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(54) PULSE AMPLITUDE MODULATION DRIVER WITH FEWER TRANSISTORS FOR DRIVING ORGANIC LIGHT-EMITTING DIODE DISPLAY

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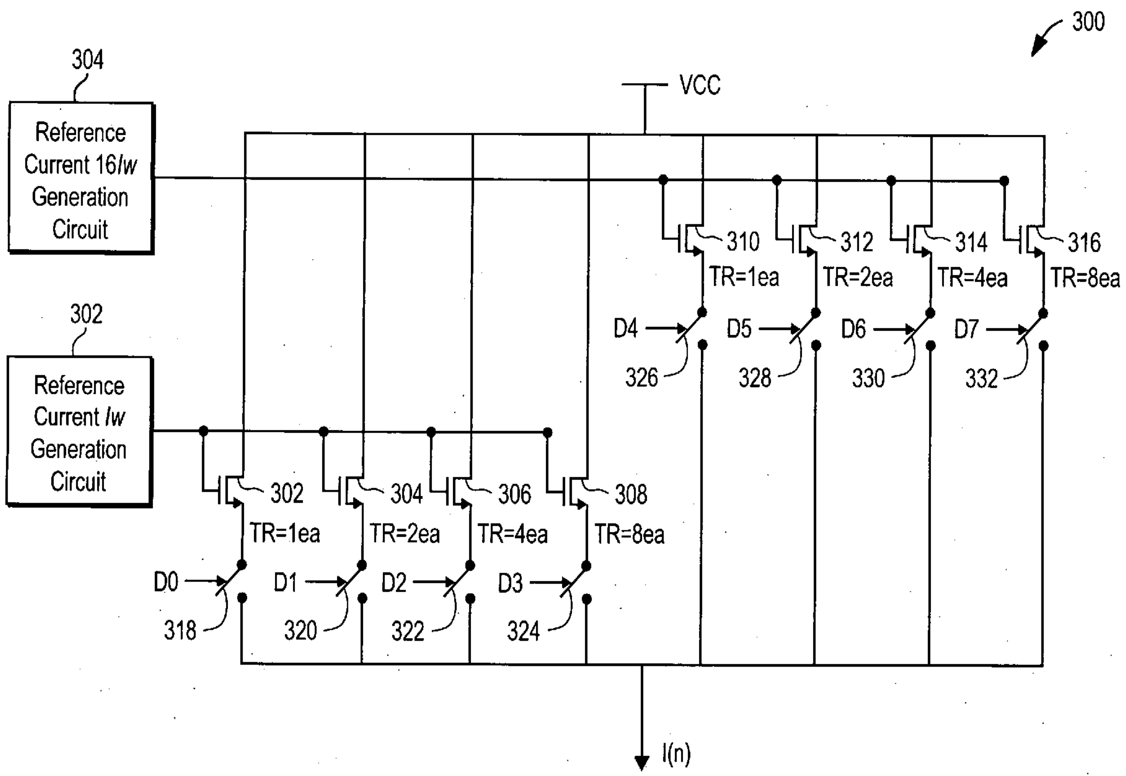
(57) ABSTRACT

An OLED driver circuit includes a plurality of current sources, where each current source comprises a first reference current generation circuit generating a first reference current, a second reference current generation circuit generating a second reference current, a first set of transistors coupled to the first reference current generation circuit and generating a first drive current based upon the first reference current in response to a first part of display data, and a second set of transistors coupled to the second reference current generation circuit and generating a second drive current based upon the second reference current in response to a second part of the display data. The first drive current and the second drive current are combined to generate the column drive current for driving OLED coupled to the column associated with said each current source. The second reference current is greater than the first reference current.



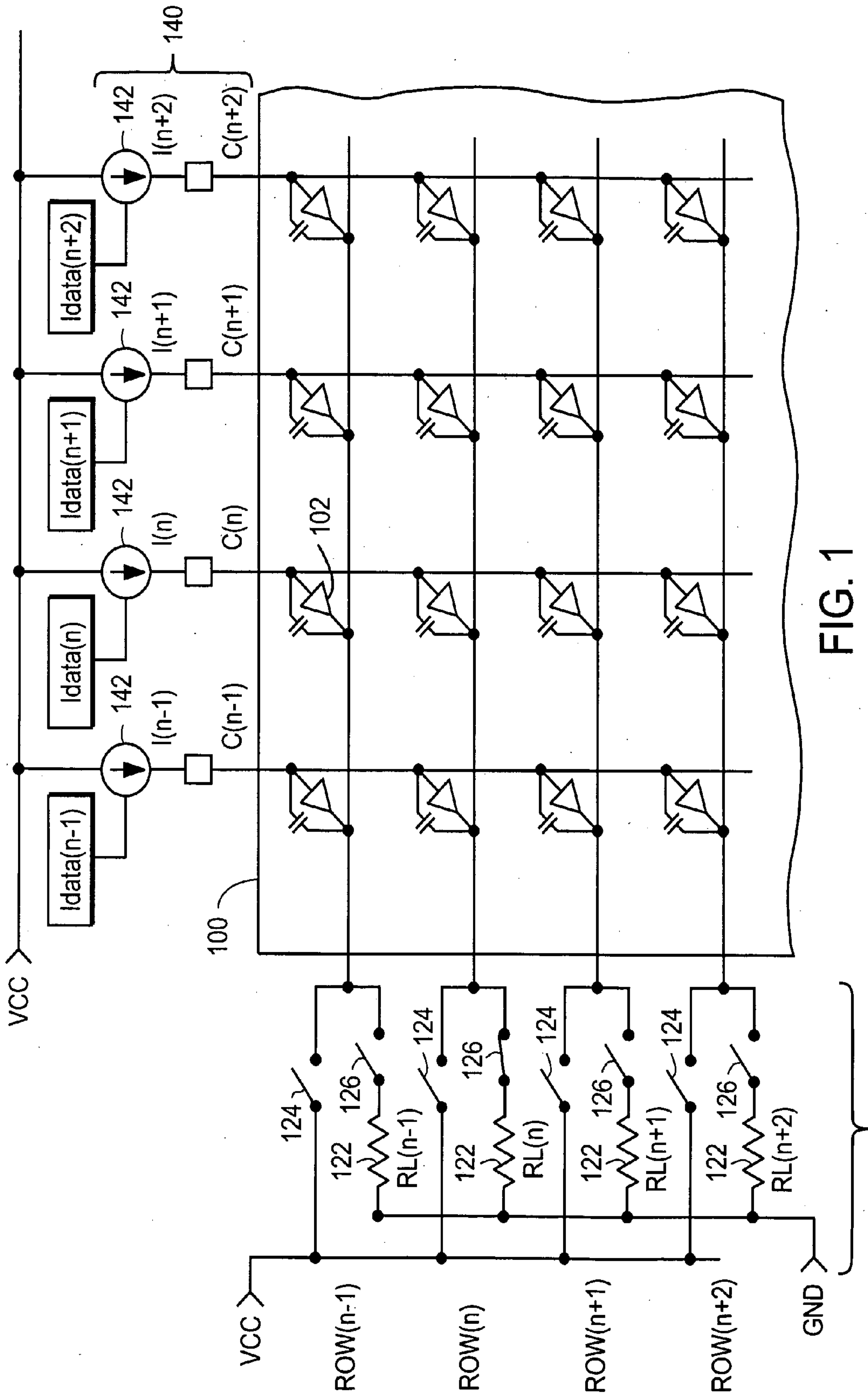


FIG. 1
(PRIOR ART)

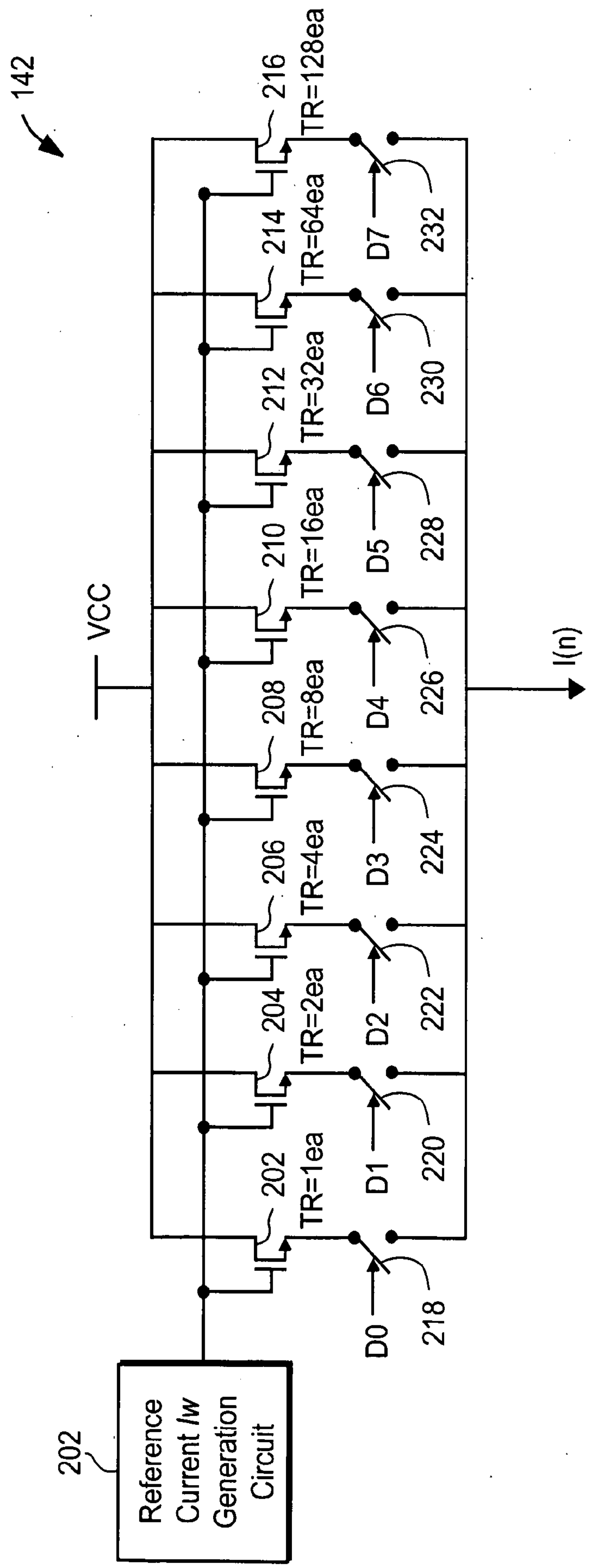


FIG. 2
(PRIOR ART)

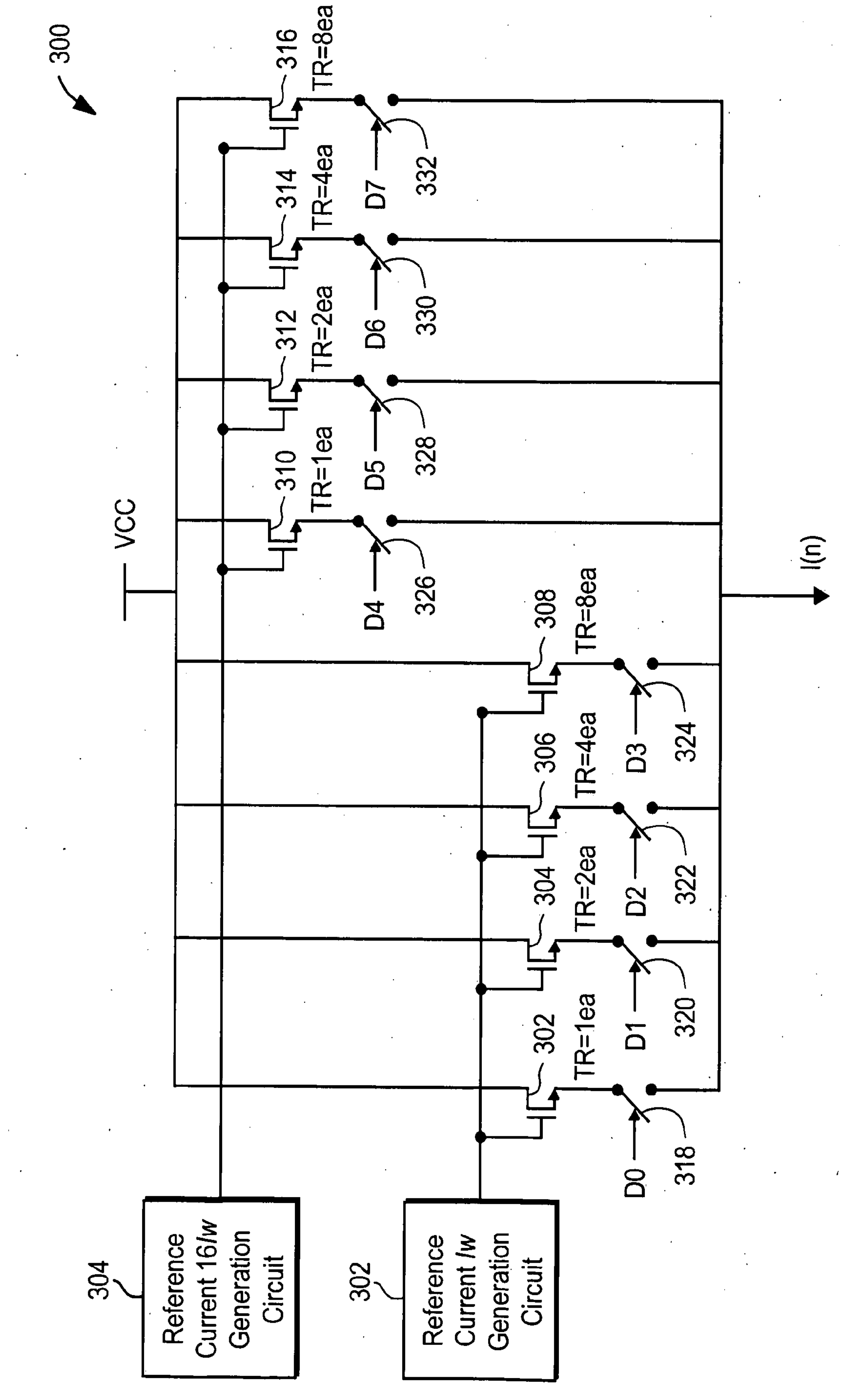

300
VCC
316
TR=8ea
314
TR=4ea
312
TR=2ea
310
TR=1ea
D7
332
D6
330
D5
328
D4
326
308
TR=8ea
306
TR=4ea
304
TR=2ea
302
TR=1ea
D3
324
D2
322
D1
320
D0
318
I(n)
304
Reference Current 16Iw Generation Circuit
302
Reference Current Iw Generation Circuit

FIG. 3

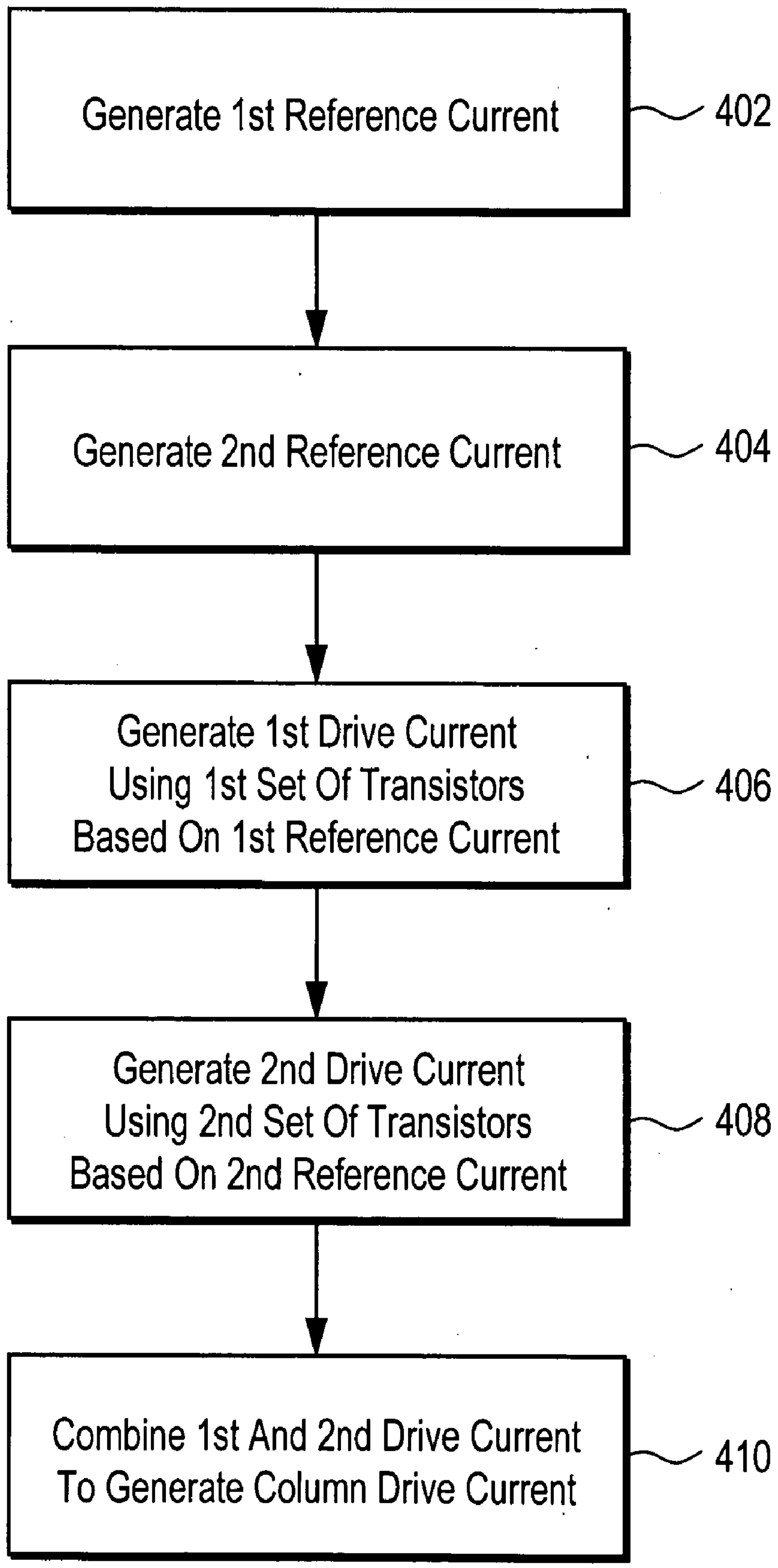

Generate 1st Reference Current
402
Generate 2nd Reference Current
404
Generate 1st Drive Current Using 1st Set Of Transistors Based On 1st Reference Current
406
Generate 2nd Drive Current Using 2nd Set Of Transistors Based On 2nd Reference Current
408
Combine 1st And 2nd Drive Current To Generate Column Drive Current
410

FIG. 4

PULSE AMPLITUDE MODULATION DRIVER WITH FEWER TRANSISTORS FOR DRIVING ORGANIC LIGHT-EMITTING DIODE DISPLAY

BACKGROUND OF THE INVENTION

[0001] 1. Field of the Invention

[0002] The present invention relates to an organic light-emitting diode (OLED) display panel driver and, more specifically, to a pulse amplitude modulation (PAM) driver with fewer transistors for generating the drive current for driving the OLED display panel.

[0003] 2. Description of the Related Art

[0004] An OLED display panel is generally comprised of an array of organic light emitting diodes (OLEDs) that have carbon-based films or other organic material films between two charged electrodes, generally a metallic cathode and a transparent anode typically being glass. In general, the organic material films are comprised of a hole-injection layer, a hole-transport layer, an emissive layer and an electron-transport layer. When voltage is applied to the OLED cell, the injected positive and negative charges recombine in the emissive layer and create electro-luminescent light. Unlike liquid crystal displays (LCDs) that require backlighting, OLED displays are self-emissive devices—they emit light themselves rather than modulate transmitted or reflected light. Accordingly, OLEDs are brighter, thinner, faster and lighter than LCDs, and use less power, offer higher contrast and are cheaper to manufacture.

[0005] An OLED display panel is typically driven by an OLED driver including a row driver and a column driver. A row driver typically selects a row of OLEDs in the display panel, and the column driver provides driving current to one or more of the OLEDs in the selected row to light the selected OLEDs according to the display data.

[0006] FIG. **1** illustrates a conventional OLED display panel driven by a conventional OLED driver. The OLED display panel **100** comprises an array of OLEDs **102** coupled between the rows and columns of the display panel **100**. The anodes of the OLEDs **102** are coupled to the columns (. . . C(n−1), C(n), C(n+1), C(n+2) . . .) and the cathodes of the OLEDs **102** are coupled to the rows (. . . ROW(n−1), ROW(n), ROW(n+1), ROW(n+2) . . .) of the display panel **100**. The OLED display panel **100** is driven by an OLED driver including a row driver **120** and a column driver **140**.

[0007] The row driver **120** includes row driver control circuitry (not shown) configured to couple the cathodes of the OLEDs **102** associated with a row (. . . ROW(n−1), ROW(n), ROW(n+1), ROW(n+2) . . .) of the display panel **100** to either a low voltage (e.g., GND) via resistors (. . . RL(n−1), RL(n), RL(n+1), RL(n+2) . . .) by closing the switches **126** and opening the switches **124** to select the row or to a high voltage (e.g., VCC) by closing the switches **124** and opening the switches **126** to unselect the row. For example, in FIG. **1**, ROW(n) is shown selected with the switch **126** associated with ROW(n) being closed to couple ROW(n) to GND. The selection of ROW(n) by the row driver **120** couples ROW(n) to GND and thus forward-biases the OLEDs **102** coupled to ROW(n).

[0008] The column driver **140** includes current sources **142** that provide current (. . . I(n−1), I(n), I(n+1), and I(n+2) . . .) to the corresponding columns (C(n−1), C (n), C(n+1), C(n+2) . . .) of the panel **100** to drive the OLEDs **102** on the columns. Once a row is selected by the row driver **120**, the current sources **142** of the column driver **140** generate current (. . . I(n−1), I(n), I(n+1), and I(n+2) . . .) for the corresponding columns (C(n−1), C (n), C(n+1), C(n+2) . . .) according to the corresponding display data (. . . Idata(n−1), Idata(n), Idata(n+1), Idata(n+2) . . .) to drives the OLEDs **102** on the selected row.

[0009] In a PAM type OLED driver, the current (. . . I(n−1), I(n), I(n+1), and I(n+2) . . .) is generated to be multiples of a unit driving current (e.g., Iw) and proportional to the display data (. . . Idata(n−1), Idata(n), Idata(n+1), Idata(n+2) . . .), and the brightness of the OLEDs **102** is also proportional to the associated driving current (. . . I(n−1), I(n), I(n+1), and I(n+2) . . .) for the corresponding column. For example, the display data may be 1-bit data indicating 2 levels of brightness, for example, bright ("1") or dark ("0"), of the OLEDs **102**. Thus, the current (. . . I(n−1), I(n), I(n+1), I(n+2) . . .) from the current sources **142** is generated to be, for example, 0 or Iw. For another example, the display data may be 2-bit data indicating 4 levels of brightness, for example, very dark ("0"), dark ("1"), bright ("2), and very bright ("3"), of the OLEDs **102**. Thus, the current (. . . I(n−1), I(n), I(n+1), I(n+2) . . .) from the current sources **142** is generated to be, for example, 0, Iw, 2×Iw, or 3×Iw. The OLEDs **102** in the selected row (e.g., ROW(n)) are lit very brightly (3×Iw), brightly (2×Iw), dark (Iw), or are unlit (zero current) based upon the drive current (. . . I(n−1), I(n), I(n+1), and I(n+2) . . .) corresponding to the columns (C(n−1), C(n), C(n+1), C(n+2) . . .) of the panel **100**.

[0010] FIG. **2** illustrates an example of a conventional current source **142** in a conventional PAM type OLED driver. The example of FIG. **2** shows a current source **142** that generates drive current I(n) for driving the associated column C(n) in response to display data Idata(n) that is comprised of 8 bits (D**0**, D**1**, D**2**, . . . , D**6**, D**7**) in this example. A reference current generation circuit **202** generates a reference current Iw. Although each of the transistors **202**, **204**, **206**, **208**, **210**, **212**, **214**, **216** is shown as a single transistor in FIG. **2** merely for simplicity of illustration, in fact each transistor **202**, **204**, **206**, **208**, **210**, **212**, **214**, **216** is a group of transistors including 2^N transistors (N=0, 1, 2, 3, 4, 5, 6, 7, respectively) of the same size as indicated by the notation TR=1ea, TR=2ea, TR=4ea, TR=8ea, TR=16ea, TR=32ea, TR=64ea, and TR=128ea, respectively. For example, transistor group **208** in fact includes 8 ($=2^3$) transistors of the same size as shown by the notation TR=8ea and transistor group **216** in fact includes 128 ($=2^7$) transistors of the same size as shown by the notation TR=128ea.

[0011] Each of the 2^N transistors in the transistor groups **202**, **204**, **206**, **208**, **210**, **212**, **214**, **216** forms current mirrors with the reference current generation circuit **202**. The switches **218**, **220**, **222**, **224**, **226**, **228**, **230**, **232** are opened or closed in response to bit DN (N=0, 1, 2, . . . , 7) of the display data Idata(n). For example, the switches **220**, **222**, **224**, **226**, **228**, **230**, **232** may be configured to be closed (ON) when the bit DN=1 (N=0, 1, 2, . . . , 7) to cause each of the transistors in the transistor groups **202**, **204**, **206**, **208**, **210**, **212**, **214**, **216** to generate current adding to the drive current I(n) and open (OFF) when the bit DN=0 (N=0, 1, 2, . . . , 7) to disconnect the transistors **202**, **204**, **206**, **208**, **210**, **212**, **214**, **216** from the current I(n). Since each of the transistor groups **202**, **204**, **206**, **208**, **210**, **212**, **214**, **216** includes 2^N transistors (N=0, 1, 2, 3, 4, 5, 6, 7, respectively) of the same size, each of the transistor groups **202**, **204**, **206**, **208**, **210**, **212**, **214**, **216** can generate current of 2^N multiple (N=0, 1, 2, 3, 4, 5, 6, 7) of the reference current Iw if the bit DN of the display data Idata(n) causes the corresponding switch **218**,**2 20**, **222**, **224**, **226**, **228**, **230**, **232** to close (ON). For example, in the example of FIG. **4**, transistor group **202** can generate current of 1×Iw ($=2^0$×Iw) if switch **218** is closed in response to D0=1, transistor group **204** can generate current of 2×Iw (=2^1×Iw) if switch **220** is closed in response to D**1**=1, transistor group **206** can generate current of 4×Iw (=2^2×Iw) if switch **222** is closed in response to D**2**=1, transistor group **208** can generate current of 8×Iw (=2^3×Iw) if switch **224** is closed in response to D**3**=1, transistor group **210** can generate current of 16×Iw (=2^4×Iw) if switch **226** is closed in response to D**4**=1, transistor group **212** can generate current of 32×Iw (=2^5×Iw) if switch **228** is closed in response to D**5**=1, transistor group **214** can generate current of 64×Iw (=2^6×Iw) if switch **230** is closed in response to D**6**=1, and transistor group **216** can generate current of 128×Iw (=2^8×Iw) if switch **232** is closed in response to D**7**=1. The column drive current I(n) is the sum of all the current generated by each of the transistors in all of the transistor groups **202**, **204**, **206**, **208**, **210**, **212**, **214**, **216**. Therefore, by controlling the bits DN (N=0, 1, 2, . . . , 7) of the display data Idata(n) for column C(n), it is possible to generate a column drive current I(n) of 256 different levels (0, 1, 2, 3 . . . , 255) to achieve 256 different levels of brightness in the OLED coupled to the column C(n) for a given selected row.

[0012] In order to accommodate for display data Idata(n) of 8 bits corresponding to 256 (=2^8) (0, 1, 2, . . . , 255) brightness levels, it can be seen that the current source **142** requires 255 transistors (255=1+2+4+8+16+32+64+128=2^8−1). If, for example, there are **100** columns in the OLED panel **100**, the column driver **140** likewise includes 100 current sources **142** each having 255 transistors, resulting in 25500 (100×255) transistors just for generating the drive current for the OLED panel **100**. In general, for an OLED panel **100** with A number of rows and B number of columns and capable of indicating 2^C number of brightness levels responsive to C bit display data, the conventional current sources **142** would require at least B×(2^C−1) transistors just for generating the drive current for the OLED panel **100**. If gamma compensation is used with the OLED panel **100**, even more transistors would be necessary to generate the drive current.

[0013] A large number of transistors directly results in increased chip size of the OLED driver that includes the column driver **140** and the row driver **120**. A large chip size also means that it will be more costly to manufacture the OLED drivers. The larger chip size becomes even a more serious drawback especially with modern displays that require a very high number of brightness levels. As the number of required brightness levels increases, the display data requires more bits, which in turn exponentially increases the number of transistors required to generate the drive current for the OLED panels.

[0014] Therefore, there is a need for an OLED column driver that can generate the drive current for the OLED panel with fewer transistors.

SUMMARY OF THE INVENTION

[0015] Embodiments of the present invention include a driver circuit for driving an organic light-emitting diode (OLED) display panel including a plurality of organic light-emitting diodes (OLEDs) arranged in rows and columns, where the driver includes a plurality of current sources for driving the OLEDs coupled to the columns and each current source has a significantly reduced number of transistors for generating the drive current. Each current source comprises a first reference current generation circuit generating a first reference current, a second reference current generation circuit generating a second reference current different from the first reference current, a first set of transistors coupled to the first reference current generation circuit and generating a first drive current based upon the first reference current in response to a first part of the display data indicative of a brightness level of the OLED coupled to the column associated with said each current source, and a second set of transistors coupled to the second reference current generation circuit and generating a second drive current based upon the second reference current in response to a second part of the display data. The first drive current and the second drive current are combined to generate the column drive current for driving the OLED coupled to the column associated with said each current source. The second reference current can be greater than the first reference current.

[0016] In one embodiment, the first set of transistors comprises P groups of transistors and the second set of transistors comprises Q groups of transistors, where P and Q are integers not less than 1. P may be different from Q. Each of the P groups of transistors comprises 2^R transistors of substantially the same size where R is an integer not less than 0 but not more than P−1, and each of the Q groups of transistors comprises 2^S transistors of substantially the same size where S is an integer not less than 0 but not more than Q−1. Each of the 2^R transistors is coupled to the first reference current generation circuit and capable of generating the same first reference current in response to the display data and each of the 2^S transistors is coupled to the second reference current generation circuit and capable of generating the same second reference current in response to the display data. Thus, each of the P groups of transistors is capable of generating a 2^R multiple of the first reference current and each of the Q groups of transistors is generating a 2^S multiple of the second reference current. The second reference current may be 2^P times greater than the first reference current, and the display data can be comprised of P+Q bits, where each of the P groups of transistors and the Q groups of transistors is associated with a corresponding one of the P+Q bits of the display data.

[0017] Thus, the OLED drive circuit according to the present invention has the advantage that significantly fewer transistors are required in the current source to generate the column drive current, by use of two or more reference current generation circuits generating different values of reference currents together with two or more sets of transistors generating current based on the different values of the reference currents. Fewer transistors in the current sources of the OLED drive circuit results in a significant decrease in the chip size required for the column driver and in turn a significant increase of the production yield in fabricating the integrated circuit (IC) for the OLED controller.

[0018] The features and advantages described in the specification are not all inclusive and, in particular, many additional features and advantages will be apparent to one of ordinary skill in the art in view of the drawings, specification, and claims. Moreover, it should be noted that the language used in the specification has been principally selected for readability and instructional purposes, and may not have been selected to delineate or circumscribe the inventive subject matter.

BRIEF DESCRIPTION OF THE DRAWINGS

[0019] The teachings of the embodiments of the present invention can be readily understood by considering the following detailed description in conjunction with the accompanying drawings.

[0020] FIG. **1** illustrates a conventional OLED display panel driven by a conventional OLED driver.

[0021] FIG. **2** illustrates an example of a conventional current source in a conventional PAM type OLED driver.

[0022] FIG. 3 illustrates an example of a current source in a PAM type OLED driver, according to one embodiment of the present invention.

[0023] FIG. 4 is a flowchart illustrating the process of generating drive current for an OLED panel, according to one embodiment of the present invention.

DETAILED DESCRIPTION OF EMBODIMENTS

[0024] The Figures (FIG.) and the following description relate to preferred embodiments of the present invention by way of illustration only. It should be noted that from the following discussion, alternative embodiments of the structures and methods disclosed herein will be readily recognized as viable alternatives that may be employed without departing from the principles of the claimed invention.

[0025] Reference will now be made in detail to several embodiments of the present invention(s), examples of which are illustrated in the accompanying figures. It is noted that wherever practicable similar or like reference numbers may be used in the figures and may indicate similar or like functionality. The figures depict embodiments of the present invention for purposes of illustration only. One skilled in the art will readily recognize from the following description that alternative embodiments of the structures and methods illustrated herein may be employed without departing from the principles of the invention described herein.

[0026] FIG. 3 illustrates an example of a current source in a PAM type OLED driver, according to one embodiment of the present invention. The embodiment of FIG. 3 shows a current source **300** that can replace the conventional current source **142** to generate drive current I(n) for driving OLEDs in the associated column C(n) in response to display data Idata(n) that is comprised of 8 bits (D**0**, D**1**, D**2**, . . . , D**6**, D**7**). Although the embodiment of FIG. **3** illustrates a current source **300** that is responsive to 8 bit display data Idata(n), note that the current source in accordance with the present invention can be used to generate OLED drive current corresponding to display data of any number of bits for displaying any number of levels of brightness.

[0027] The current source **300** includes a first set of transistors including P groups of transistors (P is an integer not less than 1) and a second set of transistors including Q groups of transistors (Q is an integer not less than 1). Note that P may be equal to or different from Q. In the example of FIG. **3**, the first set of transistors include 4 (P=4) transistor groups **302**, **304**, **306**, **308** and the second set of transistors include 4 (Q=4) transistor groups **310**, **312**, **314**, **316**. Although each of the transistor groups **302**, **304**, **306**, **308**, **310**, **312**, **314**, **316** is shown as a single transistor in FIG. **3** merely for simplicity of illustration, in fact each transistor group **302**, **304**, **306**, **308**, is a group of transistors including 2^R transistors (R=0, 1, 2, . . . P−1, respectively) of substantially the same size and each transistor group **310**, **312**, **314**, **316** is a group of transistors including 2^S transistors (S=0, 1, 2, . . . Q−1, respectively) of substantially the same size. For example, in the embodiment shown in FIG. **3**, transistor group **302** includes 1 ($=2^0$) transistor as shown by the notation TR=1ea, transistor group **304** includes 2 ($=2^1$) transistors of substantially the same size as shown by the notation TR=2ea, transistor group **306** includes 4 ($=2^2$) transistors of substantially the same size as shown by the notation TR=4ea, and transistor group **308** includes 8 ($=2^3=2^{4-1}$) transistors of substantially the same size as shown by the notation TR=8ea. Likewise, transistor group **310** includes 1 ($=2^0$) transistors as shown by the notation TR=1ea, transistor group **312** includes 2 ($=2^1$) transistors of substantially the same size as shown by the notation TR=2ea, transistor group **314** includes 4 ($=2^2$) transistors of substantially the same size as shown by the notation TR=4ea, and transistor group **316** includes 8 ($=2^3=2^{4-1}$) transistors of substantially the same size as shown by the notation TR=8ea. The combined number of the transistors in the transistor groups **302**, **304**, **306**, **308** of the first set of transistors is 2^P-1, and the combined number of the transistors in the transistor groups **310**, **312**, **314**, **316** of the second set of transistors is 2^Q-1, and the total number of transistors in the first and second set of transistors is $(2^P-1)+(2^Q-1)$. For example, the total number of transistors in the first and second sets of transistors in the embodiment of FIG. **3** is only 30 ($=(2^0+2^1+2^2+2^3)+(2^0+2^1+2^2+2^3)=(2^4-1)+(2^4-1)$).

[0028] A first reference current generation circuit **302** generates a first reference current, and a second reference current generation circuit **304** generates a second reference current different from the first reference current. The second reference current is typically larger than the first reference current, and can be larger than the largest current generated by any one of the transistor groups **302**, **304**, **306**, **308** in the first set of transistors. In one embodiment, the first reference current is Iw and the second reference current is $2^P\times$Iw, where P is the number of transistor groups in the first set of transistors. Thus, in the example shown in FIG. **3**, the first reference current is Iw and the second reference current is $2^4\times$Iw=16×Iw.

[0029] Each of the 2^R transistors in each of the transistor groups **302**, **304**, **306**, **308** forms a current mirror with the first reference current generation circuit **302** that generates the first reference current Iw. Each of the 2^S transistors in each of the transistor groups **310**, **312**, **314**, **316** forms a current mirror with the second reference current generation circuit **304** that generates the second reference current $2^P\times$Iw, where P is the number of transistor groups in the first set of transistors. The switches **318**, **320**, **322**, **324**, **326**, **328**, **330**, **332** are opened or closed in response to bit DN (N=0, 1, 2, . . . , 7) of the display data Idata(n). For example, the switches **318**, **320**, **322**, **324**, **326**, **328**, **330**, **332** may be configured to be closed (ON) when the bit DN=1 (N=0, 1, 2, . . . , 7) in order to connect the transistor groups **302**, **304**, **306**, **308**, **310**, **312**, **314**, **316** to the current I(n) and open (OFF) when the bit DN=0 (N=0, 1, 2, . . . , 7) in order to disconnect the transistors **302**, **304**, **306**, **308**, **310**, **312**, **314**, **316** from the current I(n). The transistor groups **302**, **304**, **306**, **308** of the first set of transistors generates a first part of the column drive current I(n) in response to bits D**0**, D**1**, D**2**, and D**3** of the display data Idata(n), and transistor groups **310**, **312**, **314**, **316** of the second set of transistors generates a second part of the column drive current I(n) in response to bits D**4**, D**5**, D**6**, and D**7** of the display data Idata(n).

[0030] Since each of the transistor groups **302**, **304**, **306**, **308** includes 2^R transistors (R=0, 1, 2, . . . P−1, respectively), each of the transistor groups **302**, **304**, **306**, **308** can generate current of 2^R multiples (R=0, 1, 2, . . . P−1, respectively) of the first reference current Iw in response to bits D**0**, D**1**, D**2**, and D**3**, respectively, of the display data Idata(n). In addition, since each of the transistor groups **310**, **312**, **314**, **316** includes 2^S transistors (S=0, 1, 2, . . . Q−1, respectively), each of the transistor groups **310**, **312**, **314**, **316** can generate current of 2^S multiples (S=0, 1, 2, . . . Q−1, respectively) of the second reference current $2^P\times$Iw in response to bits D**4**, D**5**, D**6**, and D**7**, respectively, of the display data Idata(n). For example, if all the switches **318**, **320**, **322**, **324**, **326**, **328**, **330**, **332** are closed in response to the display data Idata(n) (D**0**, D**1**, . . . , D**7**) in the embodiment of FIG. **3** where P=4, Q=4, R=0, 1, 2, 3, and S=0, 1, 2, 3, transistor group **302** generates current of 1×Iw (=2^0×Iw), transistor group **304** generates current of 2×Iw (=2^1×Iw), transistor group **306** generates current of 4×Iw (=2^2×Iw), transistor group **308** generates current of 8×Iw (=2^3×Iw), transistor group **310** generates current of 16×Iw (=2^0×2^4×Iw), transistor group **312** generates current of 32×Iw (=2^1×2^4×Iw), transistor group **314** generates current of 64×Iw (=2^2×2^4×Iw), and transistor group **316** generates current of 128×Iw (=2^4×2^4×Iw).

[0031] The column drive current I(n) is the sum of all the current generated by all of the transistor groups **302**, **304**, **306**, **308**, **310**, **312**, **314**, **316**. Therefore, by controlling the bits DN (N=0, 1, 2, . . . , 7) of the display data Idata(n) for column C(n), it is possible to generate column drive current I(n) of 256 (=2^8) different levels (0, 1, 2, . . . , 255) to achieve 256 different levels of brightness in the OLED coupled to the column C(n). In general, for an OLED panel **100** with A number of rows and B number of columns and capable of indicating 2^C number of brightness levels responsive to C bit display data, the current source **300** of the present invention merely requires B×((2^P−1)+(2^Q−1)) transistors just for generating the drive current for the OLED panel **100**.

[0032] For example, note that the current source **300** of FIG. **3** is able to generate the same 256 different levels of the column drive current I(n) with only 30 (=(2^4−1)+(2^4−1)) transistors in the first and second set of transistors, as compared to the conventional current generator **142** of FIG. **2** which requires 255 transistors. If the OLED panel **100** includes 100 columns, for example, the difference in the number of transistors is drastic, with only 3000 (=100×30) transistors required with the current generator **300** of FIG. **3** according to the present invention to generate 256 different levels of the column drive current while 25500 (=100×255) transistors are required with the conventional current generator **142** of FIG. **2**. Thus, the current source **300** of FIG. **3** enables reduction of the number of transistors required to approximately 12% of what is required in conventional current source **142** of FIG. **2**, resulting in a very significant decrease in the chip size required for the column driver **140** and a very significant increase of production yield in the IC fabrication process for the OLED driver.

[0033] FIG. **4** is a flowchart illustrating the process of generating column drive current for an OLED panel, according to one embodiment of the present invention. A first reference current is generated **402**, and a second reference current different from the first reference current is also generated **404**. A first drive current is generated **406** using a first set of transistors based on the first reference current, and a second drive current is generated **408** using a second set of transistors based on the second reference current. The first drive current and the second drive current are combined **410** to generate the column drive current for the corresponding column of the OLED panel. The second reference current is typically larger than the first reference current, and can be larger than (e.g., twice as large as) the largest current generated by any one of the transistor groups in the first set of transistors. Although the steps **402**, **404**, **406**, **408**, **41.0** are illustrated sequentially in FIG. **4**, note that all or some of these steps may be performed substantially at the same time or in a different order. Thus, the process of FIG. **4** is not limited to the specific order in which the steps **402**, **404**, **406**, **408**, **410** are illustrated.

[0034] Upon reading this disclosure, those of ordinary skill in the art will appreciate still additional alternative structural and functional designs for a system and a process for generating column drive current for an OLED panel in response to display data through the disclosed principles of the present invention. For example, the present invention is not limited to the two sets of transistors generating drive current based on the first and second reference currents generated by the first and second reference current generation circuits. Rather, the present invention can be similarly applied to more than 2 transistor sets generating drive current based on different reference current generated by more than two reference current generation circuits.

[0035] Thus, while particular embodiments and applications of the present invention have been illustrated and described, it is understood that the invention is not limited to the precise construction and components disclosed herein. Various modifications, changes and variations which will be apparent to those skilled in the art may be made in the arrangement, operation and details of the method and apparatus of the present invention disclosed herein without departing from the spirit and scope of the invention as defined in the appended claims.

What is claimed is:

1. A driver circuit for driving an organic light-emitting diode (OLED) display panel including a plurality of organic light-emitting diodes (OLEDs) arranged in rows and columns, the driver circuit including a plurality of current sources for driving the OLEDs coupled to the columns, each current source comprising:

a first reference current generation circuit generating a first reference current;

a second reference current generation circuit generating a second reference current different from the first reference current;

a first set of transistors coupled to the first reference current generation circuit and generating a first drive current based upon the first reference current in response to a first part of display data indicative of a brightness level of the OLED coupled to the column associated with said each current source; and

a second set of transistors coupled to the second reference current generation circuit and generating a second drive current based upon the second reference current in response to a second part of the display data, the first drive current and the second drive current being combined to generate column drive current for driving the OLED coupled to the column associated with said each current source.

2. The driver circuit of claim **1**, wherein the second reference current is greater than the first reference current.

3. The driver circuit of claim **1**, wherein the first set of transistors comprises P groups of transistors and the second set of transistors comprises Q groups of transistors, P and Q being integers not less than 1.

4. The driver circuit of claim **3**, wherein P is equal to Q.

5. The driver circuit of claim **3**, wherein the second reference current is greater than a largest current generated by any one of the Q groups of transistors.

6. The driver circuit of claim **3**, wherein each of the P groups of transistors comprises 2^R transistors of substantially same size where R is an integer not less than 0 but not more than P−1, and each of the Q groups of transistors comprises 2^S transistors of substantially the same size where S is an integer not less than 0 but not more than Q−1.

7. The driver circuit of claim **6**, wherein each of the 2^R transistors is coupled to the first reference current generation circuit and capable of generating the same first reference current in response to the display data and each of the 2^S transistors is coupled to the second reference current generation circuit and capable of generating the same second reference current in response to the display data.

8. The driver circuit of claim **7**, wherein each of the P groups of transistors is capable of generating a 2^R multiple of the first reference current and each of the Q groups of transistors is capable of generating a 2^S multiple of the second reference current.

9. The driver circuit of claim **7**, wherein the second reference current is 2^P times greater than the first reference current.

10. The driver circuit of claim **3**, wherein the display data is comprised of P+Q bits, and each of the P groups of transistors and the Q groups of transistors is associated with a corresponding one of the P+Q bits.

11. The driver circuit of claim **10**, further comprising:

a first set of P switches each coupled to a corresponding one of the P groups of transistors causing the 2^R transistors in said corresponding one of the P groups of transistors to generate the same first reference current in response to the display data; and

a second set of Q switches each coupled to a corresponding one of the Q groups of transistors causing the 2^S transistors in said corresponding one of the Q groups of transistors to generate the same second reference current in response to the display data.

12. A driver circuit for driving an organic light-emitting diode (OLED) display panel including a plurality of organic light-emitting diodes (OLEDs) arranged in rows and columns, the driver circuit including a plurality of current sources for driving the OLEDs coupled to the columns, each of the current sources generating a column drive current corresponding to an associated column in response to display data indicative of a brightness level of the OLED coupled to the associated column, each current source comprising:

a first reference current generation circuit generating a first reference current;

a second reference current generation circuit generating a second reference current different from the first reference current;

a first set of transistors including P groups of transistors, each of the P groups of transistors including 2^R transistors of substantially same size where P is an integer not less than 1 and R is an integer not less than 0 but not more than P−1, each of the P groups of transistors coupled to the first reference current generation circuit and being capable of generating a 2^R multiple of the first reference current to generate in combination a first drive current in response to P bits of the display data; and

a second set of transistors including Q groups of transistors, each of the Q groups of transistors including 2^S transistors of substantially the same size where Q is an integer not less than 1 and S is an integer not less than 0 but not more than Q−1, each of the Q groups of transistors coupled to the second reference current generation circuit and being capable of generating a 2^S multiple of the second reference current to generate in combination a second drive current in response to Q bits of the display data, the first drive current and the second drive current being combined to generate the column drive current corresponding to the associated column.

13. The driver circuit of claim **12**, wherein P is equal to Q.

14. The driver circuit of claim **12**, wherein the second reference current is 2^P times greater than the first reference current.

15. The driver circuit of claim **12**, further comprising:

a first set of P switches each coupled to a corresponding one of the P groups of transistors enabling the corresponding one of the P groups of transistors to generate the 2^R multiple of the first reference current if said each of the P switches is closed; and

a second set of Q switches each coupled to a corresponding one of the Q groups of transistors enabling the corresponding one of the Q groups of transistors to generate the 2^S multiple of the second reference current if said each of the Q switches is closed.

16. An organic light-emitting diode (OLED) display device comprising:

an OLED display panel including a plurality of organic light emitting diodes (OLEDs) arranged in rows and columns; and

a driver circuit including a plurality of current sources for driving the OLEDs coupled to the columns, each current source comprising:

a first reference current generation circuit generating a first reference current;

a second reference current generation circuit generating a second reference current different from the first reference current;

a first set of transistors coupled to the first reference current generation circuit and generating a first drive current based upon the first reference current in response to a first part of display data indicative of a brightness level of the OLED coupled to the column associated with said each current source; and

a second set of transistors coupled to the second reference current generation circuit and generating a second drive current based upon the second reference current in response to a second part of the display data, the first drive current and the second drive current being combined to generate column drive current for driving the OLED coupled to the column associated with said each current source.

17. The OLED display device of claim **16**, wherein the second reference current is greater than the first reference current.

18. The OLED display device of claim **16**, wherein the first set of transistors comprises P groups of transistors and the second set of transistors comprises Q groups of transistors, P and Q being integers not less than 1.

19. The OLED display device of claim **18**, wherein P is equal to Q.

20. The OLED display device of claim **18**, wherein the second reference current is greater than a largest current generated by any one of the Q groups of transistors.

21. The OLED display device of claim **18**, wherein each of the P groups of transistors comprises 2^R transistors of substantially same size where R is an integer not less than 0 but not more than P−1, and each of the Q groups of transistors comprises 2^S transistors of substantially the same size where S is an integer not less than 0 but not more than Q−1.

22. The OLED display device of claim **21**, wherein each of the 2^R transistors is coupled to the first reference current generation circuit and capable of generating the same first reference current in response to the display data and each of the 2^S transistors is coupled to the second reference current generation circuit and capable of generating the same second reference current in response to the display data.

23. The OLED display device of claim **21**, wherein each of the P groups of transistors is capable of generating a 2^R multiple of the first reference current and each of the Q groups of transistors is capable of generating a 2^S multiple of the second reference current.

24. The OLED display device of claim **21**, wherein the second reference current is 2^P times greater than the first reference current.

25. The OLED display device of claim **18**, wherein the display data is comprised of P+Q bits, and each of the P groups of transistors and the Q groups of transistors is associated with a corresponding one of the P+Q bits of the display data.

26. The OLED display device of claim **25**, wherein the driver circuit further comprises:

a first set of P switches each coupled to a corresponding one of the P groups of transistors causing the 2^R transistors in said corresponding one of the P groups of transistors to generate the same first reference current in response to the display data; and

a second set of Q switches each coupled to a corresponding one of the Q groups of transistors causing the 2^S transistors in said corresponding one of the Q groups of transistors to generate the same second reference current in response to the display data.

27. An organic light-emitting diode (OLED) display device comprising:

an OLED display panel including a plurality of organic light emitting diodes (OLEDs) arranged in rows and columns; and

a driver circuit including a plurality of current sources for driving the OLEDs coupled to the columns, each current source generating a column drive current corresponding to an associated column in response to display data indicative of a brightness level of the OLED coupled to the associated column, each current source comprising:

a first reference current generation circuit generating a first reference current;

a second reference current generation circuit generating a second reference current different from the first reference current;

a first set of transistors including P groups of transistors, each of the P groups of transistors including 2^R transistors of substantially same size where P is an integer not less than 1 and R is an integer not less than 0 but not more than P−1, each of the P groups of transistors coupled to the first reference current generation circuit and being capable of generating a 2^R multiple of the first reference current to generate in combination a first drive current in response to P bits of the display data; and

a second set of transistors including Q groups of transistors, each of the Q groups of transistors including 2^S transistors of substantially the same size where Q is an integer not less than 1 and S is an integer not less than 0 but not more than Q−1, each of the Q groups of transistors coupled to the second reference current generation circuit and being capable of generating a 2^S multiple of the second reference current to generate in combination a second drive current in response to Q bits of the display data, the first drive current and the second drive current being combined to generate the column drive current corresponding to the associated column.

28. The OLED display device of claim **27**, wherein P is equal to Q.

29. The OLED display device of claim **27**, wherein the second reference current is 2^P times greater than the first reference current.

30. The OLED display device of claim **27**, wherein the driver circuit further comprises:

a first set of P switches each coupled to a corresponding one of the P groups of transistors enabling the corresponding one of the P groups of transistors to generate the 2^R multiple of the first reference current if said each of the P switches is closed; and

a second set of Q switches each coupled to a corresponding one of the Q groups of transistors enabling the corresponding one of the Q groups of transistors to generate the 2^S multiple of the second reference current if said each of the Q switches is closed.

31. In a driver for driving an organic light-emitting diode (OLED) display panel including a plurality of organic light emitting diodes (OLEDs) arranged in rows and columns, a method of generating a column drive current for driving the OLED coupled to an associated column, the method comprising:

generating a first reference current;

generating a second reference current different from the first reference current;

generating a first drive current based upon the first reference current in response to a first part of display data indicative of a brightness level of the OLED coupled to the associated column;

generating a second drive current based upon the second reference current in response to a second part of the display data; and

combining the first drive current and the second drive current to generate the column drive current for driving the OLED coupled to the associated column.

32. The method of claim **31**, wherein the second reference current is greater than the first reference current.

* * * * *

专利名称(译)	具有较少晶体管的脉冲幅度调制驱动器用于驱动有机发光二极管显示器		
公开(公告)号	US20070279333A1	公开(公告)日	2007-12-06
申请号	US11/445125	申请日	2006-05-31
[标]申请(专利权)人(译)	金昌OON		
申请(专利权)人(译)	金昌OON		
当前申请(专利权)人(译)	金昌OON		
[标]发明人	KIM CHANG OON		
发明人	KIM, CHANG OON		
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摘要(译)

OLED驱动器电路包括多个电流源，其中每个电流源包括产生第一参考电流的第一参考电流产生电路，产生第二参考电流的第二参考电流产生电路，耦合到第一参考电压的第一组晶体管电流产生电路并响应于第一部分显示数据产生基于第一参考电流的第一驱动电流，以及连接至第二参考电流产生电路并基于第二参考产生第二驱动电流的第二组晶体管电流响应显示数据的第二部分。组合第一驱动电流和第二驱动电流以产生列驱动电流，用于驱动耦合到与所述每个电流源相关联的列的OLED。第二参考电流大于第一参考电流。