLED display incorporating AM OLED sub-pixel circuit **600** can include a plurality of (e.g., two or more) PWM voltage signal generators, Vp_{WM} **624.** Thus, by PWM of the gate voltage, V_{GS2} **620,** at the gate of the drive transistor **606,** the third TFT **608** can control the current through the OLED pixel involved (e.g., OLED pixel **610)** by turning "off" the drive transistor **606** and, therefore, turning "off" the OLED pixel involved (e.g., OLED pixel **610** in **Figure 6)** so that the OLED pixel involved does not emit light. As such, the PWM voltage signal generator **624** can be common to all of the pixels in the display, or each row of pixels can be provided with an independent PWM signal generator (e.g., such as PWM voltage signal generator **624).** Once again, an advantage of providing each row of pixels with a separate PWM voltage (e.g., Vp_{WM} **624),** is that the present method can significantly reduce the display's propensity for flicker in comparison with other existing approaches.

[0036] During the row addressing time period of the display operation, scan transistor **602** charges the node **620** at the storage capacitor **604** and the gate terminal of the drive transistor **606** to the data voltage (signal), V_{DATA}. After the row addressing time period, scan transistor **602** is switched off, and the OLED pixel **610** is electrically isolated from the data bus. Then, in order to adjust the luminance (e.g., brightness) of the display (e.g., OLED pixel **610),** the PW modulated signal, V_{PWM}, from PWM voltage signal generator **624** is applied to the gate of the third TFT **608,** which PW modulates the gate voltage, V_{GS2} **620,** and turns "off" the drive transistor **606.** In response, PW modulation of the drive transistor **606** controls the current through the OLED pixel involved, and turns "off" the subject OLED pixel (e.g., OLED pixel **610)** to control the brightness of the overall display. Again, using the PWM method, the dimming of the display can be achieved with optimum uniformity.

[0037] **Figure 7** depicts an electrical schematic diagram of an example AM OLED sub-pixel circuit **700,** which can be used to implement an embodiment of the present invention. As such, AM OLED sub-pixel circuit **700** can be used in a preferred method for dynamically dimming an AM OLED display using, for example, an internal (to the display) PWM scheme. Referring now to **Figure 7,** AM OLED sub-pixel circuit **700** includes a first TFT **702,** a storage capacitor **706,** a second TFT **710,** a third TFT **704,** a fourth TFT **712,** and an OLED pixel **714.** In this case, two additional transistors (e.g., third TFT **704** and fourth TFT **712),** which are both internal to the display involved, can be used at each sub-pixel in the display to enable PWM of the current through the OLED pixel involved (e.g., I_{OLED} **718)**, in order to turn "off" that OLED pixel (e.g., OLED pixel **714)** so that it does not emit light, by changing the gate voltage, V_{GS2} **716**, from a pre-selected value to "off". At a selected time after the storage capacitor **706** is charged to the pre-selected value, the PWM voltage, V_{PWM} **730**, goes high, which shuts "off" third TFT **704** and (e.g., disconnecting V_C **706** from V_{GS2} **716)** and turns "on" fourth TFT **712**, which in turn, shuts "off" drive transistor **710.** This PWM method of the present invention thus controls the current through the OLED pixel 714 involved (e.g., I_{OLED} **718)**, which controls the brightness of the overall display.

[0038] As mentioned earlier, a significant advantage of providing each row of pixels with a separate PWM voltage (e.g., Vp_{WM} **730)**, is that the present method can significantly reduce the display's propensity for flicker in comparison with other existing approaches. Also, using the PWM method of the present invention, the dimming of the AM OLED display can be achieved with optimum uniformity.

[0039] It is important to note that while the present invention has been described in the context of a fully functioning AM OLED display, those of ordinary skill in the art will appreciate that the processes of the present invention are capable of being distributed in the form of a computer readable medium of instructions and a variety of forms and that the present invention applies equally regardless of the particular type of signal bearing media actually used to carry out the distribution. Examples of computer readable media include recordable-type media, such as a floppy disk, a hard disk drive, a RAM, CD-ROMs, DVD-ROMs, and transmission-type media, such as digital and analog communications links, wired or wireless communications links using transmission forms, such as, for example, radio frequency and light wave transmissions. The computer readable media may take the form of coded formats that are decoded for actual use in a particular AM OLED display.

[0040] The description of the present invention has been presented for purposes of illustration and description, and is not intended to be exhaustive or limited to the invention in the form disclosed. Many modifications and variations will be apparent to those of ordinary skill in the art. These embodiments were chosen and described in order to best explain the principles of the invention, the practical application, and to enable others of ordinary skill in the art to understand the invention for various embodiments with various modifications as are suited to the particular use contemplated.

Claims

1. An Organic Light Emitting Diode display, comprising: at least one row address bus (720), at least one column address bus, a common power supply voltage (724), a common cathode terminal (728), a Pulse Width Modulation voltage signal generator (730), and at least a sub-pixel circuit (700), the sub-pixel circuit (730) including a first thin film transistor (702), a second thin film transistor (710), a third thin film transistor (704), a fourth thin film transistor (712), a storage capacitor (706), and an Organic Light Emitting Diode pixel (714), wherein

   said first thin film transistor (702) is coupled by its gate to the row address bus (720), coupled by one of its source and drain to the column address bus (722), and by the other of the source and drain to one terminal (707) of said storage capacitor (706) and to one of the source and drain of said third thin film transistor (704);

   said storage capacitor (706) is connected by its other terminal to the common power supply voltage (724) and to one of the source and drain of the second thin film transistor (710);

   said Organic Light Emitting Diode (714) is coupled by its cathode to the common cathode terminal (728), and by its anode (719) to the other of the source and drain of the second thin film transistor (710), and to one of the source and drain of the fourth thin film transistor (712);

   said second thin film transistor (710) is coupled by its gate to the other of the source and drain of the third thin film transistor (704), and to the other of the source and drain of the fourth thin film transistor (712); and

   said third thin film transistor (704) and said fourth thin film transistor (712) are both coupled by their gates to the means for generating a Pulse Width Modulation signal (730)

   and wherein said third thin film transistor and said fourth thin film transistor are arranged to shut off the third thin film transistor and turn on the fourth thin film transistor in response to the pulse width modulation signal being high.

Patentansprüche

1. Organische lichtemittierende Diodenanzeige, umfassend: mindestens einen Zeilenadressbus (720), mindestens einen Spaltenadressbus, eine gemeinsame Stromversorgungsspannung (724), einen gemeinsamen Kathodenanschluss (728), einen Impulsbreitenmodulationsspannungssignalgenerator (730) und mindestens eine Subpixelschaltung (700), wobei die Subpixelschaltung (730) einen ersten Dünnschichttransistor (702), einen zweiten Dünnschichttransistor (710), einen dritten Dünnschichttransistor (704), einen vierten Dünnschichttransistor (712), einen Speicherkondensator (706) und ein organisches lichtemittierendes Diodenpixel (714) beinhaltet, wobei

   der erste Dünnschichttransistor (702) durch sein

Gate an den Zeilenadressbus (720) gekoppelt ist, durch einen seiner Source und seines Drains an den Spaltenadressbus (722) gekoppelt ist und durch den anderen der Source und des Drains an einen Anschluss (707) des Speicherkondensators (706) und an einen der Source und des Drains des dritten Dünnschichttransistors (704) gekoppelt ist;
der Speicherkondensator (706) mit seinem anderen Anschluss an die gemeinsame Stromversorgungsspannung (724) und an einen der Source und des Drains des zweiten Dünnschichttransistors (710) angeschlossen ist;
wobei die organische lichtemittierende Diode (714) mit ihrer Kathode an den gemeinsamen Kathodenanschluss (728) und mit ihrer Anode (719) an den anderen der Source und des Drains des zweiten Dünnschichttransistors (710) und an einen der Source und des Drains des vierten Dünnschichttransistor (712) gekoppelt ist;
der zweite Dünnschichttransistor (710) mit seinem Gate an den anderen der Source und des Drains des dritten Dünnschichttransistors (704) und an den anderen der Source und des Drains des vierten Dünnschichttransistors (712) gekoppelt ist; und
der dritte Dünnschichttransistor (704) und der vierte Dünnschichttransistor (712) beide mit ihren Gates an das Mittel zum Generieren eines Impulsbreitenmodulationssignals (730) gekoppelt sind
und wobei der dritte Dünnschichttransistor und der vierte Dünnschichttransistor ausgelegt sind zum Abschalten des dritten Dünnschichttransistors und Einschalten des vierten Dünnschichttransistors als Reaktion darauf, dass das Impulsbreitenmodulationssignal hoch ist.

Revendications

1. Écran à diode électroluminescente organique, comprenant : au moins un bus d'adresses de ligne (720), au moins un bus d'adresses de colonne, une tension d'alimentation électrique commune (724), une borne de cathode commune (728), un générateur de signal de tension de modulation de largeur d'impulsion (730) et au moins un circuit de sous-pixel (700), le circuit de sous-pixel (730) comprenant un premier transistor à couches minces (702), un deuxième transistor à couches minces (710), un troisième transistor à couches minces (704), un quatrième transistor à couches minces (712), un condensateur de stockage (706) et un pixel à diode électroluminescente organique (714), dans lequel
ledit premier transistor à couches minces (702) est couplé par sa grille au bus d'adresses de ligne (720), couplé par l'un des deux éléments suivants, sa source et son drain, au bus d'adresses de colonne (722), et par l'autre des deux éléments suivants, sa source et son drain, à une borne (707) dudit condensateur de stockage (706) et à l'un des deux éléments suivants, la source et le drain, dudit troisième transistor à couches minces (704) ;
ledit condensateur de stockage (706) est relié par son autre borne à la tension d'alimentation électrique commune (724) et à l'un des deux éléments suivants, la source et le drain, du deuxième transistor à couches minces (710) ;
ladite diode électroluminescente organique (714) est couplée par sa cathode à la borne de cathode commune (728) et par son anode (719) à l'autre des deux éléments suivants, la source et le drain, du deuxième transistor à couches minces (710), et à l'un des deux éléments suivants, la source et la drain, du quatrième transistor à couches minces (712) ;
ledit deuxième transistor à couches minces (710) est couplé par sa grille à l'autre des deux éléments suivants, la source et le drain, du troisième transistor à couches minces (704) et à l'autre des deux éléments suivants, la source et le drain, du quatrième transistor à couches minces (712) ; et
ledit troisième transistor à couches minces (704) et ledit quatrième transistor à couches minces (712) sont tous deux couplés par leurs grilles au moyen de génération d'un signal de tension de modulation de largeur d'impulsion (730)
et dans lequel ledit troisième transistor à couches minces et ledit quatrième transistor à couches minces sont agencés pour bloquer le troisième transistor à couches minces et rendre passant le quatrième transistor à couches minces en réponse au fait que le signal de modulation de largeur d'impulsion est au niveau haut.

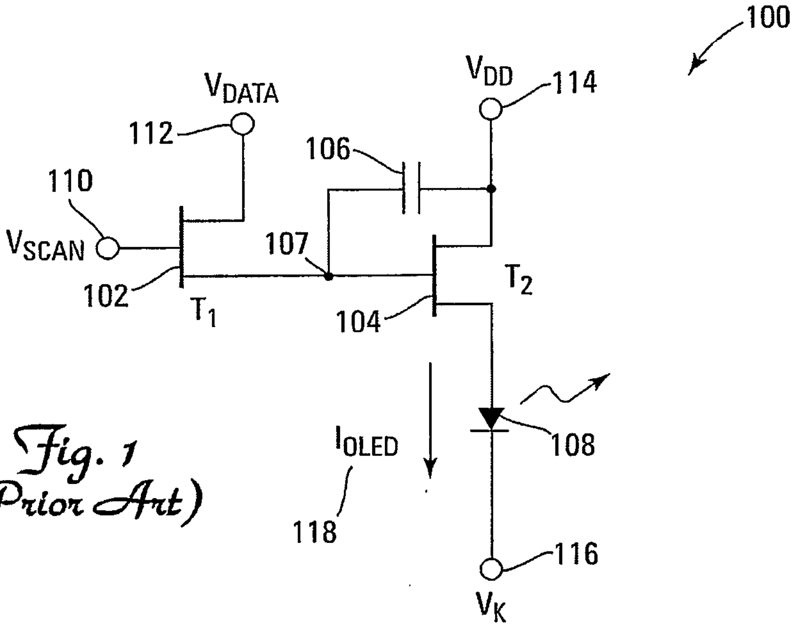


Fig. 1 (Prior Art)

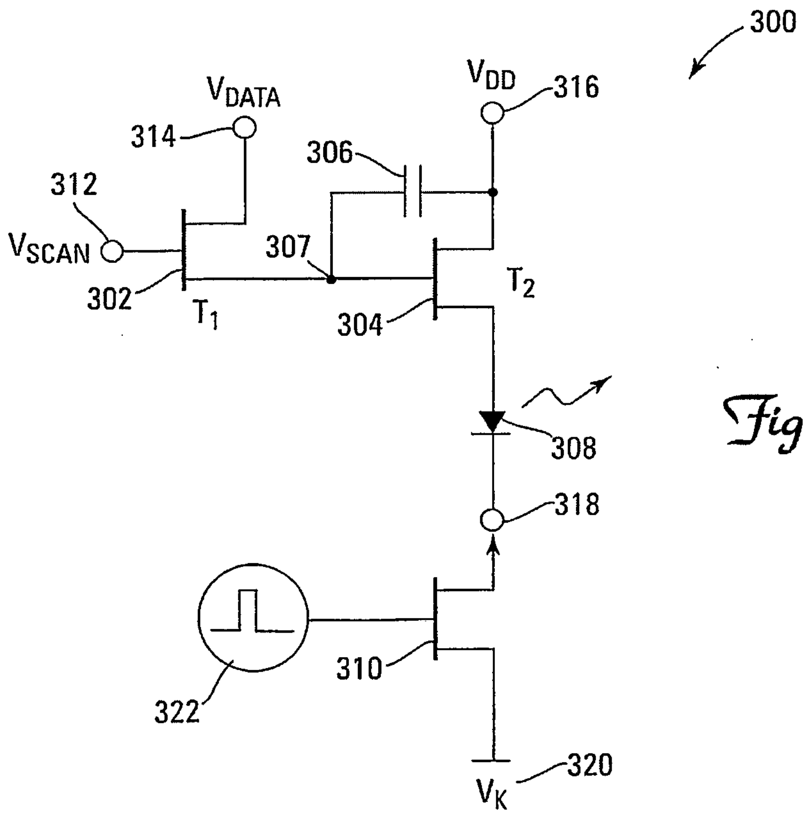


Fig. 3

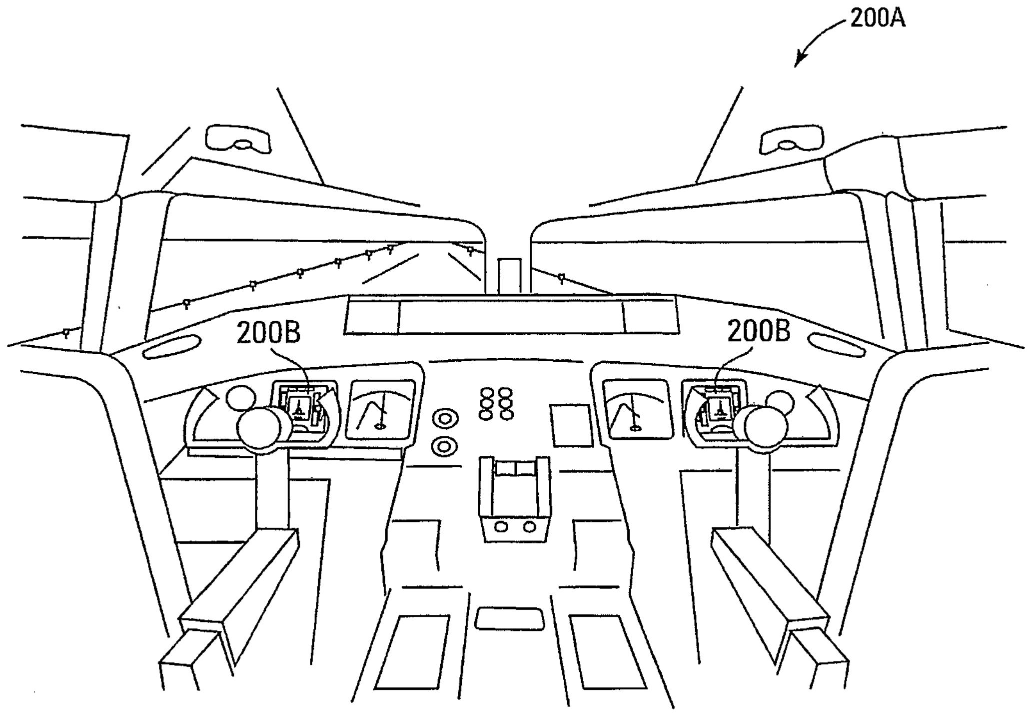


Fig. 2A

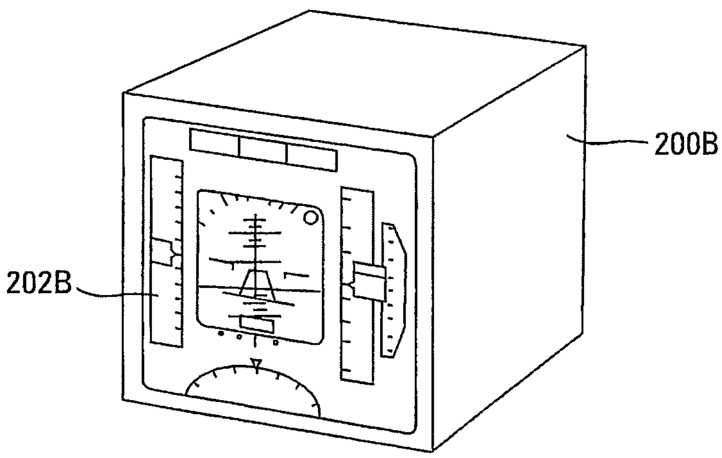
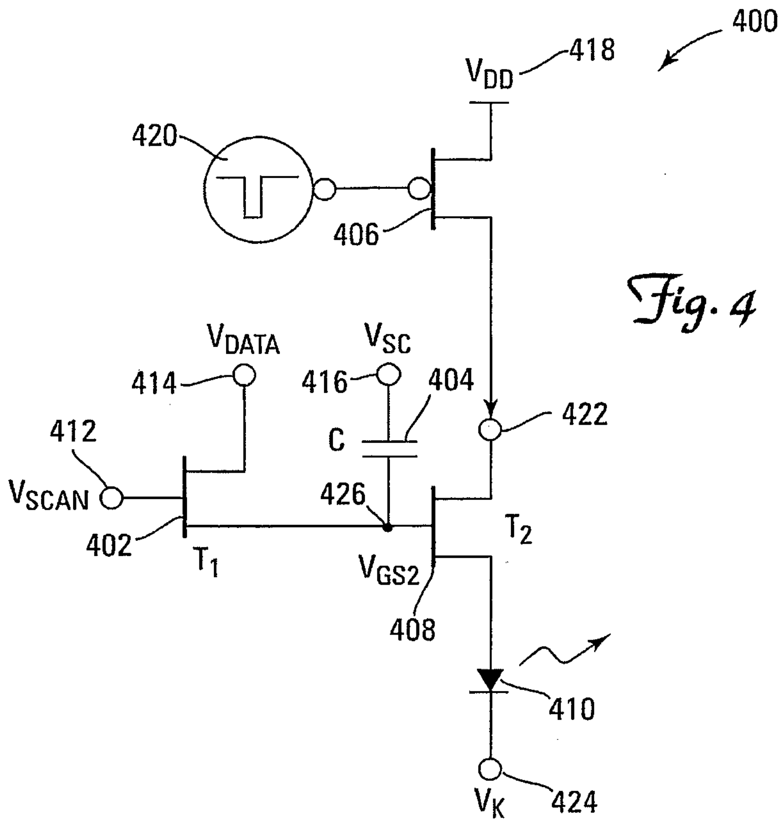


Fig. 2B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420
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C
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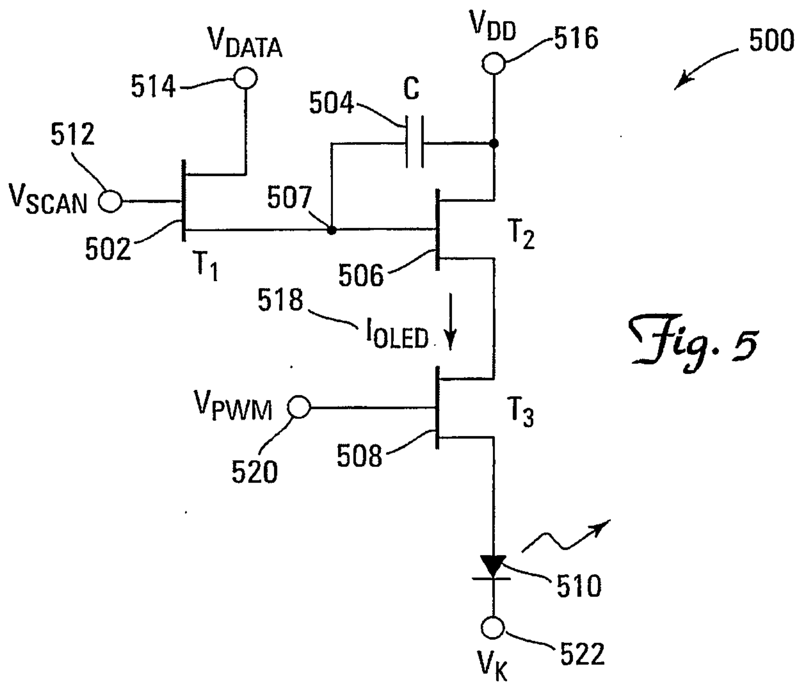
402
T_1
T_2
V_{GS2}
408
410
V_K
424

Fig. 4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C
512
V_{SCAN}
507
T_2
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T_1
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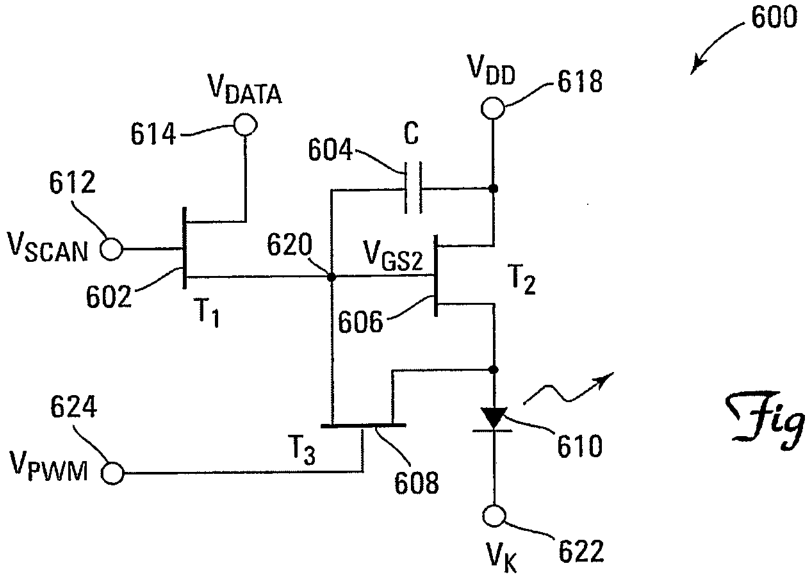
V_{PWM}
T_3
520
508
510
V_K
522

Fig. 5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T1
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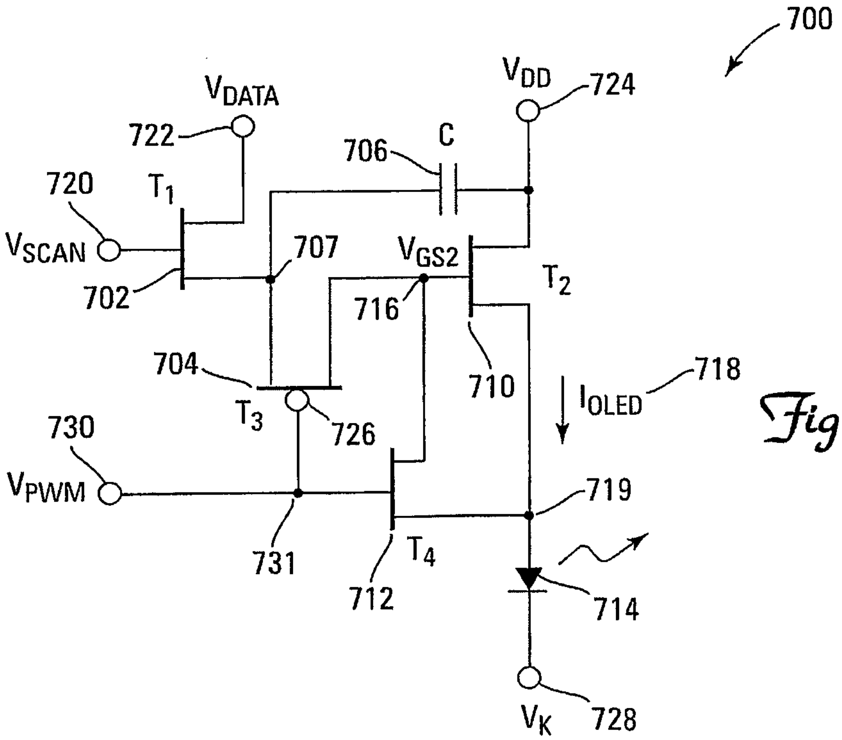
T3
610
VPWM
608
VK
622

Fig. 6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718
T3
726
730
VPWM
719
731
T4
712
714
VK
728

Fig. 7

REFERENCES CITED IN THE DESCRIPTION

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专利名称(译)	有源矩阵有机发光二极管显示器		
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当前申请(专利权)人(译)	HONEYWELL INTERNATIONAL INC.		
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发明人	SARMA, KALLURI, R. SCHMIDT, JOHN ROUSH, JERRY, A.		
IPC分类号	G09G3/32		
CPC分类号	G09G3/3233 G09G3/30 G09G2300/0842 G09G2300/0861 G09G2310/06 G09G2320/0233 G09G2320/0606 G09G2320/0626		
代理机构(译)	霍顿MARK PHILLIP		
优先权	11/043657 2005-01-26 US		
其他公开文献	EP1846910A1		
外部链接	Espacenet		

摘要(译)

公开了一种用于AM OLED显示器的改进的AM OLED像素电路和宽动态范围调光方法，其在整个调光范围内保持色彩平衡，并且还在低灰度级保持显示器的亮度和色度的均匀性，因为显示器是调暗以降低亮度值。因此，AM OLED显示器可以满足现有和未来的航空电子设备，驾驶舱和手持式军事设备显示器应用所需的严格的颜色/调光规范。基本上，所公开的OLED像素电路和调光方法使用OLED像素电流的脉冲宽度调制（PWM）来实现期望的显示亮度。公开了两个示例电路，其在外部PWM调制公共阴极电压或公共电源电压以调制OLED电流，以便实现期望的显示亮度。公开了三个示例电路，其在像素电路中并入额外的晶体管开关以在帧时间期间调制OLED电流。通过OLED电流的PWM，结合数据电压（或电流）调制，可以实现宽动态范围调光，同时保持所涉及的显示器表面上所需的色彩平衡和亮度和色度均匀性。

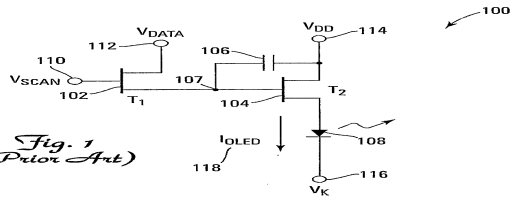

Fig. 1 (Prior Art)

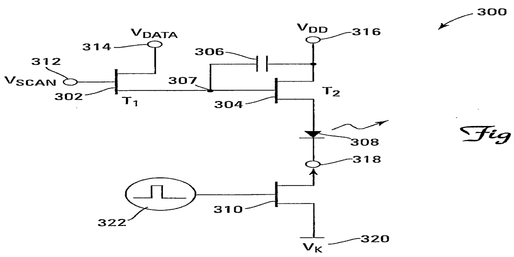

Fig. 3