



US010373556B1

(12) **United States Patent**
Patel et al.

(10) **Patent No.:** **US 10,373,556 B1**
(45) **Date of Patent:** **Aug. 6, 2019**

(54) **ORGANIC LIGHT EMITTING DIODE
DISPLAY DEVICE INCLUDING
SEGMENTED POWER LINES**

(58) **Field of Classification Search**

None

See application file for complete search history.

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(56) **References Cited**

U.S. PATENT DOCUMENTS

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2004/0257353 A1* 12/2004 Imamura G09G 3/3233
345/204
2012/0293496 A1* 11/2012 Park G09G 3/003
345/419

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* cited by examiner

(*) Notice: Subject to any disclaimer, the term of this
patent is extended or adjusted under 35
U.S.C. 154(b) by 107 days.

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(21) Appl. No.: **15/599,055**

(57) **ABSTRACT**

(22) Filed: **May 18, 2017**

A display device comprises a display panel having a plu-
rality of pixels for emitting light disposed on an active area
of the display panel. The pixels may be grouped into a
plurality of subsets, each subset of pixels coupled to a
corresponding power line. The subsets of pixels may be
programmed and operated in succession in a rolling con-
figuration. The power line may be configured to provide a
low supply voltage to turn on the corresponding subset of
pixels, or a high supply voltage to turn off the corresponding
subset of pixels. By turning off each subset of pixels when
the subset is not being programmed or controlled to emit
light, a picture quality of the display may potentially be
improved, by preventing leakages or tailing effects in the
non-emitting pixels when of the display.

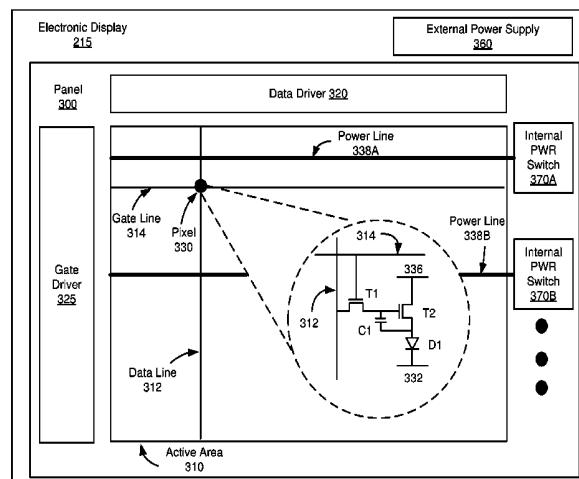
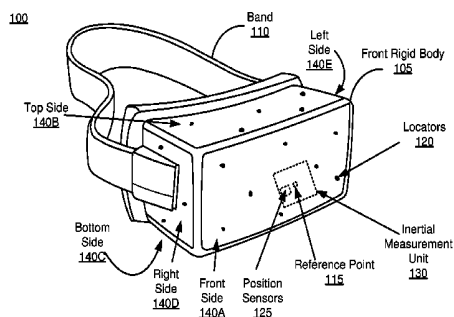
Related U.S. Application Data

(60) Provisional application No. 62/338,378, filed on May
18, 2016.

(51) **Int. Cl.**
H01L 27/32 (2006.01)
G09G 3/3233 (2016.01)

(52) **U.S. Cl.**
CPC **G09G 3/3233** (2013.01); **H01L 27/3276**
(2013.01); **G09G 2310/08** (2013.01); **G09G**
2330/028 (2013.01)

12 Claims, 3 Drawing Sheets



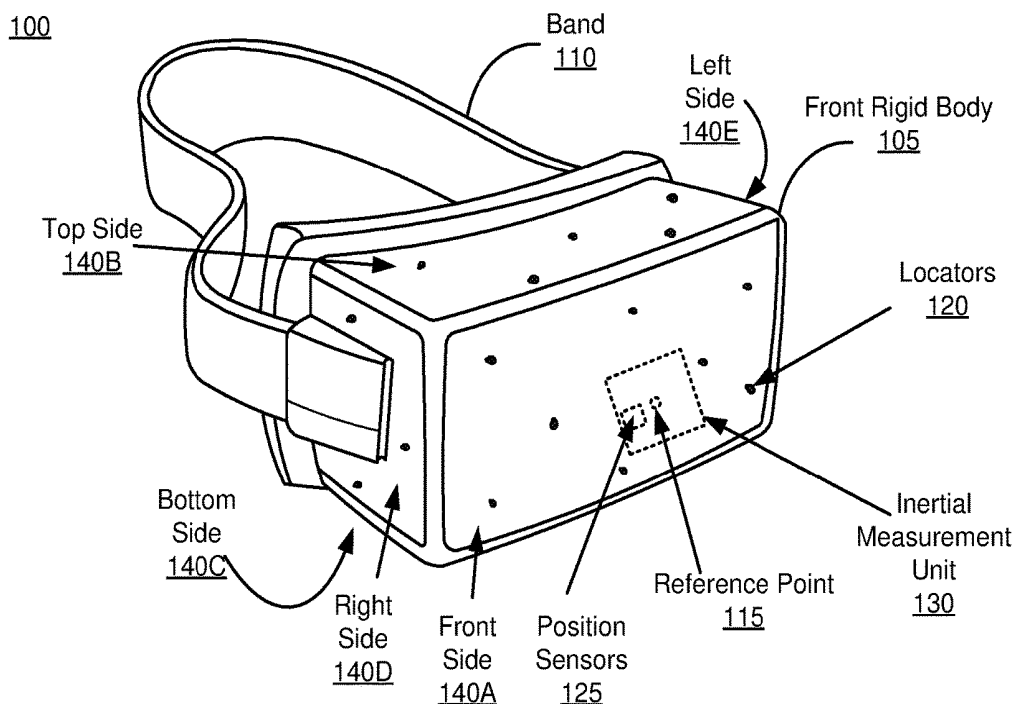


FIG. 1

225

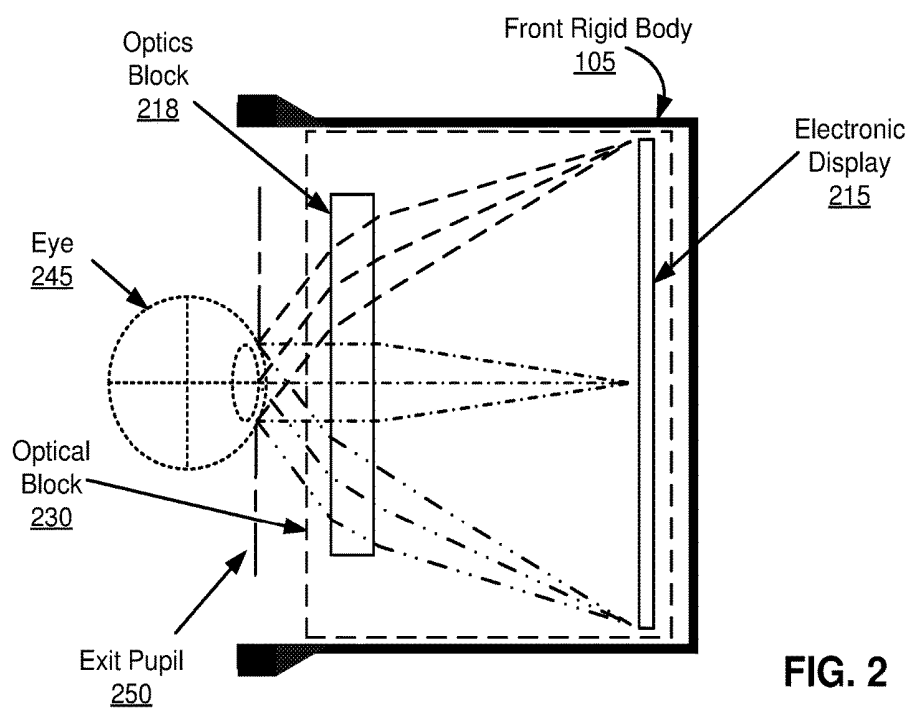


FIG. 2

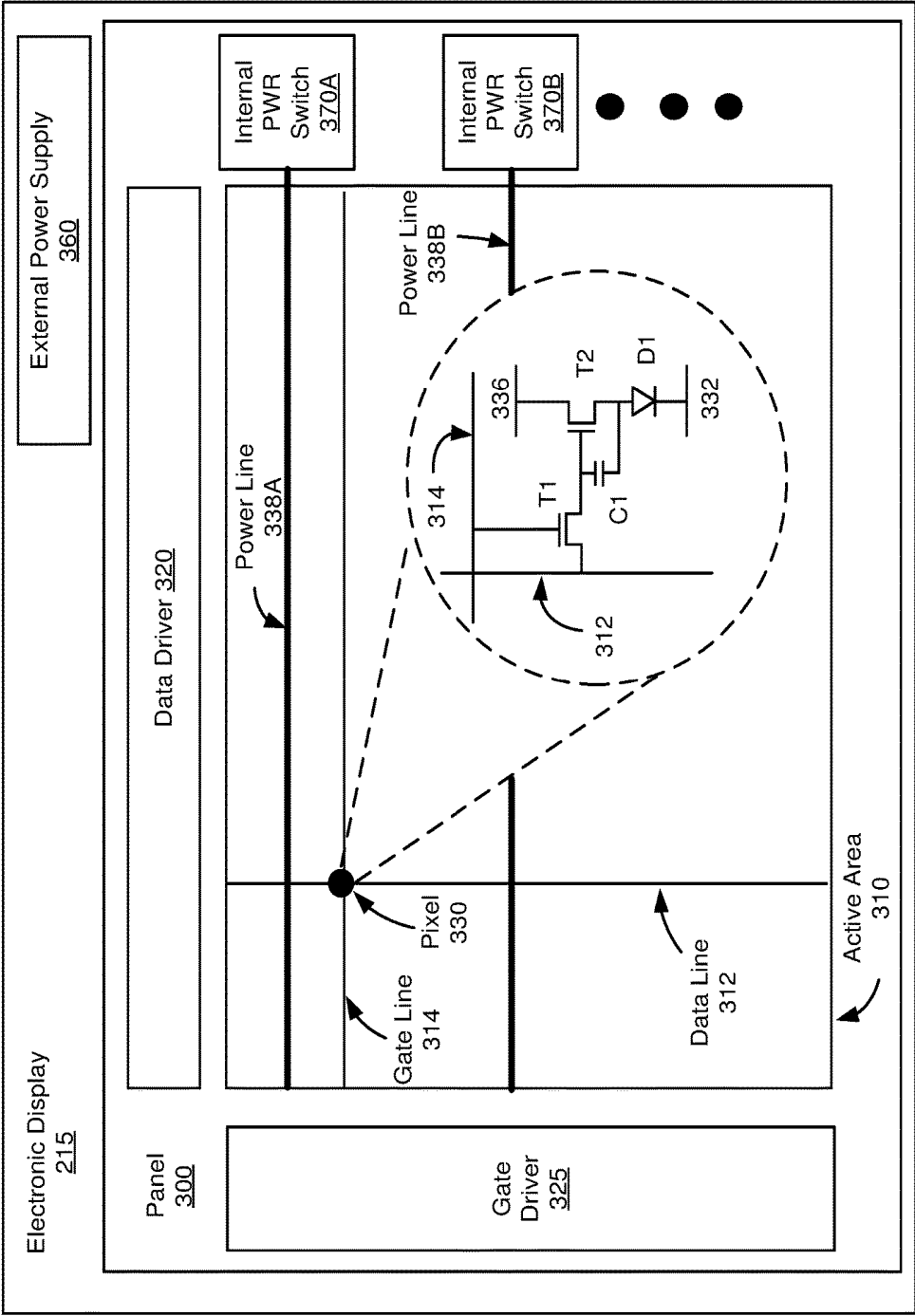


FIG. 3

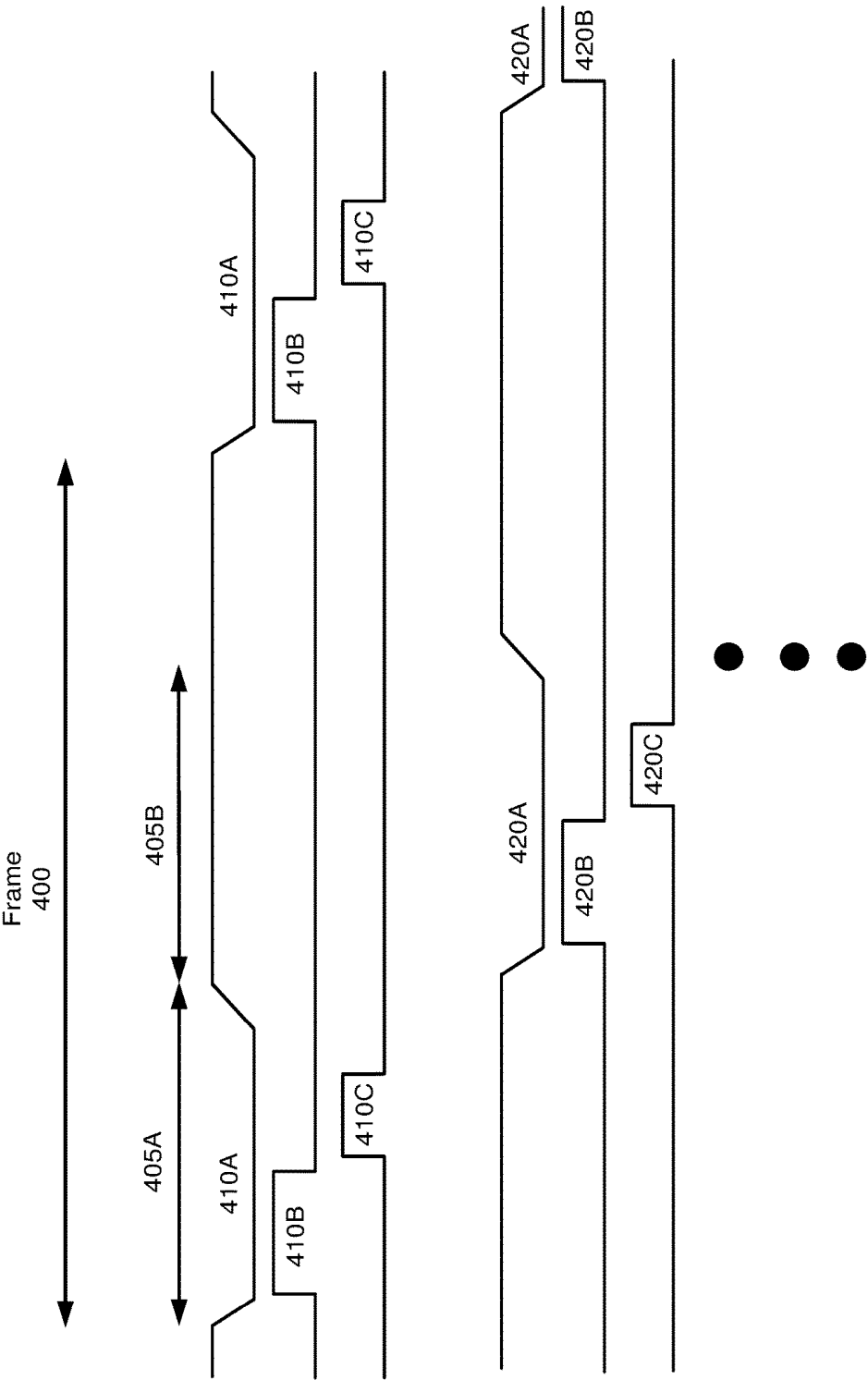


FIG. 4

ORGANIC LIGHT EMITTING DIODE DISPLAY DEVICE INCLUDING SEGMENTED POWER LINES

CROSS-REFERENCE TO RELATED APPLICATION

The present disclosure claims priority to U.S. Provisional Patent Application No. 62/338,378, titled "Organic Light Emitting Diode Display Device Including Segmented Power Lines," filed on May 18, 2016, which is hereby incorporated by reference in its entirety.

BACKGROUND

The present disclosure generally relates to an organic light emitting diode (OLED) display device.

A display of the display device may comprise an array of OLED pixels. In some implementations, the OLED pixels may be controlled in a rolling configuration. For example, the OLED pixels may be divided into a plurality of groups. The groups of OLED pixels may be programmed and emit light in succession.

SUMMARY

A display device comprises a display panel having a plurality of pixels for emitting light disposed on an active area of the display panel. The pixels may be grouped into a plurality of subsets, each subset of pixels coupled to a corresponding power line. The subsets of pixels may be programmed and operated in succession in a rolling configuration.

Each power line is coupled to a corresponding switching circuit configured to provide power to the corresponding subset of pixels at different power levels, including a low supply voltage level to turn on the corresponding subset of pixels, or a high supply voltage level to turn off the corresponding subset of pixels. By turning off each subset of pixels when the subset is not being programmed or controlled to emit light, a picture quality of the display may potentially be improved, by preventing leakages or tailing effects in the non-emitting pixels of the display.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a diagram of a headset, in accordance with an embodiment.

FIG. 2 is a cross section of a front rigid body of the headset in FIG. 1, in accordance with an embodiment.

FIG. 3 is a detailed diagram of an electronic display including segmented power lines, in accordance with an embodiment.

FIG. 4 illustrates a timing diagram of operating an OLED display device, in accordance with an embodiment.

The figures depict embodiments of the present disclosure 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, or benefits touted, of the disclosure described herein.

DETAILED DESCRIPTION

Configuration Overview

Example embodiments of disclosed configurations include an OLED display device having separate power

lines and switches coupled to corresponding power lines for independently powering OLEDs.

In one or more embodiments, the disclosed OLED display includes a plurality of OLEDs connected to power lines. A power line is a conductive component through which a voltage (e.g., ELVSS) can be applied to an electrode (e.g., cathode or anode) of an OLED. The OLEDs can be divided into a number of groups, where OLEDs in different groups are connected to separate power lines. For example, pixels in a first row are coupled to a first power line, and pixels in a second row are coupled to a second power line. Accordingly, a voltage (e.g., ELVSS) can be provided to groups of pixels at different time periods.

System Overview

FIG. 1 is a diagram of a headset **100**, in accordance with an embodiment. In one embodiment, the headset **100** includes a front rigid body **105** and a band **110**. The front rigid body **105** includes an electronic display (not shown), an inertial measurement unit (IMU) **130**, one or more position sensors **125**, and locators **120**. In one embodiment, a user movement is detected by use of the inertial measurement unit **130**, position sensors **125**, and/or the locators **120**, and an image is presented to a user through the electronic display according to the user movement detected. In one embodiment, the headset **100** can be used for presenting a virtual reality, an augmented reality, or a mixed reality to a user.

A position sensor **125** generates one or more measurement signals in response to motion of the headset **100**. Examples of position sensors **125** include: one or more accelerometers, one or more gyroscopes, one or more magnetometers, another suitable type of sensor that detects motion, a type of sensor used for error correction of the IMU **130**, or some combination thereof. The position sensors **125** may be located external to the IMU **130**, internal to the IMU **130**, or some combination thereof. In the embodiment shown by FIG. 1, the position sensors **125** are located within the IMU **130**, and neither the IMU **130** nor the position sensors **125** are visible to the user.

Based on the one or more measurement signals from one or more position sensors **125**, the IMU **130** generates calibration data indicating an estimated position of the headset **100** relative to an initial position of the headset **100**. In some embodiments, the IMU **130** rapidly samples the measurement signals and calculates the estimated position of the headset **100** from the sampled data. For example, the IMU **130** integrates the measurement signals received from the accelerometers over time to estimate a velocity vector and integrates the velocity vector over time to determine an estimated position of a reference point on the headset **100**. Alternatively, the IMU **130** provides the sampled measurement signals to a console (e.g., a computer), which determines the calibration data. The reference point is a point that may be used to describe the position of the headset **100**. While the reference point may generally be defined as a point in space; however, in practice the reference point is defined as a point within the headset **100** (e.g., a center of the IMU **130**).

The locators **120** are located in fixed positions on the front rigid body **105** relative to one another and relative to a reference point **115**. In the example of FIG. 1, the reference point **115** is located at the center of the IMU **130**. Each of the locators **120** emits light that is detectable by an imaging device (e.g., camera or an image sensor). Locators **120**, or portions of locators **120**, are located on a front side **140A**, a

top side **140B**, a bottom side **140C**, a right side **140D**, and a left side **140E** of the front rigid body **105** in the example of FIG. **1**.

FIG. **2** is a cross section **225** of the front rigid body **105** of the embodiment of the headset **100** shown in FIG. **1**. As shown in FIG. **2**, the front rigid body **105** includes an optical block **230** that provides altered image light to an exit pupil **250**. The exit pupil **250** is the location of the front rigid body **105** where a user's eye **245** is positioned. For purposes of illustration, FIG. **2** shows a cross section **225** associated with a single eye **245**, but another optical block, separate from the optical block **230**, provides altered image light to another eye of the user.

The optical block **230** includes an electronic display **215**, and the optics block **218**. The electronic display **215** emits image light toward the optics block **218**. The optics block **218** magnifies the image light, and in some embodiments, also corrects for one or more additional optical errors (e.g., distortion, astigmatism, etc.). The optics block **218** directs the image light to the exit pupil **250** for presentation to the user. In one or more embodiments, the optics block **218** may be omitted.

FIG. **3** is a detailed diagram of an electronic display **215**. The electronic display **215** includes a panel **300**, and an external power supply **360** physically separated from the panel **300**. The external power supply **360** may be coupled to the panel **300** through one or more cables. The panel **300** includes an active area **310**, a data driver **320**, a gate driver **325**, and internal power switches **370**. These components can be integrated together, for example as a gate in panel structure.

The active area **310** is a portion of the panel **300** that displays an image. The active area **310** of the panel **300** includes gate lines **314**, data lines **312** and pixels **330**. Each pixel **330** is formed at an intersection of a gate line **314** and a data line **312**. Each pixel emits light according to signals applied through its corresponding gate line **314** and data line **312**.

In the example shown in FIG. **3**, each pixel **330** has a 2T1C structure including a first transistor **T1**, a second transistor **T2**, a capacitor **C1**, and an OLED **D1**. Specifically, a first electrode (e.g., drain or source) of the first transistor **T1** is coupled to a data line **312**, and a second electrode of the first transistor **T1** is coupled to a gate electrode of the second transistor **T2**. A gate electrode of the first transistor **T1** is coupled to a gate line **314**. In addition, a first electrode (e.g., source or drain) of the second transistor **T2** is coupled to a first electrode (e.g., anode) of the OLED **D1**, and a second electrode (e.g., drain or source) of the second transistor **T2** is coupled to a first power terminal **336**. A second electrode (e.g., cathode) of the OLED **D1** is coupled to a second power terminal **332**. In addition, the capacitor **C1** is coupled between the gate electrode and the first electrode of the second transistor **T2**. In this configuration, amount of charges corresponding to a data voltage applied from the data driver **320** through the data line **312** are stored at the capacitor **C1**, according to a gate control signal applied from the gate driver **325** through the gate line **314**. According to the amount of charges stored in the capacitor **C1**, a corresponding amount of current flows through the second transistor **T2** through the OLED **D1** to emit light. The pixel structure shown in FIG. **3** is merely an example, and in other embodiments, the pixel **330** can be implemented in a different configuration than shown in FIG. **3**.

In one or more embodiments, voltages supplied to the first power terminal **336** and the second power terminal **332** are controlled for displaying an image. For example, a high

supply voltage (ELVDD) is applied to the first power terminal **336**, and a low supply voltage (ELVSS) lower than the high supply voltage is applied to the second power terminal **332**, when the pixel is programmed (i.e., a charge is stored at the capacitor **C1**) during a programming period and/or when the pixel emits light during an emission period. When the pixel is neither being programmed nor emitting light, for example, during a non-emission period, a high supply voltage (ELVDD) instead of the low supply voltage (ELVSS) may be applied to the second power terminal **332** to turn off the OLED **D1**.

The external power supply **360** generates the low supply voltage ELVSS, and provides the low supply voltage ELVSS to the panel **300** through a conductive pin of a cable. The external power supply **360** can also generate the high supply voltage ELVDD, and provide the high supply voltage ELVDD to the panel **300** through another conductive pin of the cable or another cable. In some embodiments, the external power supply **360** outputs the low supply voltage ELVSS or the high supply voltage ELVDD through the same conductive pin of the cable, depending on an operation of the panel. For example, the external power supply **360** outputs the low supply voltage ELVSS at a first time period (e.g., during the programming and the emission period), and outputs the high supply voltage ELVDD through the same conductive pin of the cable at a second time period (e.g., non-emission period). Accordingly, the external power supply **360** can enable or disable the low supply voltage ELVSS from being supplied to the second power terminal **332**.

The internal power switch **370** is an electronic component that controls a voltage applied to the second power terminal **332**. For example, the internal power switch **370** receives the low supply voltage ELVSS and the high supply voltage ELVDD from the external power supply **360**, and provides either the low supply voltage ELVSS or the high supply voltage ELVDD to the second power terminal **332** through a power line **338**. Depending on the voltage supplied to the second power terminal **332**, light can be emitted or prevented from being emitted from the OLED **D1**. In some embodiments, the internal power switch **370** sequentially provides the low supply voltage ELVSS (or the high supply voltage ELVDD) to a group of pixels (e.g., pixels in one or more rows).

In one embodiment, pixels **330** in the active area **310** are divided into groups, and the internal power switches **370** supply the low supply voltage ELVSS to pixels in different groups at different times. Specifically, second power terminals **332** of pixels **330** in a group (e.g., pixels in a row) are coupled to a single power line **338A**, where second power terminals **332** of pixels in another group (e.g., pixels in another row) are coupled to a single power line **338B**. Hence, the internal power switch **370A** coupled to the power line **338A** can provide the low supply voltage ELVSS to pixels coupled to the power line **338A**, and the internal power switch **370B** coupled to the power line **338B** can provide the low supply voltage ELVSS to pixels coupled to the power line **338B** at different time periods. Although two internal power switches **370** are shown in FIG. **3**, in other embodiments, any number of internal power switches **370** can be implemented. Moreover, any number of power lines **338** can be implemented in other embodiments. In some embodiments, pixels **330** in two or more rows as a group can be coupled to a single power line **338**.

In some embodiments, the internal power switch **370** may be omitted, and the external power supply **360** may be switched to provide either the high supply voltage ELVDD or the low supply voltage ELVSS at a different time period

to entire pixels **330** in the panel **300** (e.g., the second power terminal **332**). However, providing different voltages from the external power supply **360** may require a settling time to charge or discharge the panel **300**, and pixels in different groups may be programmed differently because of the settling time. For example, capacitors of pixels programmed towards an end of a frame (e.g., pixels in a last row) may be charged or discharged at different voltage levels than pixels in preceding rows, thus an image presented through the pixels towards the end of the frame may be degraded.

By implementing segmented power lines **338** and implementing a plurality of internal power switches **370**, each of which is coupled to a corresponding power line **338** for providing the low supply voltage ELVSS to pixels **330** coupled to the corresponding power line **338**, timing of providing the low supply voltage ELVSS to the second power terminals **332** of the pixels **330** can be individually controlled for each group to avoid errors introduced in programming due to the settling time of the external power supply **360**.

In some embodiments, a group of pixels in different rows are tied to a power line **338A**, and another group of pixels in different rows are tied to another power line **338B**. For example, pixels in rows **1** through **n** may be coupled to the power line **338A**, and pixels in rows **n+1** to **2n** are coupled to the power line **338B**. In addition, each power line **338** would then be connected to a corresponding external switch to the panel **300**, thus internal power switches **370** may be omitted. The external switch may be coupled to the external power supply **360** that would enable or disable the low supply voltage ELVSS to be supplied to pixels in each group of rows. This would eliminate the need for the internal power switches **370** on the panel **300** and achieve a similar effect.

FIG. 4 illustrates a timing diagram of operating the electronic display **215**, in accordance with an embodiment. Within a time frame **400**, pulses **410A**, **410B**, **410C** are applied to pixels in a first group (e.g., a first row) during a first time period **405A**, and pulses **420A**, **420B**, **420C** are applied to pixels in a second group (e.g., a second row) during a second time period **405B**.

In detail, the pulse **410A** represents a low supply voltage ELVSS applied to the first power line **338A** during the first time period **405A**. The pulse **410B** in the first time period **405A** represents a data voltage applied to data lines **312** for programming the pixels coupled to the first power line **338A**. The subsequent pulse **410C** in the first time period **405A** represents an emission control signal applied to the gate line **314** to enable emission of light. In one example, the pulse **410A** starts earlier than the pulse **410B** to ensure sufficient charging time of the external power supply **360**. For the remaining time in the time frame **400** after the pulse **410C**, the high supply voltage ELVDD instead of the low supply voltage ELVSS can be applied to the first power line **338A** to turn off the OLEDs coupled to the first power line **338A** to remove tailing effects, for example, due to leakage through the internal power switch **370**, that may occur if the OLEDs coupled to the first power line **338A** were continued to be supplied with the low supply voltage ELVSS outside the first time period **405A**.

The pulses **420A**, **420B**, **420C** are asserted during the second time period **405B** different from the first time period **405A**. The pulses **420A**, **420B**, **420C** are identical to the pulses **410A**, **410B**, **410C** asserted during the first time period, respectively, except the pulse **420A** is applied to a second power line **338B**, and the pulses **420B**, **420C** are

applied to pixels coupled to the second power line **338B**. Therefore, the detailed description thereof is omitted herein for the sake of brevity.

Accordingly, each row can have data, emission, and charging times specified by the required application.

Additional Configuration Information

The foregoing description of the embodiments has been presented for the purpose of illustration; it is not intended to be exhaustive or to limit the patent rights to the precise forms disclosed. Persons skilled in the relevant art can appreciate that many modifications and variations are possible in light of the above disclosure.

The language used in the specification has been principally selected for readability and instructional purposes, and it may not have been selected to delineate or circumscribe the inventive subject matter. It is therefore intended that the scope of the patent rights be limited not by this detailed description, but rather by any claims that issue on an application based hereon. Accordingly, the disclosure of the embodiments is intended to be illustrative, but not limiting, of the scope of the patent rights, which is set forth in the following claims.

What is claimed is:

1. A display device, comprising:

a display panel including:

a plurality of pixel circuits disposed on an active area of the display panel for emitting light,

at least two lines including a first line and a second line disposed on the active area, the first line coupled to a first group of pixel circuits of the plurality of pixel circuits, the second line coupled to a second group of pixel circuits of the plurality of pixel circuits, and

a first switching circuit, the first switching circuit coupled to the first line, and configured to:

(i) in a first state, supply power at a first power level to the first group of pixel circuits coupled to the first line, and

(ii) in a second state, supply power at a second power level to the first group of pixel circuits coupled to the first line; and

a second switching circuit, the second switching circuit coupled to the second line, and configured to:

(i) in the first state, supply power at the first power level to the second group of pixel circuits coupled to the second line, and

(ii) in the second state, supply power at the second power level to the second group of pixel circuits coupled to the second line; and

wherein a pixel circuit of the plurality of pixel circuits is configured to receive at least a first pulse along a data line to program a value for the pixel circuit, and a second pulse corresponding to an emission control signal to enable the pixel circuit to emit light based upon the programmed value, wherein the first and second pulses are received during a time period when the corresponding switching circuit is operating in the first state.

2. The display device of claim 1, wherein the first switching circuit is configured to operate in the second state while the second switching circuit operates in the first state.

3. The display device of claim 1, wherein the first power level is lower than the second power level.

4. The display device of claim 1, wherein each group of pixel circuits is configured to emit light during at least a portion of when the corresponding switching circuit is

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operating in the first state, and to emit no light when the corresponding switching circuit is operating in the second state.

5. The display device of claim 1, wherein each of the plurality of pixel circuits comprises a first power terminal and a second power terminal, and wherein each of the at least two lines are coupled to the second power terminals of each of the corresponding group of pixel circuits.

6. The display device of claim 5, wherein the first power terminal of each of the pixel circuits is configured to receive power at the second power level during the first and second states.

7. A display device, comprising:

a display panel including:

a plurality of pixels disposed on an active area of the display panel for emitting light,

a plurality of lines disposed on the active area, each line of the plurality of lines coupled to a corresponding subset of pixels of the plurality of pixels, and

a plurality of switching circuits, each switching circuit coupled to a corresponding line of the plurality of lines and the corresponding subset of pixels coupled to the corresponding line, each of the plurality of switching circuits individually controlled to selectively provide power to the corresponding subset of pixels at a first power level or at a second power level;

wherein a pixel of the plurality of pixels is configured to receive at least a first pulse along a data line to program a value for the pixel, and a second pulse

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corresponding to an emission control signal to enable the pixel to emit light based upon the programmed value, wherein the first and second pulses are received during a time period when the corresponding switching circuit is controlled to provide power at the first power level.

8. The display device of claim 7, wherein when a first switching circuit of the plurality of switching circuits is controlled to provide power to its corresponding line at the first power level, the remaining switching circuits of the plurality switching circuit are controlled to provide power to the corresponding lines at the second power level.

9. The display device of claim 7, wherein the first power level is lower than the second power level.

10. The display device of claim 7, wherein each subset of pixels is configured to emit light during at least a portion of when the corresponding switching circuit is controlled to provided power at the first power level, and to emit no light when the corresponding switching circuit is controlled to provide power at the second power level.

11. The display device of claim 7, wherein each of the plurality of pixels comprises a first power terminal and a second power terminal, and wherein each of the plurality of lines are coupled to the second power terminals of each of the corresponding subset of pixels.

12. The display device of claim 11, wherein the first power terminal of each of the pixels is configured to receive power at the second power level.

* * * * *

Diagram of a head-mounted display (HMD) 100. The HMD includes a Band 110, Left Side 140E, Right Side 140D, Top Side 140B, Bottom Side 140C, Front Side 140A, Position Sensors 115, Reference Point 116, Inertial Measurement Unit 130, and Location 120.

