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(12) **United States Patent**
Hall

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(54) **DISPLAY SYSTEM HAVING MONITORING CIRCUIT AND METHODS THEREOF**

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(73) Assignee: **Ultravision Technologies, LLC**, Dallas, TX (US)

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Related U.S. Application Data

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(51) **Int. Cl.**
G09G 3/32 (2006.01)
G06F 1/16 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC .... ***G09G 3/3208*** (2013.01); ***G06F 1/1601*** (2013.01); ***G06F 3/1446*** (2013.01); (Continued)

(58) **Field of Classification Search**
CPC G09G 2300/026; G09G 3/1431; G09G 3/1438; G06F 11/30; G06F 11/3041; G06F 11/3062; G06F 3/1431; G06F 3/1438
See application file for complete search history.

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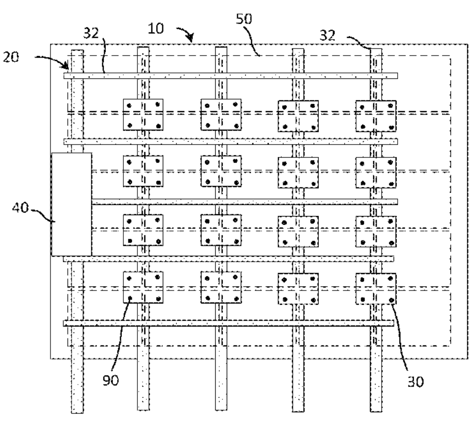
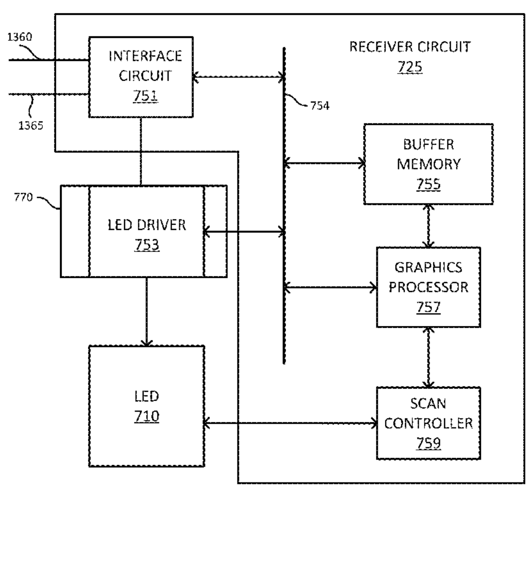
(57) **ABSTRACT**

A modular multi-panel display system includes a mechanical support structure, an array of light emitting diode (LED) display panels arranged in rows and columns and mounted to the mechanical support structure so as to form an integrated display. A receiver box is mounted to the mechanical support, where the receiver box is housed in a housing that is separate from housings of each of the led display panels. The receiver box includes a receiver card coupled to feed data to be displayed on the integrated display to a plurality of the led display panels, where the receiver box includes a network interface card configured to receive data from a control box disposed at a remote location. A monitoring circuit is disposed within the receiver box, where the monitoring circuit is configured to generate an operational data of the array of LED display panels, where the network interface card is configured to send the operational data from the monitoring circuit to a monitoring server.

28 Claims, 15 Drawing Sheets





(51) **Int. Cl.**

G09G 3/34	(2006.01)
G09G 3/20	(2006.01)
G06F 3/14	(2006.01)
G09F 13/22	(2006.01)
G09F 15/00	(2006.01)
G09G 3/00	(2006.01)

(52) **U.S. Cl.**

CPC ***G09F 13/22*** (2013.01); ***G09F 15/0006*** (2013.01); ***G09G 3/006*** (2013.01); ***G09G 3/2096*** (2013.01); ***G09G 3/32*** (2013.01); ***G09G 3/3233*** (2013.01); ***G09G 3/3406*** (2013.01); ***G09G 3/3413*** (2013.01); ***G09G 3/3426*** (2013.01); *G06F 2200/1612* (2013.01); *G09F 2013/222* (2013.01); *G09G 2300/026* (2013.01); *G09G 2310/024* (2013.01); *G09G 2310/0235* (2013.01); *G09G 2320/062* (2013.01); *G09G 2320/064* (2013.01); *G09G 2320/0633* (2013.01); *G09G 2320/0693* (2013.01); *G09G 2330/02* (2013.01); *G09G 2360/04* (2013.01); *G09G 2360/14* (2013.01); *G09G 2360/145* (2013.01); *G09G 2360/16* (2013.01); *G09G 2380/06* (2013.01)

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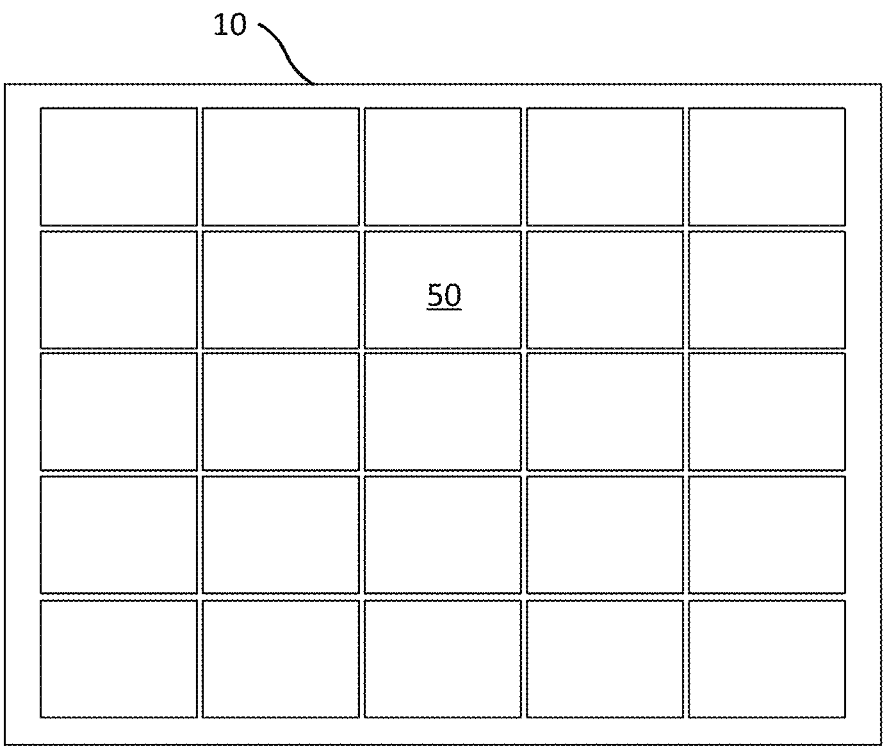
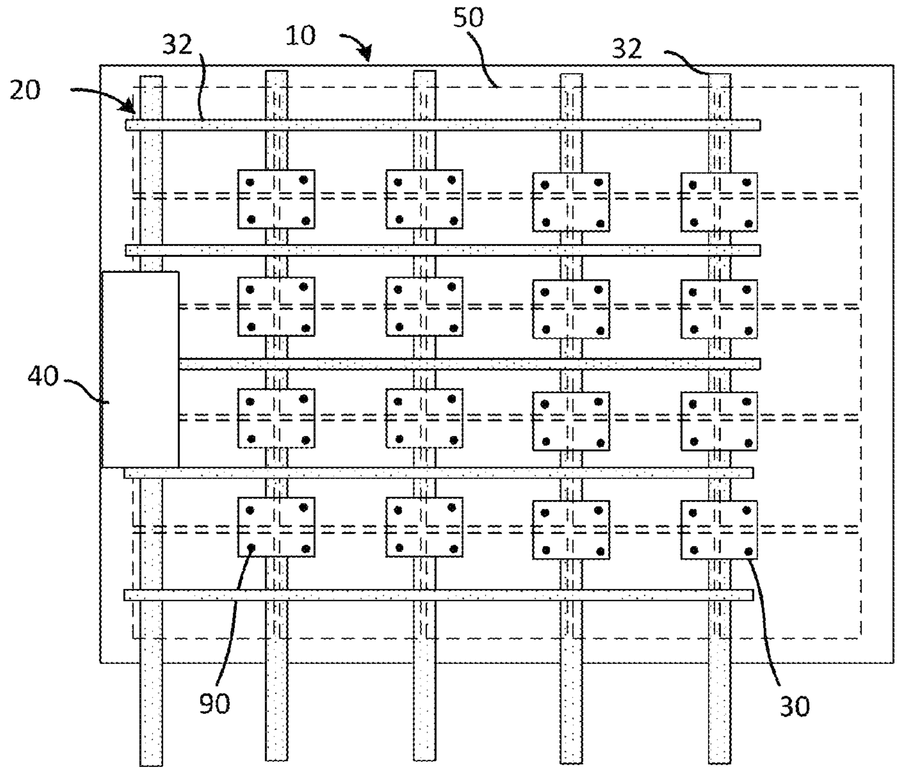


Fig. 1



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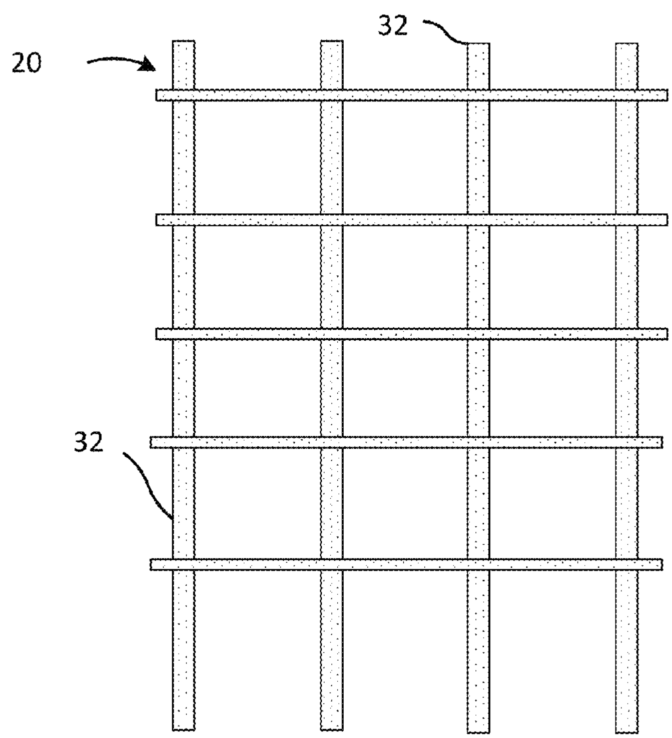


Fig. 3

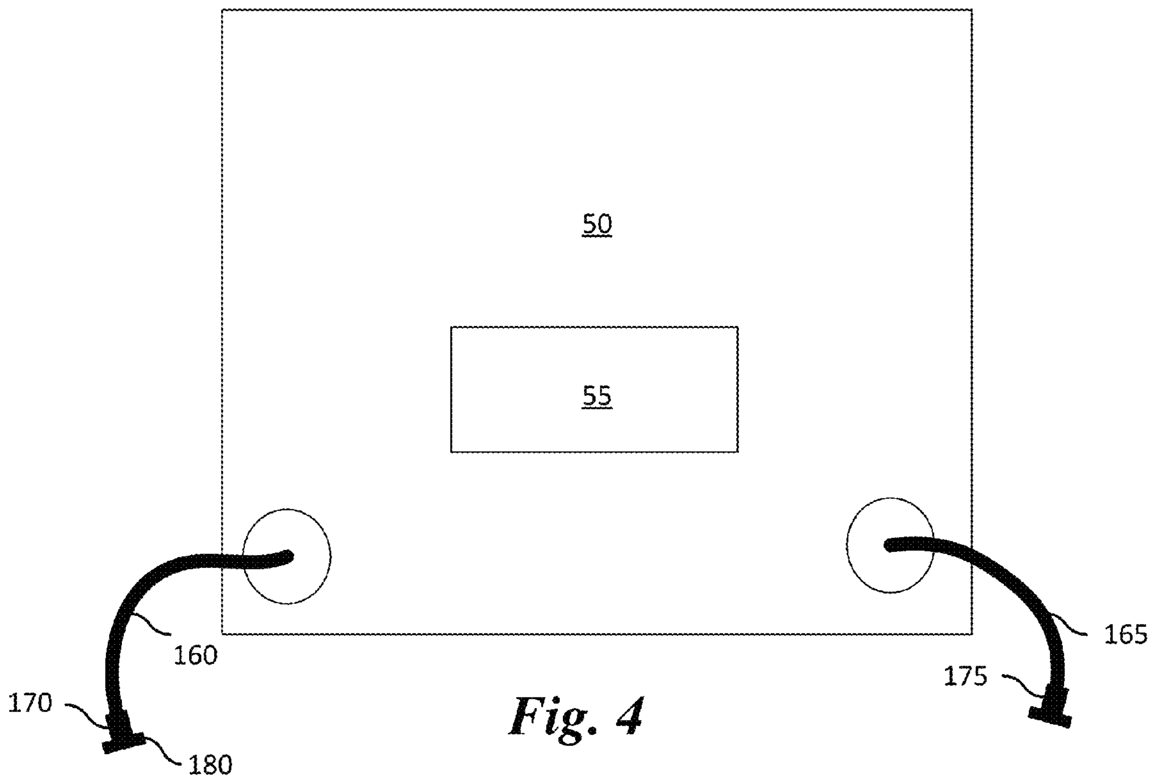


Fig. 4

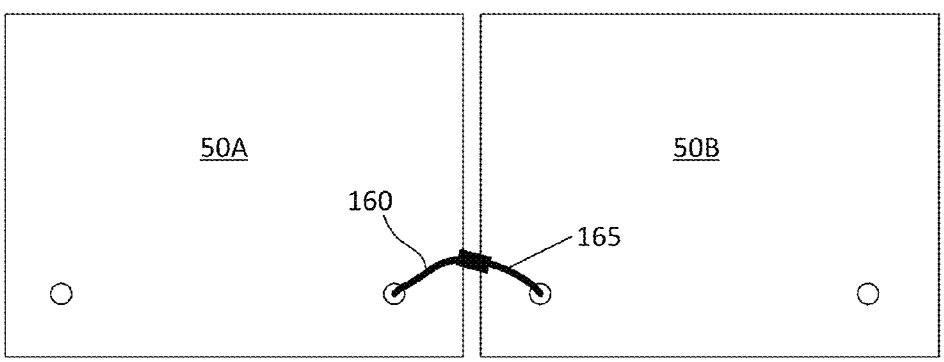
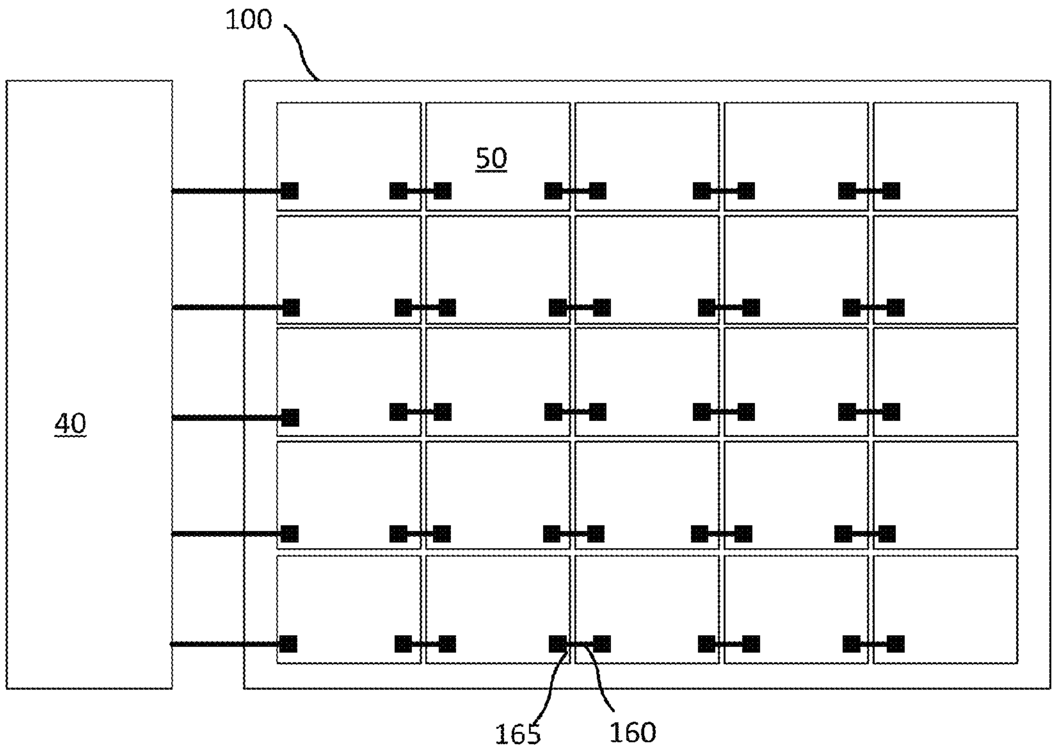


Fig. 5



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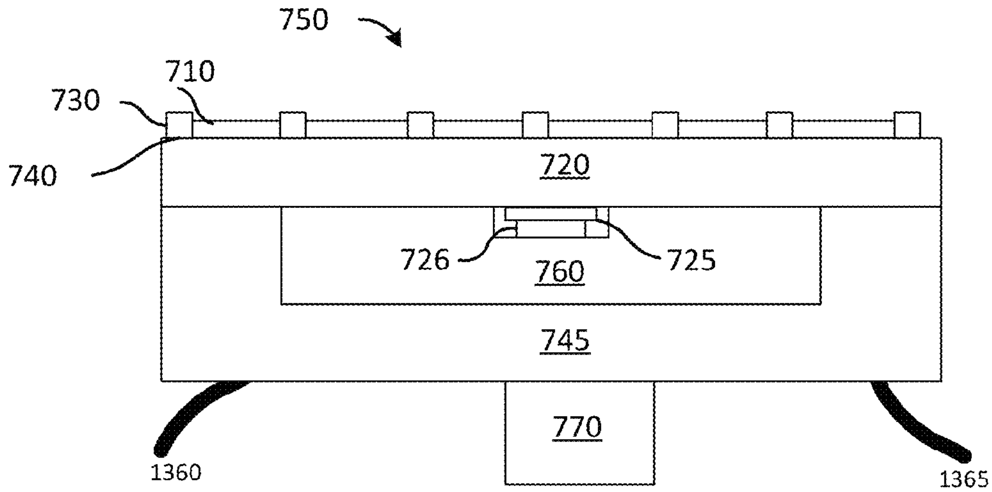
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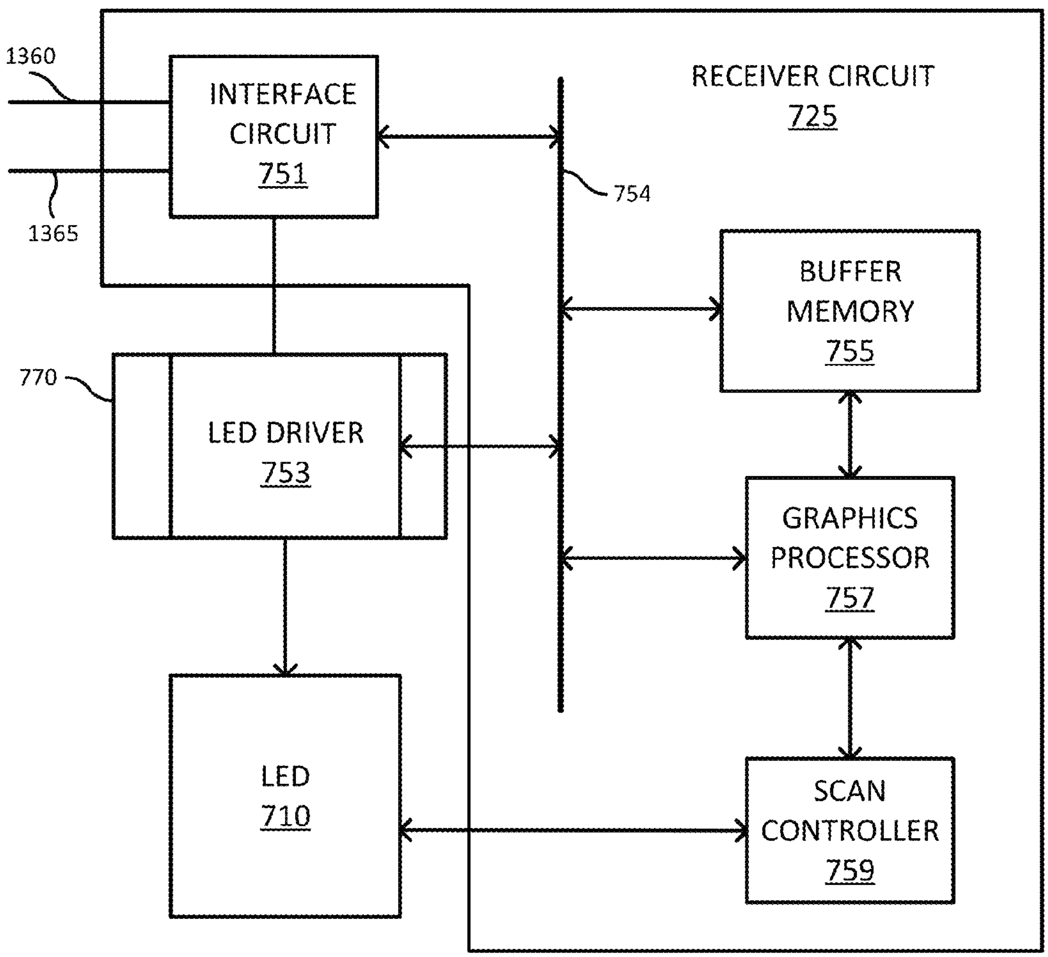
770
1360
1365

Fig. 7A


1360
1365
INTERFACE CIRCUIT 751
RECEIVER CIRCUIT 725
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BUFFER MEMORY 755
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LED DRIVER 753
GRAPHICS PROCESSOR 757
LED 710
SCAN CONTROLLER 759

Fig. 7B

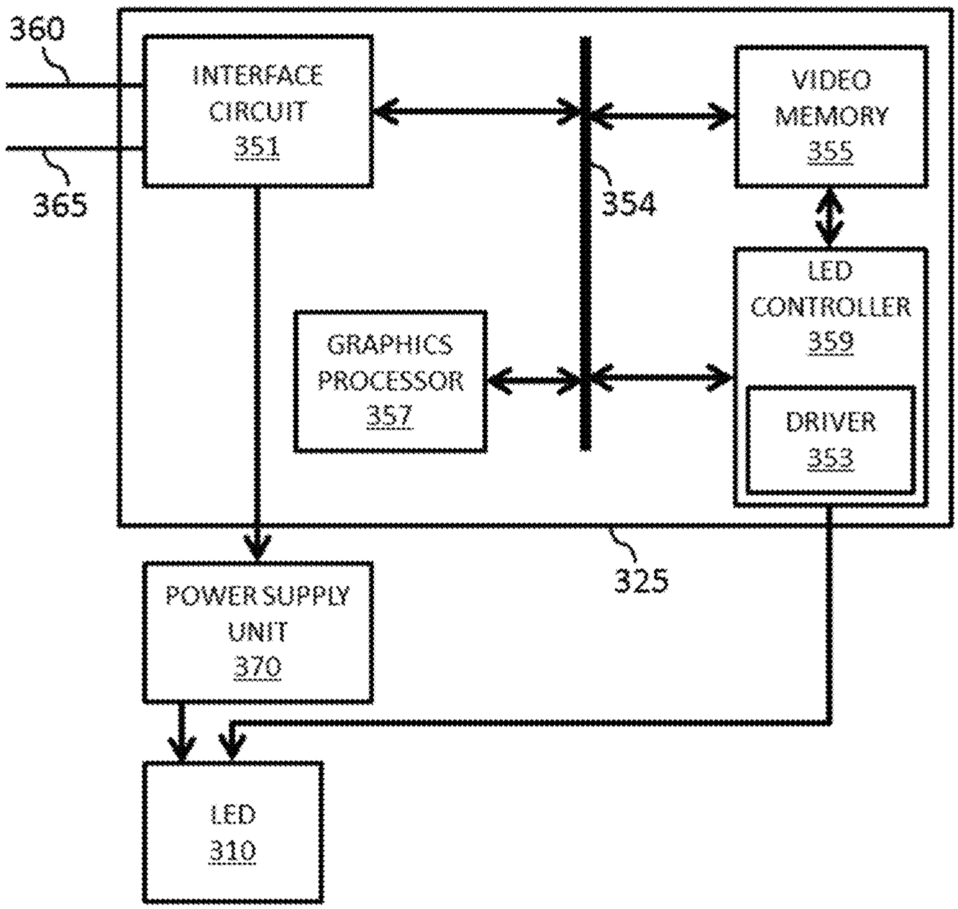
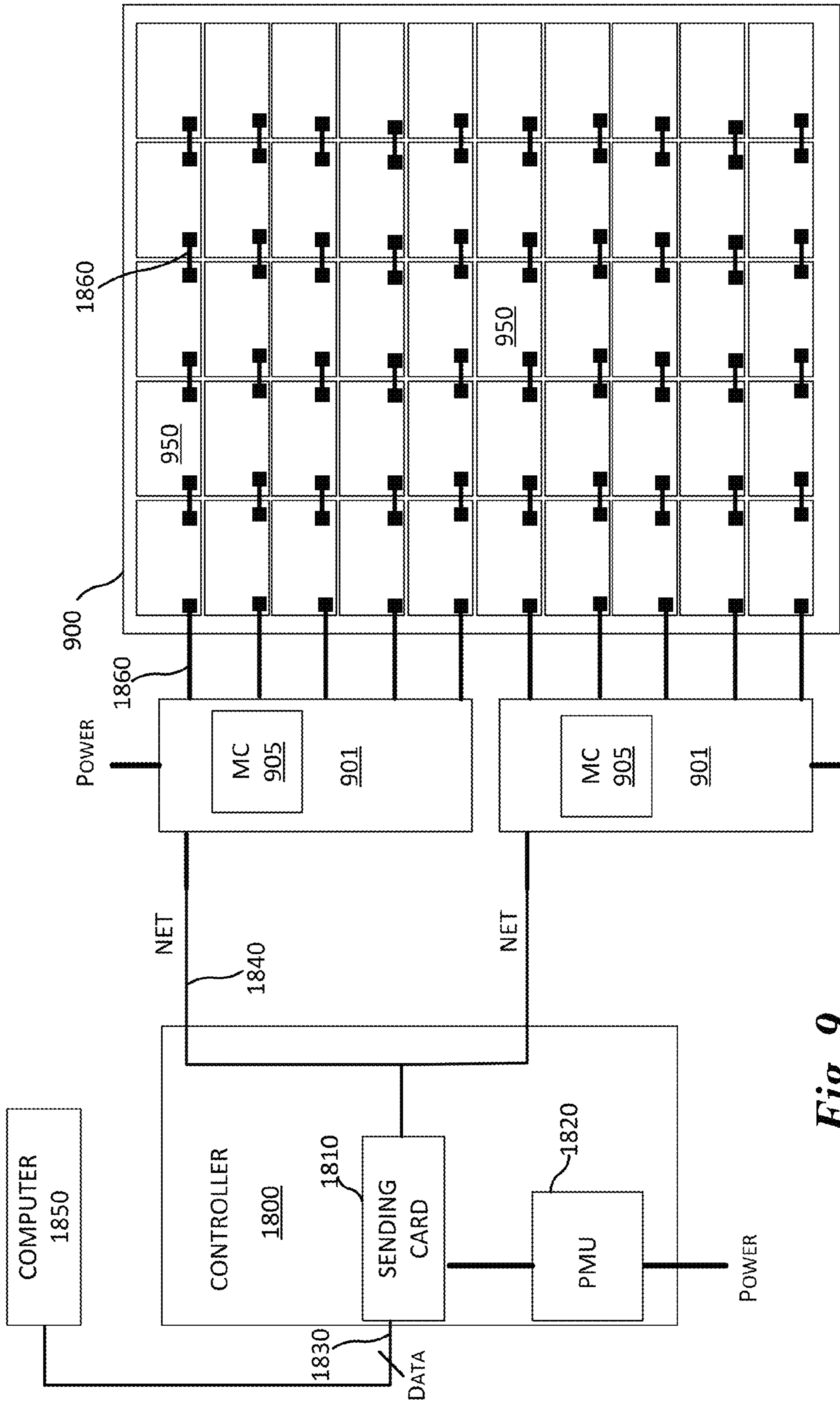

360
365
INTERFACE CIRCUIT 351
354
VIDEO MEMORY 355
LED CONTROLLER 359
GRAPHICS PROCESSOR 357
DRIVER 353
325
POWER SUPPLY UNIT 370
LED 310

Fig. 8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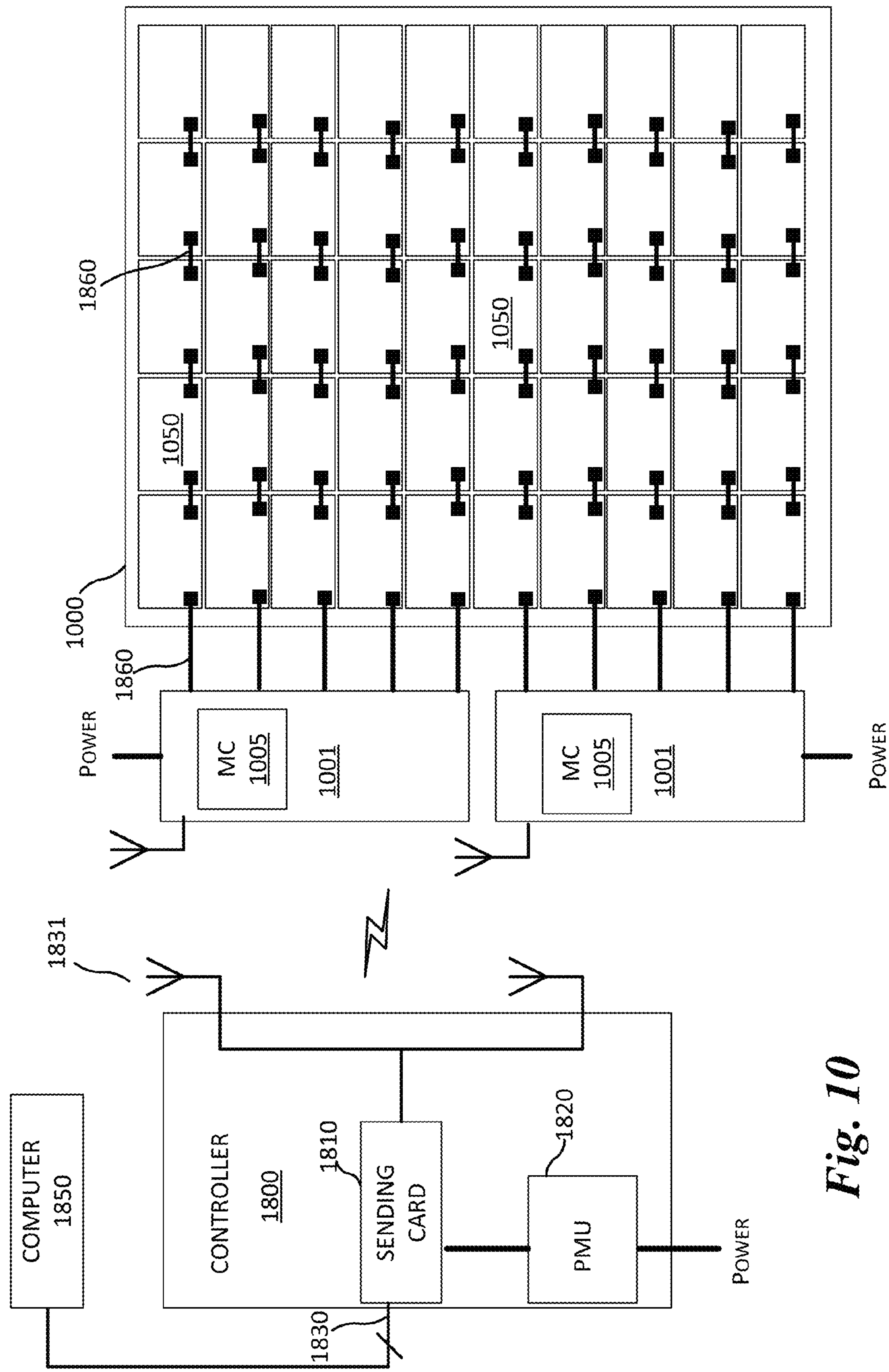
900
950
950
1860
POWER
MC
905
901
MC
905
901
POWER
NET
1840
NET
CONTROLLER
1800
1810
SENDING
CARD
1820
PMU
POWER
COMPUTER
1850
1830
DATA

Fig. 9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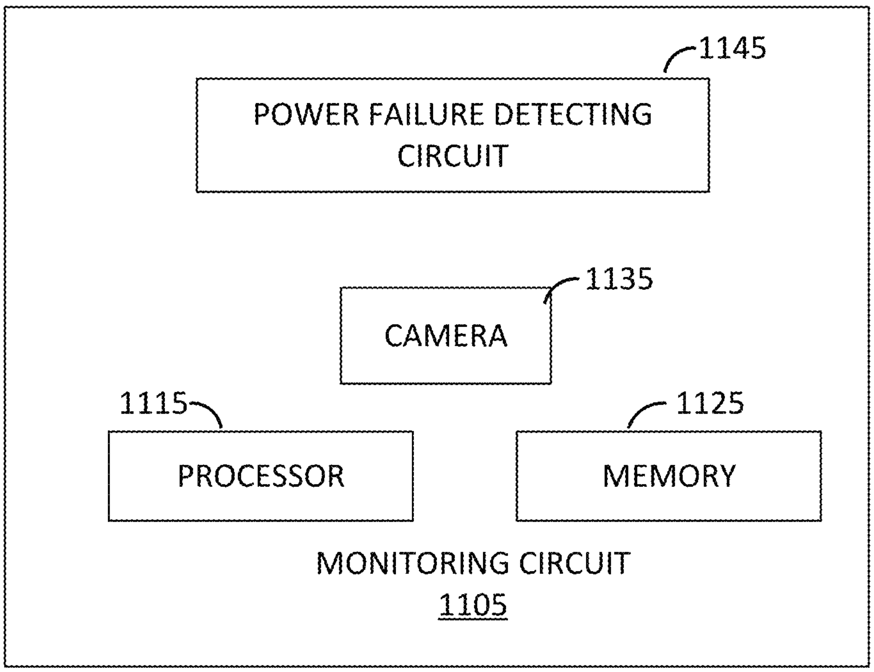
1050
1050
POWER
MC
1005
1001
MC
1005
1001
POWER
1831
COMPUTER
1850
CONTROLLER
1800
1810
SENDING
CARD
1820
PMU
POWER
1830

Fig. 10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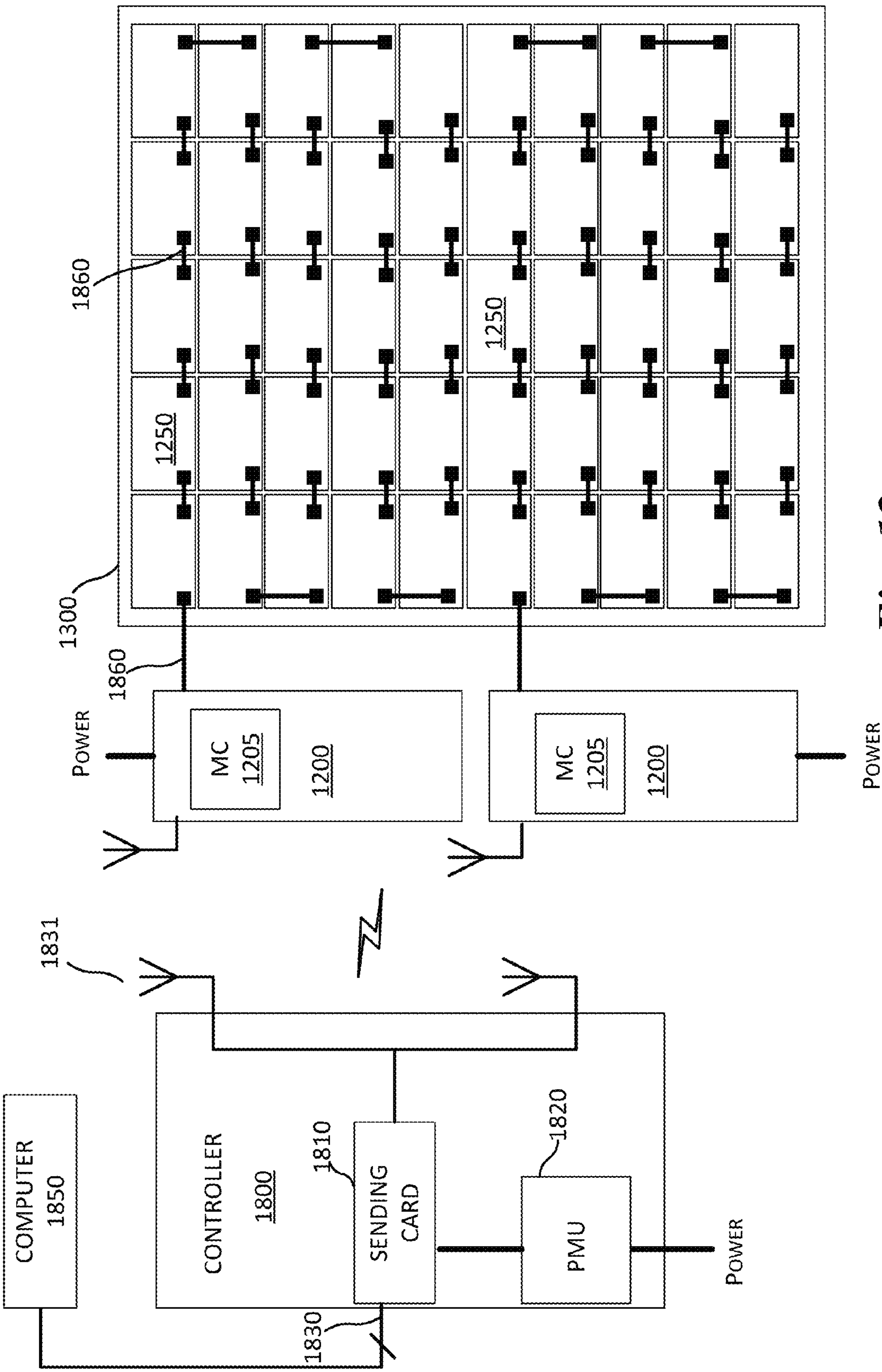
POWER FAILURE DETECTING CIRCUIT
1135
CAMERA
1115
PROCESSOR
1125
MEMORY
MONITORING CIRCUIT
1105

Fig. 11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MC
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MC
1205
1200
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COMPUTER
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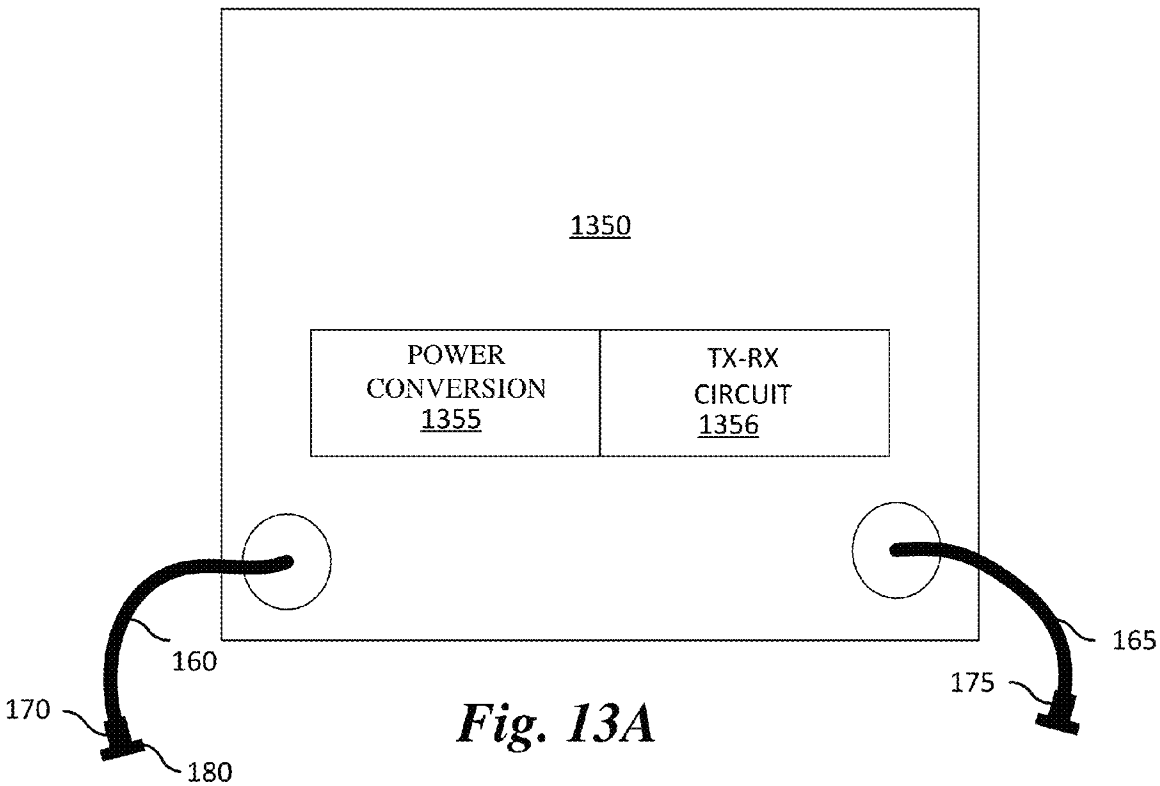
CONTROLLER
1800
1810
SENDING
CARD
1820
PMU
POWER
1830

Fig. 12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POWER
CONVERSION
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TX-RX
CIRCUIT
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160
165
170
175
180

Fig. 13A

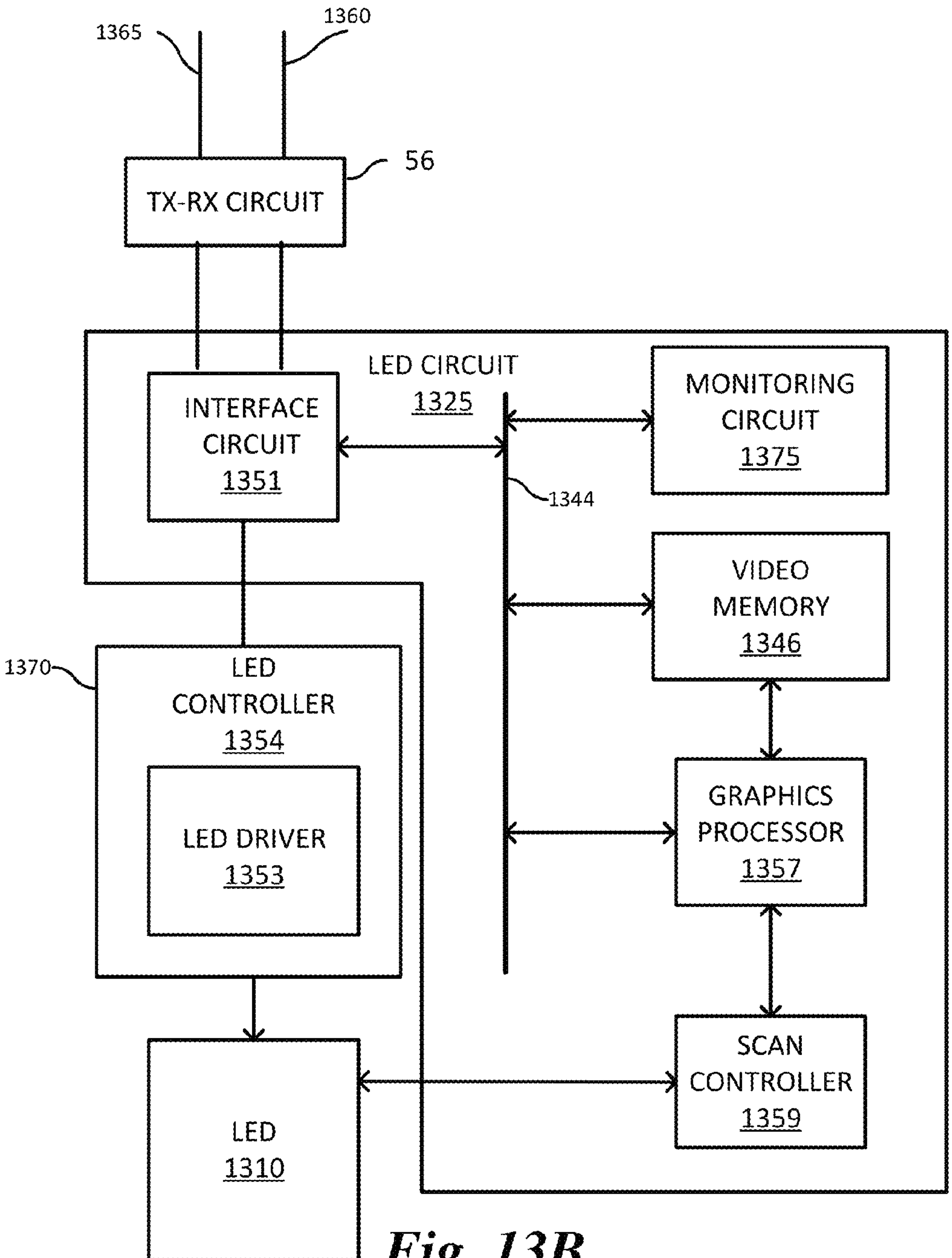
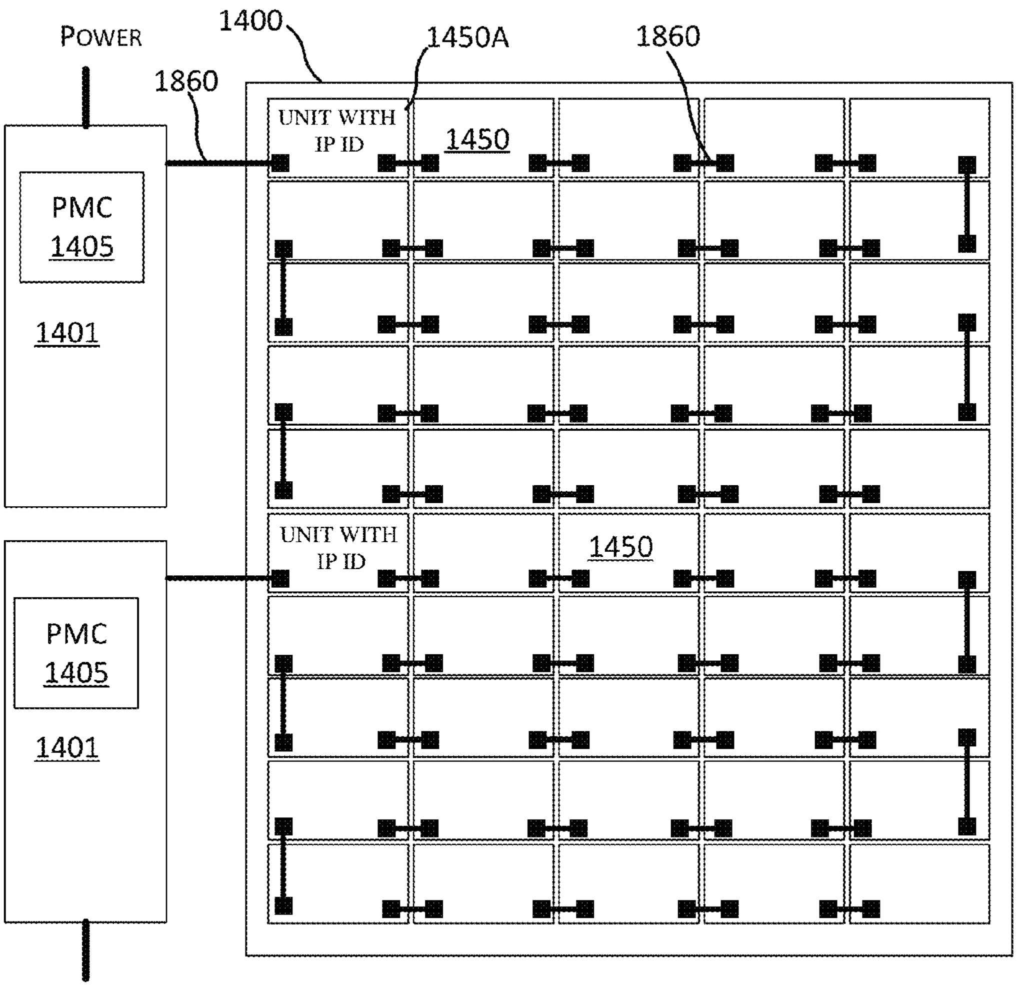

1365
1360
56
TX-RX CIRCUIT
LED CIRCUIT
1325
INTERFACE
CIRCUIT
1351
MONITORING
CIRCUIT
1375
1344
VIDEO
MEMORY
1346
1370
LED
CONTROLLER
1354
LED DRIVER
1353
GRAPHICS
PROCESSOR
1357
SCAN
CONTROLLER
1359
LED
1310

Fig. 13B



POWER
1400
1450A
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1860
UNIT WITH IP ID
1450
PMC
1405
1401
UNIT WITH IP ID
1450
PMC
1405
1401

Fig. 14

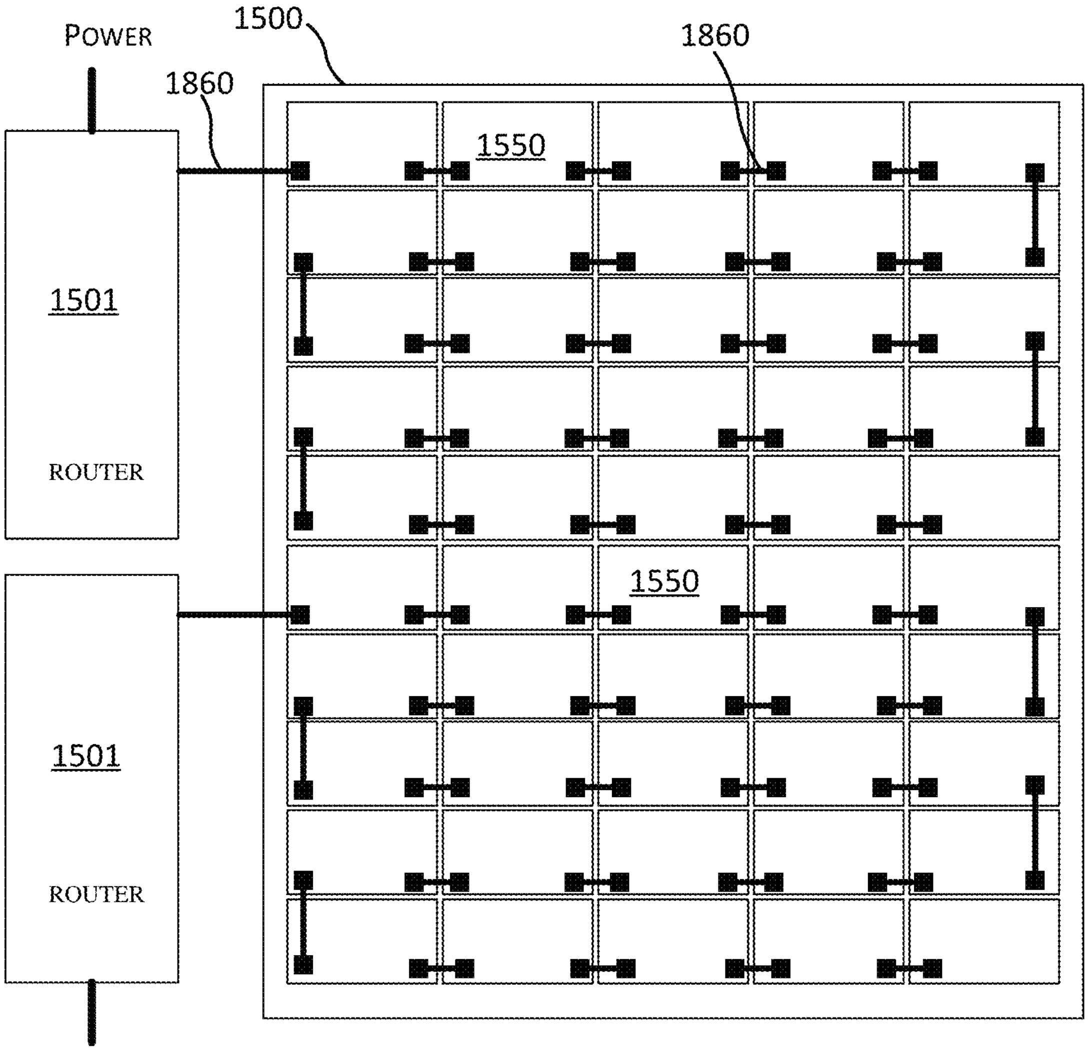

Fig. 15

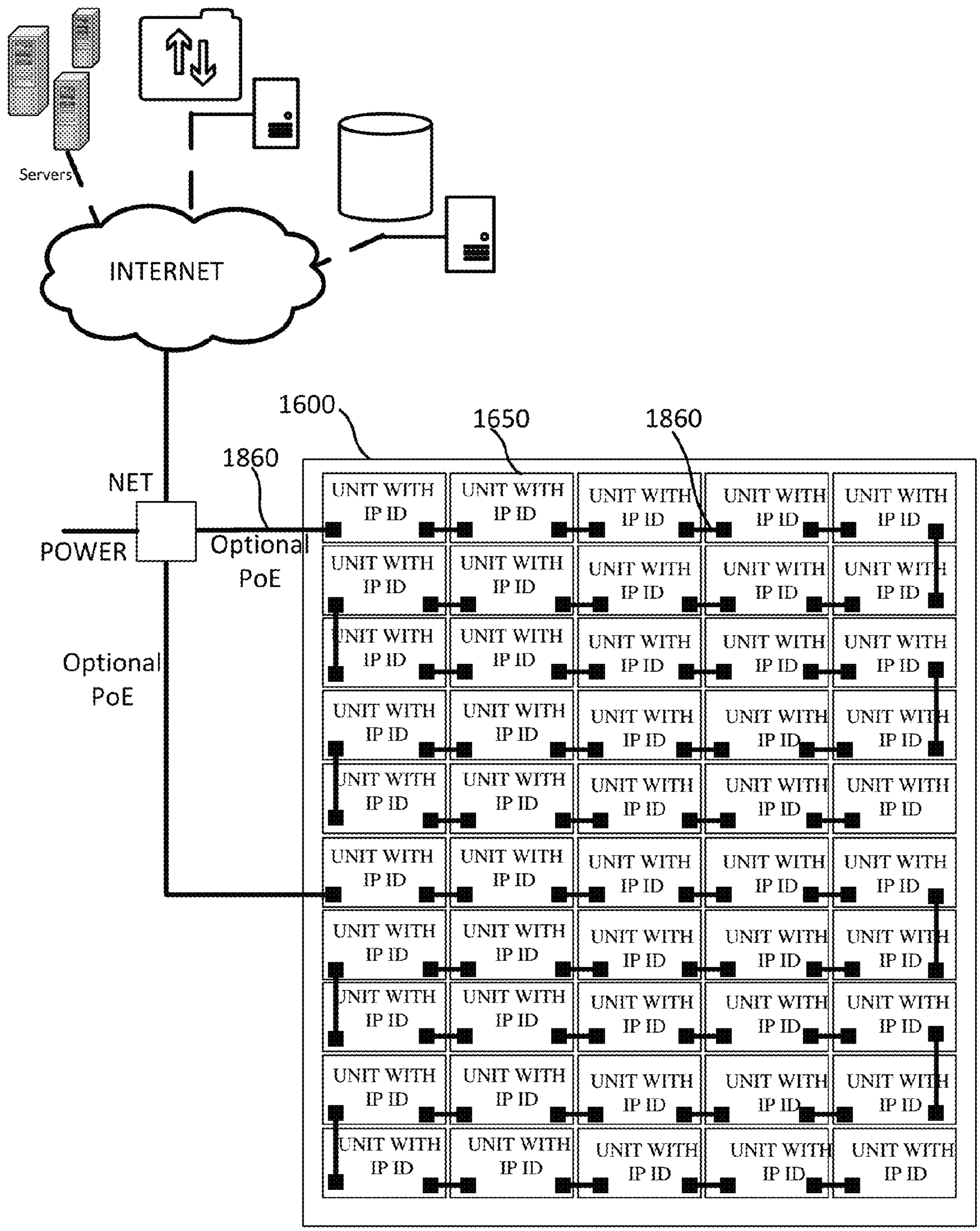
Servers
INTERNET
NET
POWER
Optional PoE
Optional PoE
1860
1600
1650
1860
UNIT WITH IP ID

Fig. 16

DISPLAY SYSTEM HAVING MONITORING CIRCUIT AND METHODS THEREOF

The present application claims priority to the following applications: U.S. Provisional Application 62/158,989 filed on May 8, 2015, U.S. Provisional Application 62/113,342 filed on Feb. 6, 2015, U.S. Provisional Application No. 62/093,157, filed on Dec. 17, 2014, U.S. Provisional Application No. 62/065,510, filed on Oct. 17, 2014, U.S. Provisional Application No. 62/025,463, filed on Jul. 16, 2014. These applications are incorporated herein by reference.

TECHNICAL FIELD

The present invention relates generally to a display panels and systems, and, in particular embodiments, to display system having modular display panel with circuitry for bidirectional communication.

BACKGROUND

Large displays (e.g., billboards), such as those commonly used for advertising in cities and along roads, generally have one or more pictures and/or text that are to be displayed under various light and weather conditions. As technology has advanced and introduced new lighting devices such as the light emitting diode (LED), such advances have been applied to large displays. An LED display is a flat panel display, which uses an array of light-emitting diodes. A large display may be made of a single LED display or a panel of smaller LED panels. LED panels may be conventional panels made using discrete LEDs or surface-mounted device (SMD) panels. Most outdoor screens and some indoor screens are built around discrete LEDs, which are also known as individually mounted LEDs. A cluster of red, green, and blue diodes, or alternatively, a tri-color diode, is driven together to form a full-color pixel, usually square in shape. These pixels are spaced evenly apart and are measured from center to center for absolute pixel resolution.

Many LED display manufacturers sell displays with different resolutions. A present disadvantage of these LED displays is that each one must be a different size to accommodate the pitch needed to obtain the desired resolution. In turn, the existing cabinets and mounting structures must be built to be suitable with the size of the displays.

SUMMARY

In accordance with an embodiment of the present invention, a modular multi-panel display system includes a mechanical support structure, an array of light emitting diode (LED) display panels arranged in rows and columns and mounted to the mechanical support structure so as to form an integrated display. A receiver box is mounted to the mechanical support, where the receiver box is housed in a housing that is separate from housings of each of the led display panels. The receiver box includes a receiver card coupled to feed data to be displayed on the integrated display to a plurality of the led display panels, where the receiver box includes a network interface card configured to receive data from a control box disposed at a remote location. A monitoring circuit is disposed within the receiver box, where the monitoring circuit is configured to generate an operational data of the array of LED display panels, where the network interface card is configured to send the operational data from the monitoring circuit to a monitoring server.

In accordance with another embodiment of the present invention, a modular multi-panel display system includes a mechanical support structure, and an array of led display panels arranged in rows and columns and mounted to the mechanical support structure so as to form an integrated display. Each of the array LED display panels includes a network interface card configured to receive data from a control box disposed at a remote location. Each of the array LED display panels includes a network interface card coupled to feed data to be displayed on the integrated display. Each of the array LED display panels includes a monitoring circuit configured to generate an operational data for the corresponding led display panel, where the network interface card is configured to send the operational data from the monitoring circuit to a monitoring server.

In accordance with another embodiment of the present invention, a method of maintaining a modular multi-panel display includes a mechanical support structure and a plurality of LED display panels detachably coupled to the mechanical support structure without a cabinet, where each led display panel has a data port that is bidirectionally coupled to at least one other LED display panel and includes a power supply coupled to a power line that extends along a group of the led display panels. The method further includes monitoring the power supply of each LED display panel, and determining that a defective LED display panel has a defect by determining that the power supply of the defective led display panel is not converting power.

In accordance with another embodiment of the present invention, a method of maintaining a modular multi-panel display includes a mechanical support structure and a plurality of LED display panels detachably coupled to the mechanical support structure without a cabinet. Each led display panel has a data port that is bidirectionally coupled to at least one other LED display panel. The method further includes monitoring power consumption of each LED pixel in each LED display panel and determining that a defective LED display panel has a defective LED pixel based upon a result of the monitoring.

BRIEF DESCRIPTION OF THE DRAWINGS

For a more complete understanding, reference is now made to the following description taken in conjunction with the accompanying drawings in which:

FIG. **1** illustrates a modular display panel in accordance with an embodiment of the present invention;

FIG. **2** illustrates a modular display panel attached to a supporting frame in accordance with an embodiment of the present invention;

FIG. **3** illustrates a frame used to provide mechanical support to the modular display panel in accordance with an embodiment of the present invention.

FIG. **4** illustrates one LED display panel of the multi-panel modular preassembled display unit comprising an input cable and an output cable;

FIG. **5** illustrates two display panels next to each other and connected through the cables such that the output cable of the left display panel is connected with the input cable of the next display panel;

FIG. **6** illustrates a modular multi-panel display system comprising a plurality of LED display panels connected together using the afore-mentioned cables;

FIGS. **7A** and **7B**, illustrates a display panel in accordance with an embodiment of the present invention, wherein FIG. **7A** illustrates a cross-sectional view of a display panel while

FIG. **7**B illustrates a system diagram schematic of the display panel in accordance with an embodiment of the present invention;

FIG. **8** illustrates an alternative system diagram schematic of the display panel in accordance with an embodiment of the present invention;

FIG. **9** illustrates an embodiment of the present invention describing a monitoring controller disposed within a data receiver box;

FIG. **10** illustrates an alternative embodiment, in which the data receiver box **1001** also has wireless connectivity;

FIG. **11** illustrates a general schematic of a monitoring circuit in accordance with an embodiment of the present invention;

FIG. **12** illustrates an embodiment of the present invention in which the display panels are connected serially;

FIG. **13**A illustrates a back side of an individual LED display panel in accordance with an embodiment of the present invention;

FIG. **13**B illustrates a more detailed schematic of the circuit with a LED circuit showing a separate TX-RX circuit for establishing bidirectional communication;

FIG. **14** illustrates an embodiment of the display system in which the data receiver box has minimal functionality;

FIG. **15** illustrates an alternative embodiment of the present invention; and

FIG. **16** illustrates an alternative embodiment of the present invention in which each display panel has a unique IPV6 IP address.

DETAILED DESCRIPTION OF ILLUSTRATIVE EMBODIMENTS

In the following discussion, exterior displays are used herein for purposes of example. It is understood that the present disclosure may be applied to lighting for any type of interior and/or exterior display.

Installation of large display panels is a labor intensive process requiring skilled labor working in dangerous conditions for extended times. For example, to install a conventional display on a large multi-story building, the installers have to climb to the mounting wall (typically many stories high) and individually screw in each display and the corresponding cables etc. This is both time consuming and poses a significant safety threat thereby increasing the cost of the system dramatically.

Further, it is very difficult to know when a panel becomes defective. Typically, an observer or a customer has to take notice and inform the operator of the billboard when one or more panels are not functioning or functioning poorly. Embodiments of the present invention overcome these and other limitations by enabling bidirectional communication in which the billboard includes intelligence to initiate the replacement.

Further, when a particular display becomes defective during operation, the cost of replacement can be very high due to need for a highly skilled person to work in such difficult working conditions. The defective display has to be individually removed and replaced from the housing or cabinet in which it is mounted.

Embodiments of the invention provide preassembled display panel units, each of which provides a completely self-contained building block that is lightweight. Consequently, replacement of defective units is very simple and a person with no skill can easily remove and replace a defective display. Accordingly, embodiments of the present invention significantly reduce the operating cost of the display.

These display units are designed to be weather proof, without a heavy cabinet, although it is understood that the present disclosure may be applied to lighting for any type of interior and/or exterior display. The lightweight design allows for easier installation and maintenance, thus lowering total cost of ownership.

Embodiments of the invention provide building block panels that are configurable with future expandability. These displays can offer complete expandability to upgrade in the future without having to replace the entire display. Installation is fast and easy with very little down-time, which allows any electronic message to be presented more quickly.

In various embodiments, the display panels are "hot swappable." By removing one screw in each of the four corners of the panel, servicing the display panel is fast and easy. Since a highly-trained, highly-paid electrician or technician is not needed to correct a problem, cost benefits can be achieved.

Embodiments of the invention relate to lighting systems and, more particularly, to multi-panel lighting systems for providing interior or exterior displays.

FIG. **1** illustrates a modular display panel in accordance with an embodiment of the present invention. FIG. **2** illustrates a modular display panel attached to a supporting frame in accordance with an embodiment of the present invention. FIG. **3** illustrates a frame used to provide mechanical support to the modular display panel in accordance with an embodiment of the present invention.

The multi-panel modular preassembled display unit **10** comprises a plurality of LED display panels **50**. In various embodiments describe herein, the light emitting diode (LED) display panels **50** are attached to a frame **20** or skeletal structure that provides the framework for supporting the LED display panels **50**. The LED display panels **50** are stacked next to each other and securely attached to the frame **20** using attachment plate **30**, which may be a corner plate in one embodiment. The attachment plate **30** may comprise holes through which attachment features **90** may be screwed in, for example.

In various embodiments, the preassembled display unit **10** may be used in a window display, billboard display, or other types of displays such as video walls, personal display screens and others. The preassembled display unit **10** may be sound enabled, for example, coupled to a common sound system in some embodiments. The sound system may be activated or deactivated depending on external conditions such as the presence of a user in some embodiments.

Referring to FIGS. **1** and **2**, the LED display panels **50** are arranged in an array of rows and columns. Each LED display panel **50** of each row is electrically connected to an adjacent LED display panel **50** within that row.

Referring to FIG. **3**, the frame **20** provides mechanical support and electrical connectivity to each of the LED display panels **50**. The frame **20** comprises a plurality of beams **32** forming the mechanical structure. The frame **20** comprises a top bar, a bottom bar, a left bar, a right bar, and a plurality of vertical bars extending from the top bar to the bottom bar, the vertical bars disposed between the left bar and the right bar. The top bar, the bottom bar, the left bar and the right bar comprise four inch aluminum bars and wherein the vertical bars comprise 2"×4"×½" aluminum tubes. The top bar, the bottom bar, the left bar and the right bar are each capable of bearing a load of 1.738 lb/ft and the vertical bars are each capable of bearing a load of 3.23 lb/ft.

The size of the individual panels may vary, for example, may be 2 ft×3 ft, 3 ft×4 ft, as examples. For example, a display system could include 336 panels that are each 1'×2' in dimension to create a 14'×48' display. In such a display, because each panel is lighter than typical panels, the entire display could be built to weigh only 5500 pounds. This compares favorably to commercially available displays of the size, which generally weigh from 10,000 to 12,000 pounds. In another embodiment, a display system could include 320 LED display panels **50** arranged in ten rows and thirty-two columns so that the integrated display panel **100** has a display surface that is approximately fifty feet and four inches wide and fifteen feet and eight and three-quarters inches high. In other embodiments, displays with an arbitrary number of panels can be used.

The frame **20** may include support structures for the electrical cables, data cables, electrical power box powering the LED display panels **50**, data receiver box controlling power, data, and communication to the LED display panels **50**.

However, the frame **20** does not include any additional enclosures to protect the LED panels, data, power cables from the environment. Rather, the frame **20** is exposed to the elements and further exposes the LED display panels **50** to the environment. The frame **20** also does not include air conditioning, fans, heating units to maintain the temperature of the LED display panels **50**. Rather, the LED display panels **50** are hermetically sealed themselves and are designed to be exposed to the outside ambient. Further, in various embodiments, there are no additional cabinets that are attached to the frame **20** or used for housing the LED display panels **50**. Accordingly, in various embodiments, the multi-panel modular preassembled display unit **10** is designed to be only passively cooled.

FIG. **4** illustrates one LED display panel **50** of the multi-panel modular preassembled display unit **10** comprising an input cable **160** and an output cable **165**. The LED display panels **50** are electrically connected together for data and for power using the input cable **160** and the output cable **165**.

Each modular LED display panel **50** is capable of receiving input using an integrated data and power cable from a preceding modular LED display panel and providing an output using another integrated data and power cable to a succeeding modular LED display panel. Each cable ends with an end-point device or connector, which is a socket or alternatively a plug.

Referring to FIG. **4**, in accordance with an embodiment, a LED display panel **50** comprises an attached input cable **160** and an output cable **165**, a first connector **170**, a second connector **175**, a sealing cover **180**. The sealing cover **180** is configured to go over the second connector **175** thereby hermetically sealing both ends (first connector **170** and the second connector **175**). The sealing cover **180**, which also includes a locking feature, locks the two cables together securely. The input cable **160** and the output cable **1365** comprise integrated data and power wires with appropriate insulation separating them.

FIG. **5** illustrates two display panels next to each other and connected through the cables such that the output cable **165** of the left display panel **50**A is connected with the input cable **160** of the next display panel **50**B. The sealing cover **180** locks the two cables together as described above.

FIG. **6** illustrates a modular multi-panel display system comprising a plurality of LED display panels connected together using the afore-mentioned cables.

Referring to FIG. **6**, for each row, a LED display panel **50** at a first end receives an input data connection from a data source and has an output data connection to a next LED display panel in the row. Each further LED display panel **50** provides data to a next adjacent LED display panel until a LED display panel **50** at second end of the row is reached. The power line is run across each row to power the LED display panels **50** in that row.

In one embodiment, the plurality of LED display panels **50** are arranged in ten rows and thirty-two columns so that the integrated display panel **100** has a display surface that is approximately fifty feet and four inches wide and fifteen feet and eight and three-quarters inches high.

In various embodiments, as illustrated in FIGS. **2** and **6**, a data receiver box **40** is mounted to the mechanical support structure or frame **20**. The data receiver box **40** is configured to provide power, data, and communication to the LED display panels **50**. With a shared data receiver box **40**, the panels themselves do not need their own receiver card. This configuration saves cost and weight.

FIGS. 7A and 7B, illustrates a display panel in accordance with an embodiment of the present invention. FIG. **7**A illustrates a cross-sectional view of a display panel while FIG. **7**B illustrates a schematic of the display panel.

Referring to FIG. 7A, the modular LED display panel comprises a plurality of LEDs **710** mounted on one or more printed circuit boards (PCBs) **720**, which are housed within a hermetically sealed enclosure or casing. A framework of louvers **730** is attached to the PCB **720** using an adhesive **740**, which prevents moisture from reaching the PCB. However, the LEDs **710** are directly exposed to the ambient in the direction of light emission. The LEDs **710** themselves are water repellent and therefore are not damaged even if exposed to water. The louvers **730** rise above the surface of the LEDs and help to minimize reflection and scattering of external light, which can otherwise degrade the quality of light output from the LEDs **710**.

The PCB is mounted within a cavity of an enclosure, which may be a plastic casing **745**. A heat sink **760** is attached between the PCB **720** and the casing **745** and contacts both the PCB **720** and the casing **745** to maximize heat extraction. A thermal grease may be used between the back side of the casing **745** and the PCB **720** to improve thermal conduction. In one example embodiment, the thermal grease is between the heat sink **760** and the back side of the casing **745**. In a further example embodiment, the thermal grease is between the PCB **720** and the heat sink **760**.

A receiver circuit **725** is mounted on the PCB **1620**. The receiver circuit **725** may be a single chip in one embodiment. Alternatively, multiple components may be mounted on the PCB **720**. The receiver circuit **725** may be configured to process the received media and control the operation of the individual LEDs **710**. For example, the receiver circuit **725** may determine the color of the LED to be displayed at each location (pixel). Similarly, the receiver circuit **725** may determine the brightness at each pixel location, for example, by controlling the current supplied to the LED.

The air gap within the cavity is minimized so that heat is conducted out more efficiently. Thermally conductive standoffs **726** may be introduced between the PCB **720** to minimize the air gap, for example, between the receiver circuit **725** and the heat sink **760**. The PCB **720** is designed to maximize heat extraction from the LEDs **710** to the heat sink **760**. As described previously, the casing **745** of the display panel **750** has openings through which an input cable **1360** and output cable **1365** may be attached. The cables may have connectors or plugs for connecting to an adjacent panel or alternatively the casing **745** may simply have input and output sockets.

A power supply unit **770** may be mounted over the casing **745** for powering the LEDs **710**. The power supply unit **770** may comprise a LED driver in various embodiments. The LED driver may include a power converter for converting AC to DC, which is supplied to the LEDs **710**. Alternatively, the LED driver may comprise a down converter that down converts the voltage suitable for driving the LEDs **710**. For example, the down converter may down convert a DC voltage at a first level to a DC voltage at a second level that is lower than the first level. This is done so that large DC currents are not carried on the power cables. The LED driver is configured to provide a constant DC current to the LEDs **710**.

Examples of down converters (DC to DC converters) include linear regulators and switched mode converters such as buck converters. In further embodiments, the output from the power supply unit **770** is isolated from the input power. Accordingly, in various embodiments, the power supply unit **770** may comprise a transformer. As a further example, in one or more embodiments, the power supply unit **770** may comprise a forward, half-bridge, full-bridge, push-pull topologies.

The power supply unit **770** may be placed inside a Faraday cage to minimize RF interference to other components. The LED driver of the power supply unit **770** may also include a control loop for controlling the output current. In various embodiments, the display panel **750** is sealed to an IP 67 standard. As discussed herein, other ratings are possible.

FIG. **7**B illustrates a system diagram schematic of the display panel in accordance with an embodiment of the present invention.

Referring to FIG. **7**B, a data and power signal received at the input cable **1360** is processed at an interface circuit **751**. The incoming power is provided to the LED driver **753**. Another output from the incoming power is provided to the output cable **1365**. This provides redundancy so that even if a component in the display panel **750** is not working, the output power is not disturbed. Similarly, the output cable **765** includes all the data packets being received in the input cable **1360**.

The interface circuit **751** provides the received data packets to the graphics processor **757** through a receiver bus **754**. In some embodiments, the interface circuit **751** provides only the data packets intended for the display panel **750**. In other embodiment, the interface circuit **751** provides all incoming data packets to the graphics processor **757**. For example, the graphics processor **757** may perform any decoding of the received media. The graphics processor **757** may use the buffer memory **755** or frame buffer as needed to store media packets during processing.

A scan controller **759**, which may include an address decoder, receives the media to be displayed and identifies individual LEDs in the LEDs **710** that need to be controlled. The scan controller **759** may determine an individual LEDs color, brightness, refresh time, and other parameters associated to generate the display. In one embodiment, the scan controller **759** may provide this information to the LED driver **753**, which selects the appropriate current for the particular LED.

Alternatively, the scan controller **759** may interface directly with the LEDs **710** in one embodiment. For example, the LED driver **753** provides a constant current to the LEDs **710** while the scan controller **759** controls the select line needed to turn ON or OFF a particular LED. Further, in various embodiments, the scan controller **759** may be integrated into the LED driver **753**.

FIG. **8** illustrates an alternative system diagram schematic of the display panel in accordance with an embodiment of the present invention.

Referring to FIG. **8**, a data and power signal received at first cable **360** is processed at an interface circuit **351** of receiver circuit **325**. The incoming power is provided to a power supply unit **370**.

Another output from the incoming power is provided to second cable **365**. This provides redundancy so that even if a component in the LED display panel **150** is not working, the output power is not disturbed. Similarly, second cable **365** includes all the data being received in first cable **360**.

In this embodiment, the interface circuit **351** provides the received data to the graphics processor **357** through a data bus **354**. In some embodiments, the interface circuit **351** provides only the data segments intended for the LED display panel **150**. In other embodiments, the interface circuit **351** provides all incoming data to the graphics processor **357**. For example, the graphics processor **357** may perform any necessary decoding or (when signaling between panels is analog) analog-to-digital conversion of the received media. In other embodiments, the interface circuit **351** interfaces directly with the LED controller **359** without use of a graphics processor **357**. In the embodiment of FIG. 3B, the graphics processor **357**, LED controller **359**, or interface circuit **351** may use the buffer video memory **355** as needed to store video segments during processing. In some embodiments, the buffer video memory **355** may be a component of the LED controller **359**. The buffer video memory **355** may also be used to digitally store video segments temporarily until the receiver circuit **325** collects enough data for simultaneous display by the LEDs **310**. This collection of data may be a video frame for simultaneous display by all of the LEDs of the display panel, or it may be a smaller portion of data for display by a subset of the LEDs in accordance with, for example, a scanning pattern. The buffer video memory **355** may also be used to temporarily store video segments destined for other display panels.

The LED controller **359**, which may include an address decoder (e.g., a demultiplexer), receives the media to be displayed and identifies individual LEDs in the LEDs **310** that need to be controlled. The LED controller **359** may determine an individual LED's color, brightness, refresh time, and other parameters associated to generate the display. For example, at each pixel location in the display, the color of the pixel may be selected by powering one or more combination of red, blue, green, and white LEDs. The LED controller **359** may include control circuitry such as a row selector and column selector for determining LED parameters as an example. In one embodiment, the LED controller **359** may provide these LED parameters to the current driver **353**, which acts as either a current source or a current sink to select the appropriate current for the particular LED. In some embodiments, the current driver **353** acts as a current source or sink to provide a constant current with a constant pulse width to the LEDs **310**. In other embodiments, the current driver **353** varies the duty cycle of a constant current to pulse width modulate the brightness of the LEDs **310**. The current driver **353** may either be a component of the LED controller **359** or may be located outside the LED controller **359**, such as, for example, being located inside the power supply unit **370**.

The power supply unit **370** may include, for example, a power converter for converting AC to DC, which is supplied to the LEDs **310**. Alternatively, the power supply unit **370** may include a down converter that down converts the voltage suitable for driving the LEDs **310**.

In one embodiment, the power supply unit includes a scan controller that interfaces directly with the LEDs **310**. For example, the current driver **353** may provide a constant current to the LEDs **310** while a scan controller of the power supply unit **370** controls the select line needed to turn ON or OFF a particular LED. In some embodiments, a scan controller of the power supply unit **370** is implemented as an array of switches or transistors that switches incoming power to a selected row or column of LEDs **310**. In other embodiments, the scan controller switches the output of the LED controller **359** to a selected row or column. The scan controller switches the LED controller output or power in accordance with, for example, an LED address, a row address, a column address, a pre-configured scanning pattern for scan groups of linked LEDs that should be activated simultaneously, or a scan select signal that specifies which scan group should be activated.

FIG. **9** illustrates an embodiment of the present invention describing a monitoring controller **905** disposed within a data receiver box **901**. The monitoring controller **905** is configured to monitor power failure in one or more display panels **950** and report to the computer **1850** or to a different receiving monitoring server. In various embodiments, the monitoring controller **905** is configured to monitor illumination or brightness of one or more panels. The monitoring controller **905** may also monitor the network between the data receiver box **901** and the outside internet including computer **1850** as well as the local area network (or equivalent wireless network) connecting the individual display panels **950** of the display system **900**.

The monitoring controller **905** may be used for other purposes as well. For example, in one or more embodiments, the display panels **950** may include one or more sensors to self-regulate operation based on external conditions. For example, the sensor may reduce or increase the brightness of the display panels based on the ambient light. Alternatively, in some embodiments, the display panels may sense the presence of an observer (e.g., human) and modulate the content being displayed. For example, the display may be powered off until a human approaches the display.

FIG. **10** illustrates an alternative embodiment, in which the data receiver box **1001** also has wireless connectivity. The data receiver box **1001** may include wired data connection as described in FIG. **9**, as well as wireless data connection as illustrated in FIG. **10**. Accordingly, for example, if a network failure is detected, the monitoring circuit **1005** may generate an error message, which is then transmitted to a monitoring server or the computer **1850** using the wireless channel.

FIG. **11** illustrates a general schematic of a monitoring circuit in accordance with an embodiment of the present invention.

In one or more embodiments, as illustrated in FIG. **11**, a monitoring circuit **1105** may include a power failure detecting circuit **1145**, a camera **1135**, which may include both visible, infrared and other spectrum to collect additional information. The monitoring circuit **1105** may include a processor **1115** or may use the common processor within the data receiver box. The camera may be automatically periodically activated to image the display system. The image may be processed to identify any issues with the display. For example, using an image processing software executing on the processor **1115**, the power failure, dark pixels, lowered brightness may be detected. In case of a failure, a failure message is generated and transmitted to a monitoring server.

The monitoring circuit **1105** may include a memory **1125** to store the images and the results of the processing. In one or more embodiments, the monitoring circuit may include only a camera **1135**. In one embodiment, the camera **1135** may be a sensor to measure brightness.

The processing may be performed remotely, for example, in some embodiments. The camera **1135** may periodically capture images of the display system and send the unprocessed image to a monitoring server performing the remaining monitoring functions. Accordingly, a more detailed image processing analysis may be performed at the remote media server, which is likely to have better computational power than the on-site processing at the display.

FIG. **12** illustrates an embodiment of the present invention in which the display panels **1250** are connected serially.

In this embodiment, each individual display panel **1250** includes a media processing chip comprising a network interface card. Thus each panel has an individual media access control (MAC) address, which enables each display panel **1250** to communicate in both directions (receive and send data).

In one or more embodiments, the display panels **1250** may be powered using a serial connection. In this embodiment, the use of a monitoring circuit **1205** within the data receiver box **1200** may be optional because each individual panel may be configured to communicate bidirectionally. Accordingly, the functioning of the monitoring circuit **1205** may be incorporated into the individual panel. For example, each panel **1250** may include software and/or hardware to perform the monitoring functions. If a defect is identified within the panel **1250** (or on an adjacent panel), the panel **1250** communicates the detection of the defect to the controller **1800**.

FIG. **13**A illustrates a back side of an individual LED display panel in accordance with an embodiment of the present invention.

Referring to FIG. **13**A, in one embodiment, the back side of an individual LED panel **1350** has enclosures for attaching a power conversion unit **1355** and a TX-RX circuit **1356**. The TX-RX circuit **1356** may be a media processing chip comprising a network interface controller, for example. In one or more embodiments, the power conversion unit **1355** and the TX-RX circuit **1356** are both placed within separate enclosures and mounted to the back side of the LED display panel **1350**. Alternatively, in one embodiment, the power conversion unit **1355** and the TX-RX circuit **1356** are both placed within the same enclosure and mounted to the back side of the LED display panel **1350**.

In a further embodiment, the TX-RX circuit **1356** may be incorporated within the panel casing, for example, within the receiver circuit **725** of FIG. **7**A or mounted under the PCB **720** of FIG. **7**A as a separated chip.

FIG. **13**B illustrates a more detailed schematic of the circuit with a LED circuit **1325** showing a separate TX-RX circuit **56** and a monitoring circuit **1375** for monitoring the panel and communicating using the established bidirectional communication. The TX-RX circuit **56** may include a unique MAC address/network card so that the device can be identified. In one or more embodiments, a single media process chip may include, i.e., integrate more than one component. For example, a single media processing chip is used to power and render images using the LED **1310**. The media processing chip may include the functions of the TX-RX circuit **56**, interface circuit **1351**, bus **1344**, video memory **1346**, graphics processor **1357**, scan controller **1359**. The LED controller **1354** with the LED driver **1353** may be part of a different chip or may also be integrated.

The monitoring circuit **1375** may be implemented in software and/or hardware and may be instructions to be performed using the graphics processor **1357** or other processor available to the monitoring circuit **1375**. The monitoring circuit **1375** may also include sensors such as temperature sensor, optical sensor including ambient light sensor, magnetic sensor, current sensor, power sensor, as well as other sensors. Based on the results from the sensor, the monitoring circuit **1375** determines the need to communicate with the receiver box or with a remote monitoring computer. In one embodiment, an error message is generated by the monitoring circuit **1375** identifying the type of defect and the ID of the panel and then transmitted using the TX-RX circuit **56**.

FIG. **14** illustrates an embodiment of the display system in which the data receiver box **1400** has minimal functionality.

The data receiver box **1401** may simply connect the first display panel of the display system **1400** with an interconnect (TCP/IP) port. The first display panel may include an identifier for the whole system so that the display system advertises a single IP address. For example, the IP address of the display system **1400** may be identified from the first display panel **1450**A. The remaining panels **1450** may be daisy chained.

The media processing chip within each display panel **1450** identifies and processes the correct media that is to be displayed from the data stream that includes all the media for all the panels in the chain.

The first panel in the series of panels includes a unique IP address. Thus, when connected to the internet, the network card at the first display panel **1450**A receives the data to be displayed by all the panels within the same series. The remaining panels use the data processed through the common network card at the first network. The remaining panels have to be calibrated so that they know which portion of the data is to be displayed by that particular unit.

In one or more embodiments, the first display panel **1450**A may include a monitoring circuit for monitoring the status of one or more panels being serviced by the first display panel **1450**A.

FIG. **15** illustrates an alternative embodiment of the present invention.

In this embodiment, a router **1501** is coupled between the display panels **1550** and the internet. The router **1501** may be coupled to a plurality of display panels **1550**, where each panel has its own network interface card each thereby having its unique MAC address.

In some embodiments, the first display panel may include the router **1501**, i.e., the router **1501** may be integrated into the first display panel. The devices within the local area of the router may now be individually addressed using the display panels' **1550** respective MAC address. Accordingly, packets destined to each panel are routed by the router **1501**. In this embodiment, the display panels **1550** within a single display system **1500** may be served from different locations. For example, a larger part of the screen may show an advertisement from a media server whereas a lower portion may show the temperature from a weather server or a sports score from a sport network server.

In one or more embodiments, each of the display panel **1550** may include a monitoring circuit for monitoring the status of one or more panels.

FIG. **16** illustrates an alternative embodiment of the present invention in which each display panel has a unique IPV6 IP address.

In this embodiment, each display panel **1650** of the display system **1600** has a unique IP address, for example, an IPV6 IP address. The media to be displayed may be split at the source of a single media server or may be obtained from multiple media server through the internet. For example, different portions of the display system **1600** may be leased to a different company displaying its own content. This embodiment enables multiple users to share a single display board. For example, an expensive display location may be shared in time or space by multiple companies reducing their costs while improving effectiveness of the display. The display panels may be powered individually or through Power over Ethernet technologies using cat5, cat6 cables.

In one or more embodiments, each of the display panel **1650** may include a monitoring circuit for monitoring the status of one or more panels.

Embodiments of the invention provide a display panels, each of which provides a completely self-contained building block that is lightweight. These displays are designed to protect against weather, without a heavy cabinet. The panel can be constructed of aluminum or plastic so that it will about 50% lighter than typical panels that are commercially available. The lightweight design allows for easier installation and maintenance, thus lowering total cost of ownership.

In certain embodiments, the display is IP 67 rated and therefore waterproof and corrosion resistant. Because weather is the number one culprit for damage to LED displays, and IP 67 rating provides weatherproofing with significant weather protection. These panels are completely waterproof against submersion in up to 3 feet of water. In other embodiments, the equipment can be designed with an IP 68 rating to operate completely underwater. In lower-cost embodiments where weatherproofing is not as significant, the panels can have an IP 65 or IP 66 rating.

One aspect takes advantage of a no cabinet design-new technology that replaces cabinets, which are necessary in commercial embodiments. Older technology incorporates the use of cabinets in order to protect the LED display electronics from rain. This creates an innate problem in that the cabinet must not allow rain to get inside to the electronics, while at the same time the cabinet must allow for heat created by the electronics and ambient heat to escape.

Embodiments that the do not use this cabinet technology avoid a multitude of problems inherent to cabinet-designed displays. One of the problems that has been solved is the need to effectively cool the LED display. Most LED manufacturers must use air-conditioning (HVAC) to keep their displays cool. This technology greatly increases the cost of installation and performance.

Displays of the present invention can be designed to be light weight and easy to handle. For example, the average total weight of a 20 mm, 14'×48' panel can be 5,500 pounds or less while typical commercially available panels are at 10,000 to 12,000 pounds. These units are more maneuverable and easier to install saving time and money in the process.

Embodiments of the invention provide building block panels that are configurable with future expandability. These displays can offer complete expandability to upgrade in the future without having to replace the entire display. Installation is fast and easy with very little down-time, which allows any electronic message to be presented more quickly.

In some embodiments, the display panels are "hot swappable." By removing one screw in each of the four corners of the panel, servicing the display is fast and easy. Since a highly-trained, highly-paid electrician or LED technician is not needed to correct a problem, cost benefits can be achieved.

Various embodiments utilize enhanced pixel technology (EPT), which increases image capability. EPT allows image displays in the physical pitch spacing, but also has the ability to display the image in a resolution that is four-times greater. Images will be as sharp and crisp when viewed close as when viewed from a distance, and at angles.

In some embodiments is advantageous to build multipanel displays where each of the LEDs is provided by a single LED manufacturer, so that diodes of different origin in the manufacture are not mixed. It has been discovered that diode consistency can aid in the quality of the visual image. While this feature is not necessary, it is helpful because displays made from different diodes from different suppliers can create patchy inconsistent color, e.g., "pink" reds and pink looking casts to the overall image.

While this invention has been described with reference to illustrative embodiments, this description is not intended to be construed in a limiting sense. Various modifications and combinations of the illustrative embodiments, as well as other embodiments of the invention, will be apparent to persons skilled in the art upon reference to the description. It is therefore intended that the appended claims encompass any such modifications or embodiments.

What is claimed is:

1. A method of maintaining a modular multi-panel display that includes a mechanical support structure and a plurality of LED display panels detachably coupled to the mechanical support structure without a cabinet, wherein each LED display panel has a data port that is bidirectionally coupled to at least one other LED display panel and includes a power supply coupled to a power line that extends along a group of the LED display panels, the method comprising:
- monitoring the power supply of each LED display panel;
- determining that an LED display panel of the plurality of LED display panels is a defective LED display panel by determining that the power supply of the defective LED display panel is not providing a power output for powering the defective LED display panel; and
- removing the defective LED display panel by hot swapping the defective LED display panel from the mechanical support structure.

2. The method of claim 1, further comprising:
- electrically disconnecting the defective LED display panel from the multi-panel display;
- placing a replacement LED display panel at a location formerly taken by the defective LED display panel; and
- electrically connecting the replacement LED display panel to the multi-panel display.

3. The method of claim 1, wherein the determining is performed by a monitoring circuitry within a box mounted to the mechanical support structure.

4. The method of claim 1, wherein the determining is performed by circuitry within the defective LED display panel.

5. The method of claim 4, further comprising communicating an error message from the defective LED display panel to a receiver box coupled to each of the LED display panels.

6. The method of claim 4, further comprising communicating an error message from the defective LED display panel to a remotely located monitoring server.

7. The method of claim 1, further comprising monitoring power consumption of each LED pixel in each LED display panel.

8. A method of maintaining a modular multi-panel display that includes a mechanical support structure and a plurality of LED display panels detachably coupled to the mechanical support structure without a cabinet, wherein each LED display panel has a data port that is bidirectionally coupled to at least one other LED display panel, the method comprising:
- monitoring each of the plurality of LED display panels;
- determining that a defective LED display panel has a defective LED pixel based upon a result of the monitoring, wherein the monitoring and determining is performed by a monitoring circuitry comprising a power failure detecting circuit and a camera, wherein the monitoring comprises periodically activating the camera to capture an image and processing the image, and wherein the determining comprises identifying a dark pixel, wherein a dark pixel is a pixel having a lower brightness than an associated brightness to be displayed for the pixel; and
- removing the defective LED display panel by hot swapping the defective LED display panel from the mechanical support structure.

9. The method of claim 8, further comprising:
- electrically disconnecting the defective LED display panel from the multi-panel display;
- removing an attachment plate from the defective LED display panel;
- removing the defective LED display panel from the multi-panel display;
- placing a replacement LED display panel at a location formerly taken by the defective LED display panel;
- attaching the attachment plate to the replacement LED display panel; and
- electrically connecting the replacement LED display panel to the multi-panel display.

10. The method of claim 8, wherein the determining is performed by circuitry within the defective LED display panel.

11. The method of claim 10, further comprising communicating an error message from the defective LED display panel to a receiver box coupled to each of the LED display panels.

12. The method of claim 10, further comprising communicating an error message from the defective LED display panel to a remotely located monitoring server.

13. The method of claim 8, wherein, at the monitoring circuit, identifying from the image if brightness of a panel of the plurality of LED display panels is less than a predetermined threshold.

14. The method of claim 8, wherein, determining that a defective LED display panel has a defective LED pixel comprises, at the monitoring circuit, identifying from the image if a panel of the plurality of LED display panels has more number of dark pixels than a predetermined threshold for dark pixels.

15. The method of claim 8, wherein the determining is further performed by measuring power consumption of the plurality of LED display panels, and computing a change in power consumption of the plurality of LED display panels, wherein the power consumption is a total power consumed by all of the plurality of LED display panels.

16. The method of claim 8, wherein the determining is further performed by measuring power consumption of the plurality of LED display panels, and computing a change in power consumption of the plurality of LED display panels, and wherein the power consumption is a total power consumed by each of the plurality of LED display panels.

17. The method of claim 8, further comprising:
- generating an operational data of the plurality of LED display panels; and
- sending the operational data from the monitoring circuit to a monitoring server.

18. The method of claim 17, further comprising identifying if a communication network to one or more of the plurality of LED display panels is defective or slow and report the results into the operational data.

19. The method of claim 8, wherein the determining is further performed by using an image captured using a temperature sensor facing the plurality of LED display panels.

20. The method of claim 19, wherein the temperature sensor comprises an infrared sensor.

21. A method of maintaining a modular multi-panel display, the method comprising:

electronically monitoring each of a plurality of light emitting diode (LED) display panels by using bidirectional communication with a network interface card having a unique Internet Protocol (IP) address inside each of the LED display panel, wherein each of the plurality of LED display panels is individually attached to a common frame, wherein the plurality of LED display panels is attached to the frame without cabinets, wherein each of the plurality of LED display panels includes a power supply coupled to a power line that extends along a group of the LED display panels;

during operation of the modular multi-panel display, electronically identifying a LED display panel is a defective LED display panel by determining that the power supply of the identified LED display panel is not providing a power output for powering the defective LED display panel; and

removing the defective LED display panel by hot swapping the defective LED display panel from the common frame.

22. The method of claim **21**, wherein removing the defective LED display panel by hot swapping further comprises:

electrically disconnecting the defective LED display panel from the multi-panel display;

removing the defective LED display panel from the multi-panel display;

placing a replacement LED display panel at a location formerly taken by the defective LED display panel; and

electrically connecting the replacement LED display panel to the multi-panel display.

23. The method of claim **21**, wherein the determining is performed by a monitoring circuitry within a box mounted to the common frame.

24. The method of claim **21**, wherein the determining is performed by circuitry within the defective LED display panel.

25. The method of claim **24**, further comprising communicating an error message from the defective LED display panel to a receiver box coupled to each of the LED display panels.

26. The method of claim **24**, further comprising communicating an error message from the defective LED display panel to a remotely located monitoring server.

27. The method of claim **21**, further comprising monitoring power consumption of each LED pixel in each LED display panel.

28. The method of claim **21**, further comprising removing the identified LED display panel from the frame without removing any of the other plurality of LED display panels from the frame.

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