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Lande

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(54) **FLEXIBLE COMPONENTIZED LIGHT ENGINE**

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F21V 23/06	(2006.01)
F21Y 105/16	(2016.01)
F21Y 115/10	(2016.01)

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

CPC ***F21V 23/005*** (2013.01); ***F21V 23/0457*** (2013.01); ***F21V 23/06*** (2013.01); *F21V 2200/00* (2015.01); *F21Y 2105/16* (2016.08); *F21Y 2115/10* (2016.08)

(58) **Field of Classification Search**

CPC F21V 23/005; F21V 23/0457; F21V 23/06

See application file for complete search history.

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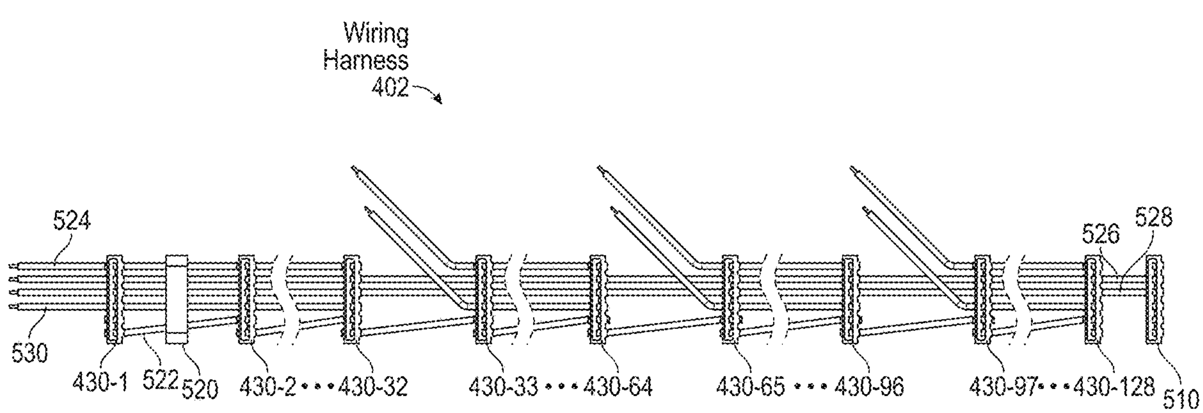
(57) **ABSTRACT**

A light device, a lighting apparatus, and a system including a controller and multiple light devices are described. An example light device includes a printed circuit board (PCB), an input connector disposed at a first side of the PCB, an output connector disposed at second side of the PCB, one or more light engines disposed on the PCB between the input connector and the output connector, and one or more drivers disposed on the PCB. Each light engine of the one or more light engines includes multiple light emitting diodes (LEDs). Each driver of the one or more drivers is configured to control illumination emitted from a respective light engine of the one or more light engines.

19 Claims, 11 Drawing Sheets



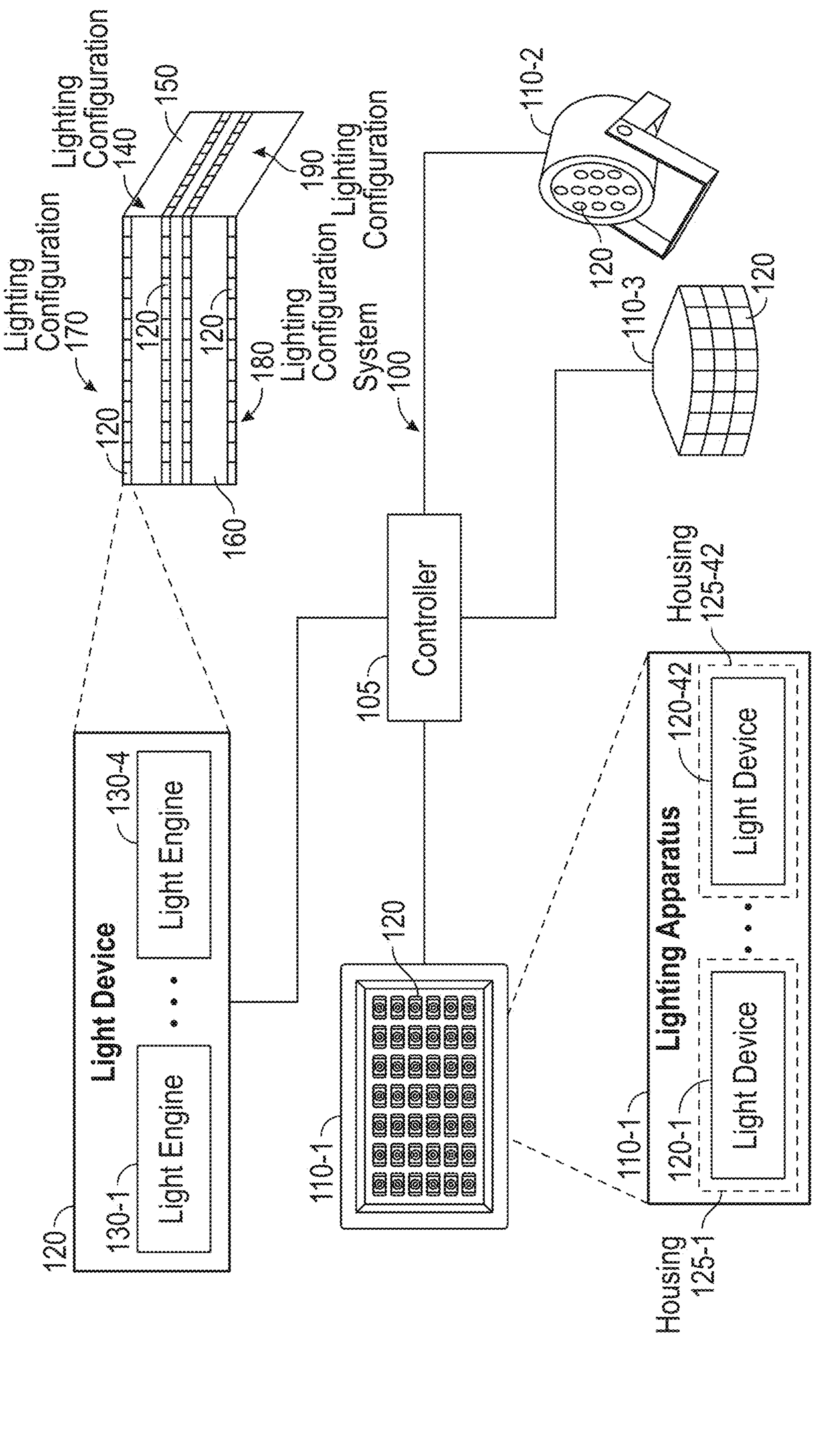

Lighting Configuration 170
Lighting Configuration 140
150
120
120
120
160
180 Lighting Configuration
Lighting Configuration 190
System 100
110-2
120
110-3
120
105
Controller
120
Light Device
130-1
Light Engine
130-4
Light Engine
120
110-1
Lighting Apparatus
110-1
120-1
Light Device
120-42
Light Device
Housing 125-1
Housing 125-42

FIG. 1

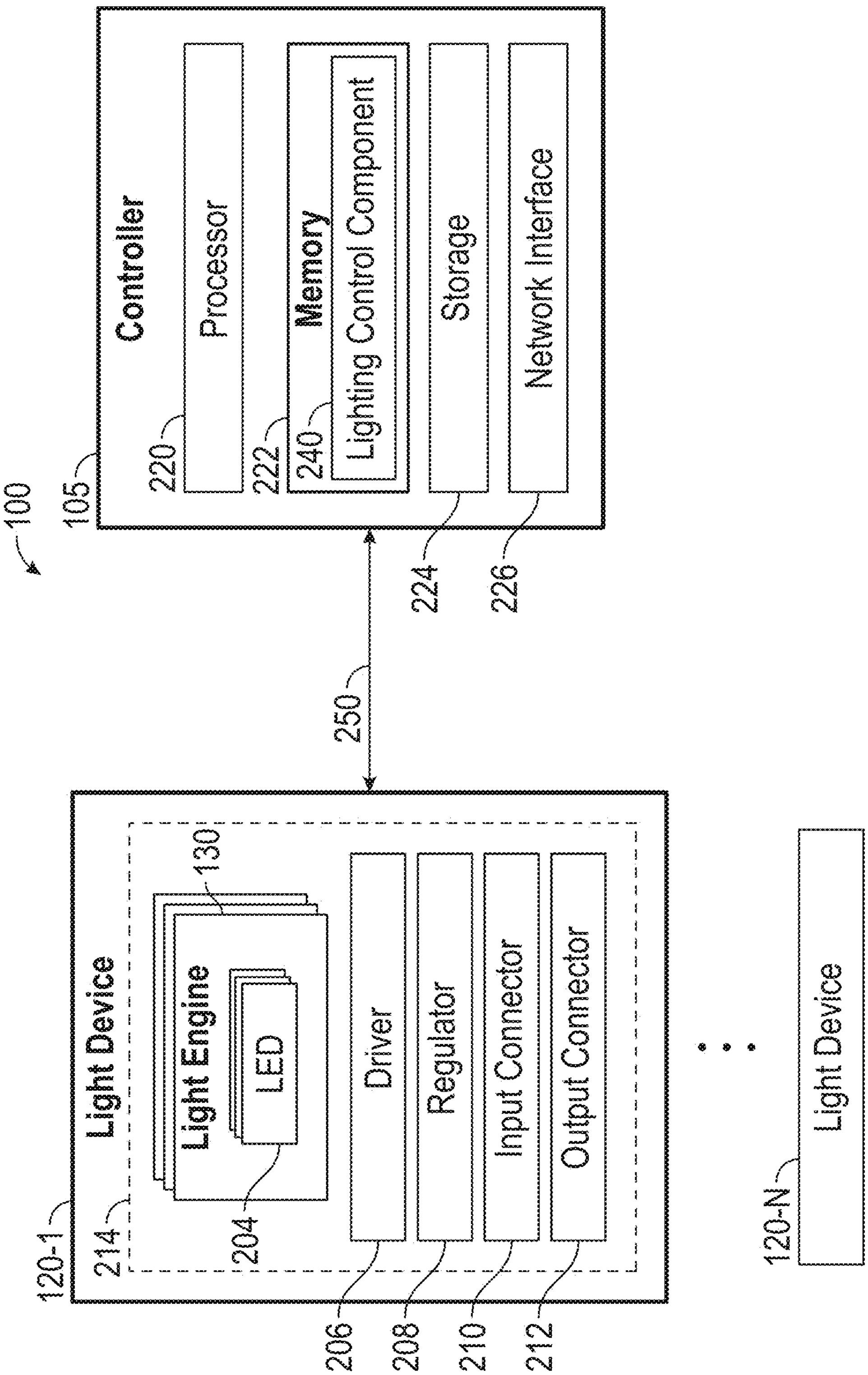
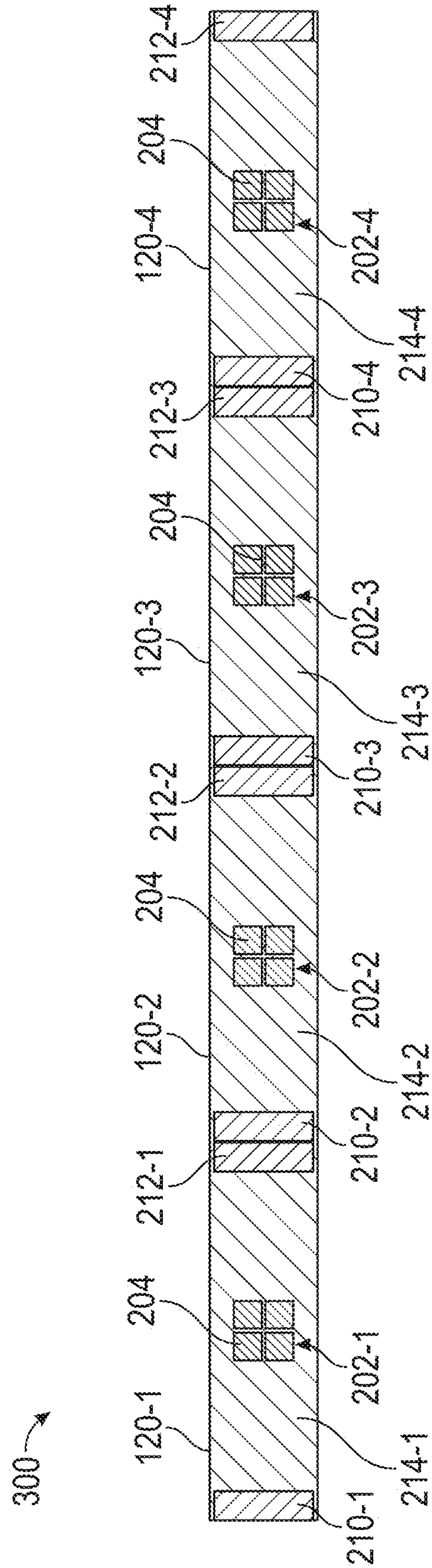

100
105
Controller
220
Processor
222
Memory
240
Lighting Control Component
224
Storage
226
Network Interface
250
120-1
Light Device
214
130
Light Engine
LED
204
Driver
206
Regulator
208
Input Connector
210
Output Connector
212
120-N
Light Device

FIG. 2


300
120-1
120-2
120-3
120-4
202-1
202-2
202-3
202-4
204
204
204
204
210-1
210-2
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212-1
212-2
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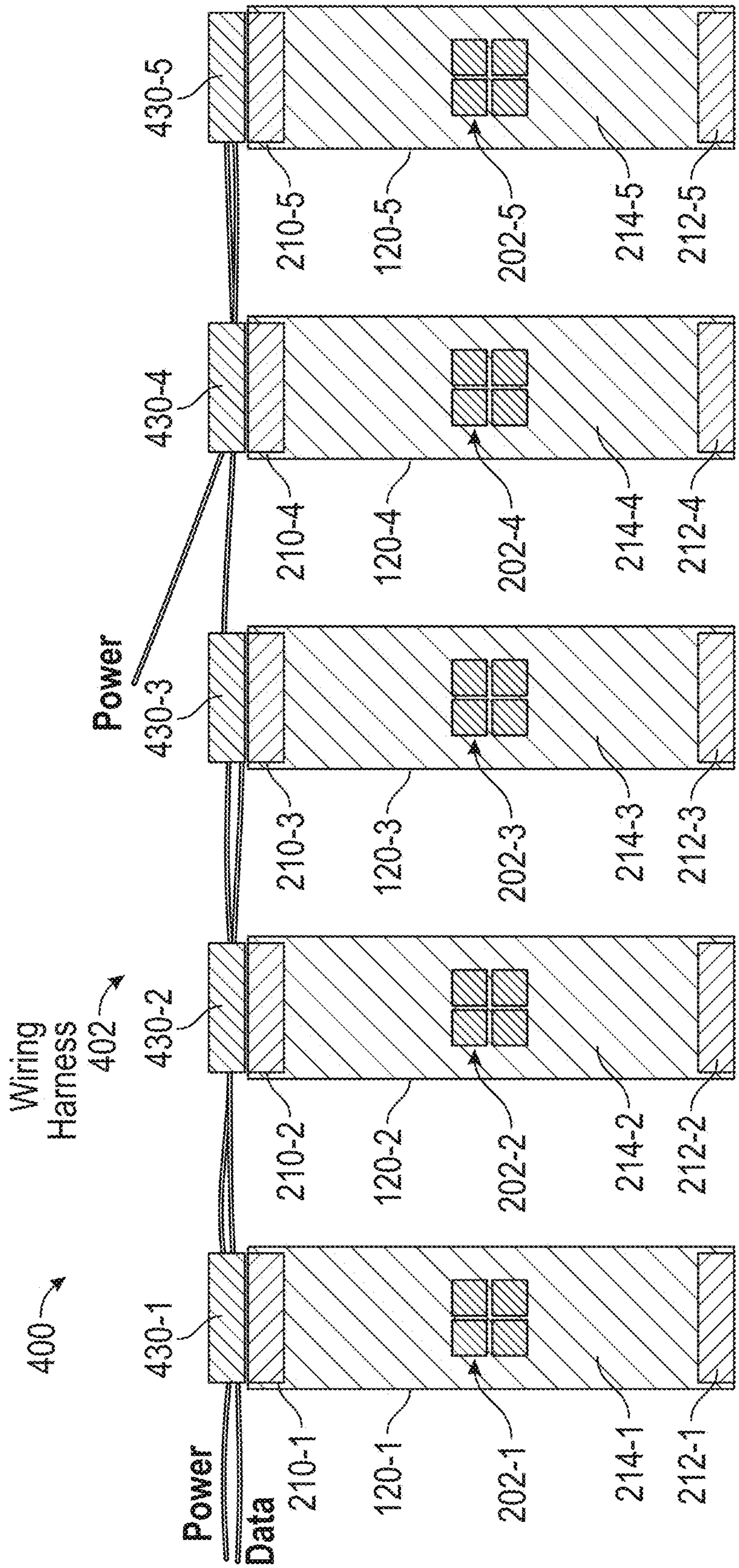
212-4
214-1
214-2
214-3
214-4

FIG. 3


400
Wiring Harness 402
Power
Data
Power
430-1
430-2
430-3
430-4
430-5
210-1
210-2
210-3
210-4
210-5
120-1
120-2
120-3
120-4
120-5
202-1
202-2
202-3
202-4
202-5
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212-1
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212-3
212-4
212-5

FIG. 4

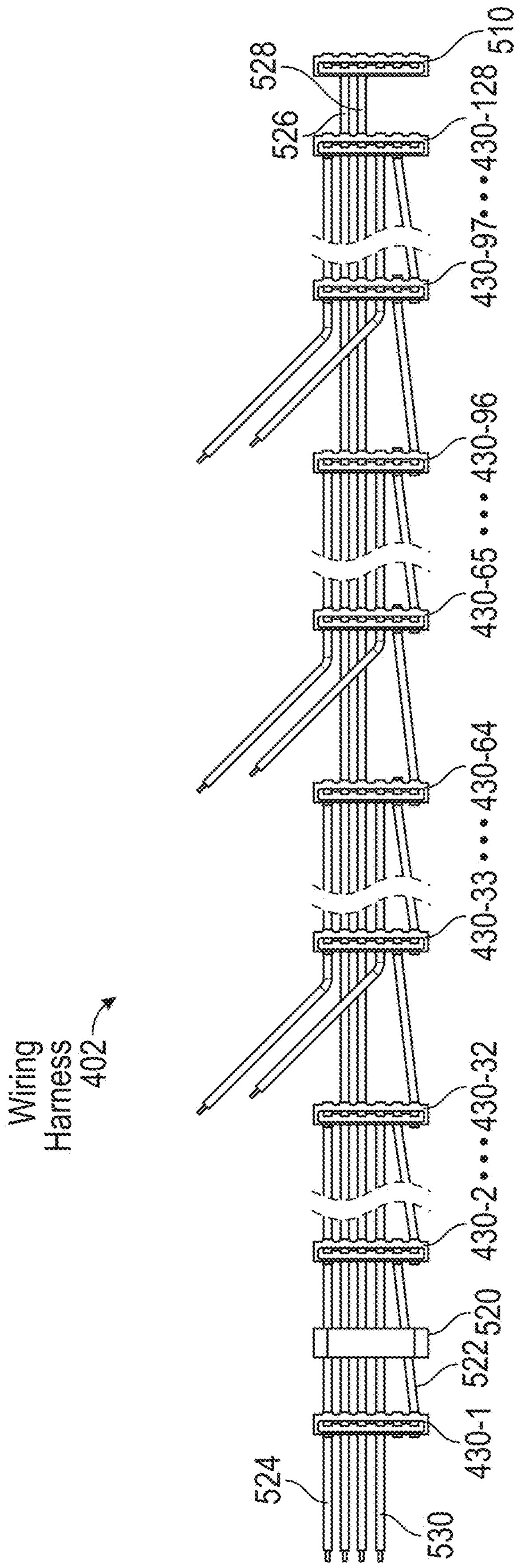
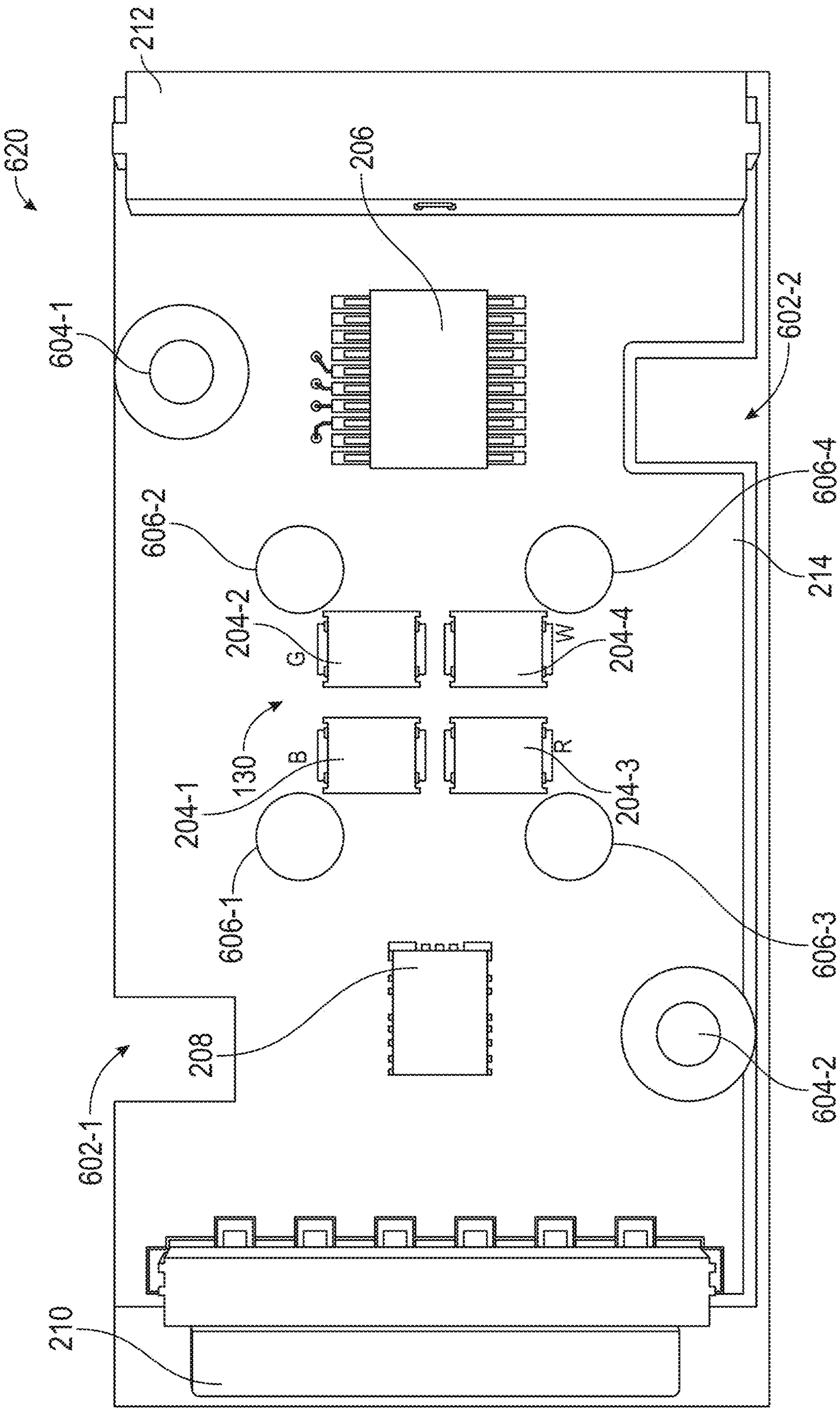

510
528
526
430-128
430-97
430-96
430-65
430-64
430-33
430-32
430-2
520
522
430-1
524
530
Wiring
Harness
402

FIG. 5



620
212
206
604-1
602-2
606-2
606-4
214
204-2
G
W
204-4
130
B
R
204-1
204-3
606-1
606-3
208
602-1
604-2
210

FIG. 6

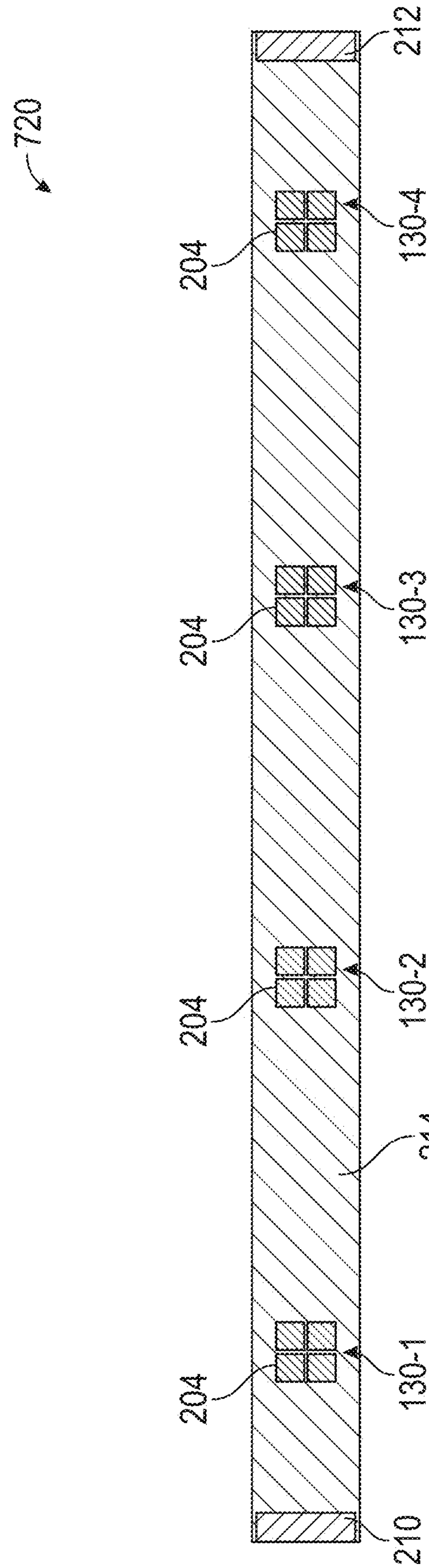


FIG. 7

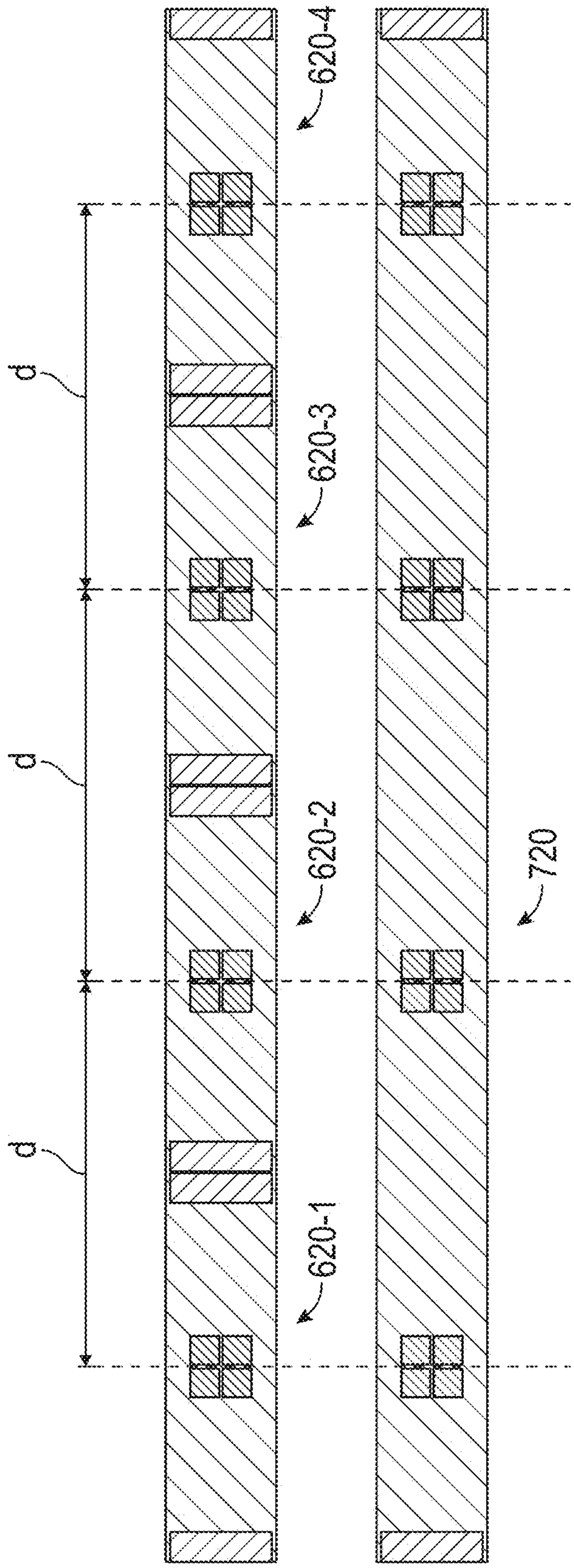


FIG. 8

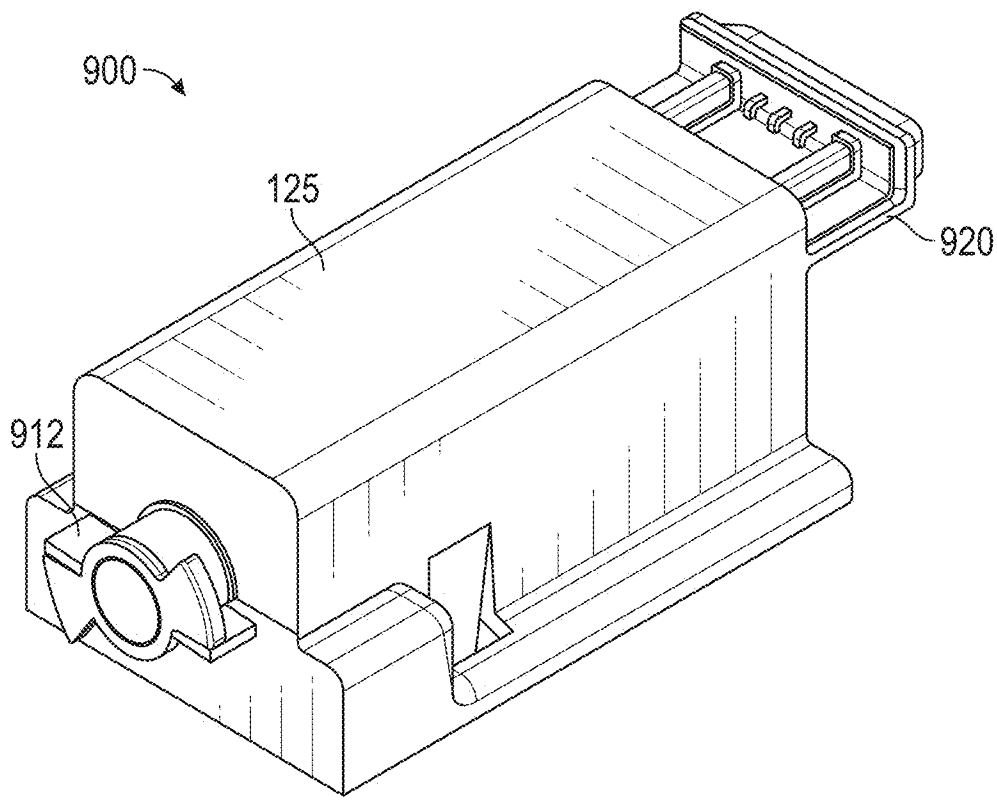


FIG. 9A

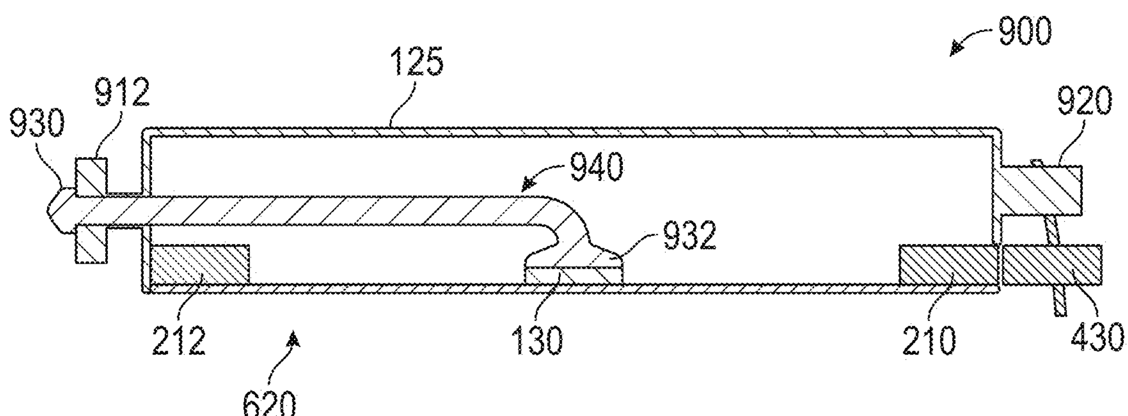


FIG. 9B

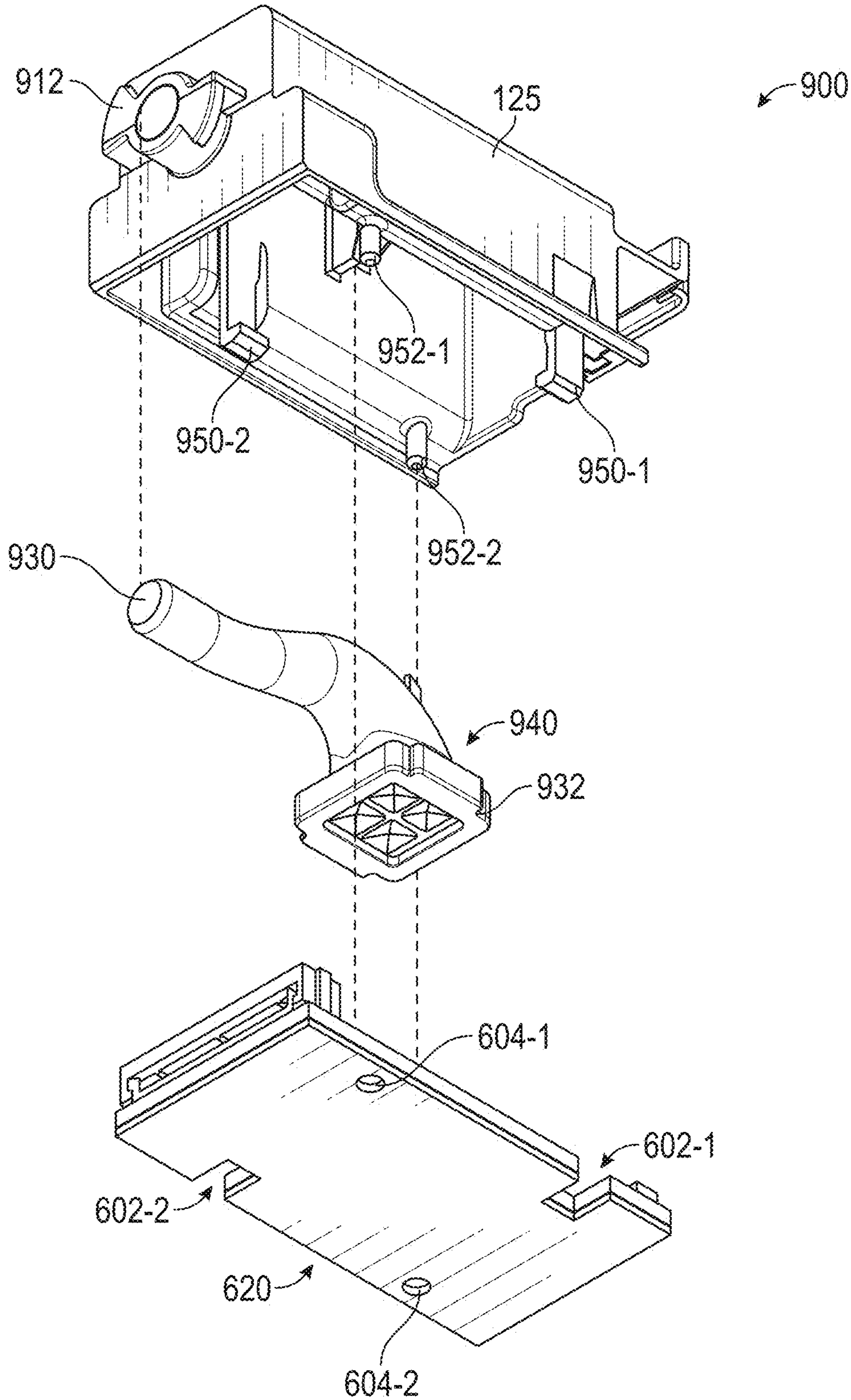

912
125
900
952-1
950-2
950-1
952-2
930
940
932
604-1
602-1
602-2
620
604-2

FIG. 9C

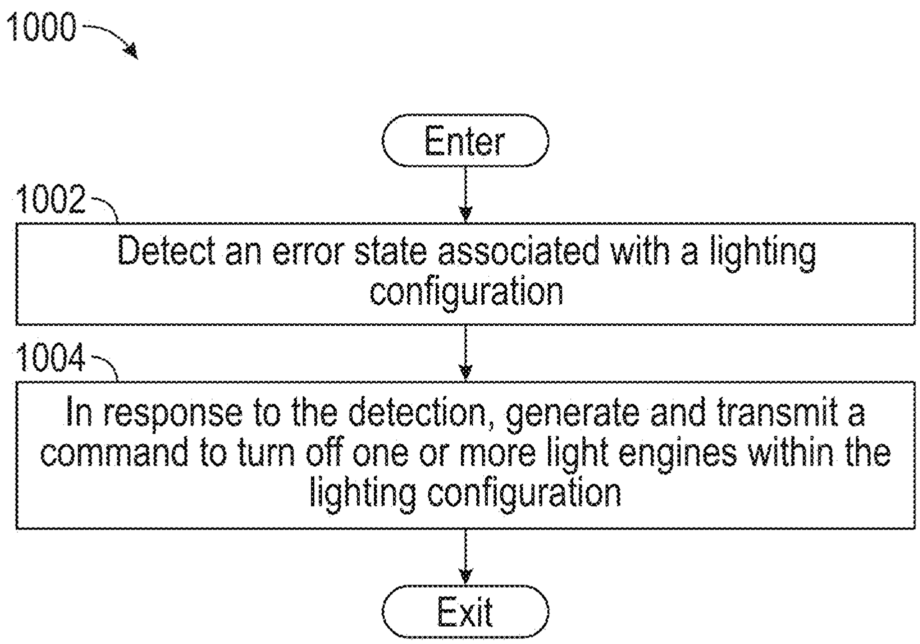

1000
Enter
1002
Detect an error state associated with a lighting configuration
1004
In response to the detection, generate and transmit a command to turn off one or more light engines within the lighting configuration
Exit

FIG. 10

FLEXIBLE COMPONENTIZED LIGHT ENGINE

INTRODUCTION

The present disclosure generally relates to lighting. More specifically, embodiments disclosed herein provide a flexible, modular, light device with one or more light engines.

Light emitting diode (LED) technology is used in a wide variety of applications, including entertainment applications, residential applications, commercial applications, and industrial applications, as illustrative examples. In many entertainment applications, LED technology may be used to provide lighting effects for themed entertainment attractions, theatrical productions, show sets, stages, displays, and props, as illustrative examples. In such applications, the lighting effects are generally created by LED devices, such as LED tape, LED light strips, and LED rope lights, as illustrative examples.

SUMMARY

One embodiment described herein is a light device. The light device includes: a printed circuit board (PCB), an input connector disposed at a first side of the PCB, and an output connector disposed at second side of the PCB. The light device also includes one or more light engines disposed on the PCB between the input connector and the output connector, each light engine of the one or more light engines comprising a plurality of light emitting diodes (LEDs). The light device further includes one or more drivers disposed on the PCB, each driver of the one or more drivers being configured to control illumination emitted from a respective light engine of the one or more light engines.

Another embodiment described herein is a lighting apparatus. The lighting apparatus includes a plurality of light devices. Each light device of the plurality of light devices includes: a printed circuit board (PCB); an input connector disposed at a first side of the PCB; an output connector disposed at second side of the PCB; a light engine disposed on the PCB between the input connector and the output connector, the light engine comprising a plurality of light emitting diodes (LEDs); a driver configured to control illumination emitted from the light engine; a light pipe having a first portion disposed on and aligned with the light engine and having a second portion disposed above the output connector, the light pipe being configured to pass light emitted from the plurality of LEDs of the light engine from the first portion to the second portion; and a housing attached to the PCB and forming an enclosure around the input connector, the output connector, the light engine, the driver, and the first portion of the light pipe.

Another embodiment described herein is a computer-implemented method. The computer-implemented method includes detecting, by a controller, an error state associated with a lighting configuration comprising a plurality of light devices. Each light device includes (i) at least one light engine comprising a plurality of light emitting diodes (LEDs) and (ii) at least one driver for controlling the at least one light engine. The computer-implemented method also includes, responsive to the detection, sending, by the controller, a command to turn off one or more of the light engines.

BRIEF DESCRIPTION OF THE DRAWINGS

So that the manner in which the above recited aspects are attained and can be understood in detail, a more particular

description of embodiments described herein, briefly summarized above, may be had by reference to the appended drawings.

It is to be noted, however, that the appended drawings illustrate typical embodiments and are therefore not to be considered limiting; other equally effective embodiments are contemplated.

FIG. **1** illustrates an example lighting system, according to one embodiment.

FIG. **2** further illustrates a light device and a controller of the lighting system illustrated in FIG. **1**, according to one embodiment.

FIG. **3** illustrates an example lighting configuration, according to one embodiment.

FIG. **4** illustrates another example lighting configuration, according to one embodiment.

FIG. **5** illustrates an example wiring harness for the lighting configuration illustrated in FIG. **4**, according to one embodiment.

FIG. **6** illustrates an example light device, according to one embodiment.

FIG. **7** illustrates another example light device, according to one embodiment.

FIG. **8** illustrates an example of spacing between different types of light devices, according to one embodiment.

FIGS. **9**A-**9**C illustrate different views of another example light device, according to one embodiment.

FIG. **10** is a flowchart of a method for controlling one or more light devices, according to one embodiment.

DETAILED DESCRIPTION

Today, existing LED light devices used in many entertainment applications (e.g., themed entertainment attractions, concerts, theatrical productions, show sets, props, etc.) and other applications (e.g., residential, commercial, etc.) are generally low quality, mass produced LED tape or LED module style devices. Such devices, however, may have a number of drawbacks that make them unsuitable and unreliable for certain applications (e.g., entertainment applications).

For example, such devices may have a limited color gamut (e.g., range of colors that can be created) that is not tuned for stage lighting, object lighting, backdrop illumination, and other lighting effects typically used in entertainment applications and other applications. Additionally, using multiple LED devices of the same and/or different form factors together may introduce illumination matching problems (e.g., different devices may not emit matching colors) which can take a significant amount of time to address. Additionally, in many cases, there may be a limited number of remote drivers that are compatible with conventional LED light devices, as such devices may be designed to interact with proprietary remote drivers and control protocols. Additionally, the life span of conventional LED light devices may be limited by a lack of thermal management for such devices. Further, in many cases, when a single LED in a conventional LED light device (e.g., LED string) fails, often the entire LED light device will fail or the device may behave in an unexpected manner (e.g., create a strobe effect) that compromises the overall quality of the illumination effect. In such cases, the entire LED light device (e.g. LED string) may have to be replaced, a process that can be complicated and time-consuming for many entertainment installations.

Embodiments described herein provide a flexible, modular, componentized, and highly reliable light device that can used in a variety of applications, such as entertainment applications, residential applications, commercial applications, and others. The light device described herein may alleviate and/or address one or more of the aforementioned drawbacks associated with conventional LED devices.

For example, as described below, certain embodiments of the light device may include one or more light engines that can be designed to emit illumination customized for a particular application. For entertainment applications, for example, each light engine may include a set of LEDs that have a higher wide color gamut (e.g., a higher color rendering index (CRI)), allowing tuning for various lighting effects generally used in entertainment applications (e.g., stage lighting, object lighting, backdrop illumination, etc.). Additionally, certain embodiments of the light device described herein may have onboard driver hardware, eliminating the need for proprietary drivers, and may have built-in thermal management, allowing the light device to have an extended life span relative to conventional LED devices. Each light device described herein may be individually controlled via the on-board driver, allowing for individually controlling the illumination of the light device as well as turning off the light device in the case of failure or unexpected behavior.

Additionally, certain embodiments of the light device described herein may have a modular form factor that allows the light device to be used individually or in combination with other light devices in different lighting configurations (e.g., chain configuration, string configuration, and other configurations). The modularity of the light devices described herein may allow for any light device within a configuration of light devices to be easily replaced without replacing the entire configuration. That is, the failure of a single light device may not lead to failure of the entire configuration. In certain embodiments, rather than replacing a light device, the light device may be turned off, e.g., via the on-board driver, to prevent unexpected behavior.

Note that while many of the embodiments described herein use entertainment applications as an illustrative example of applications in which the light device described herein can be implemented, the light device described herein is not limited to entertainment applications; other applications are contemplated. For example, the light device described herein can be used in residential applications, commercial applications, industrial applications, and other applications involving illumination.

As used herein, a hyphenated form of a reference numeral refers to a specific instance of an element and the unhyphenated form of the reference numeral refers to the collective element. Thus, for example, device "**12-1**" refers to an instance of a device class, which may be referred to collectively as devices "**12**" and any one of which may be referred to generically as a device "**12**".

As used herein, the term "connected with" or "connected to" in the various tenses of the verb "connect" may mean that element A is directly connected to element B or that other elements may be connected between elements A and B (i.e., that element A is indirectly connected with element B). In the case of electrical components, the term "connected with" or "connected to" may also be used herein to mean that a wire, trace, or other electrically conductive material is used to electrically connect elements A and B (and any components electrically connected therebetween).

FIG. **1** illustrates an example illumination system **100** (hereinafter referred to as "system **100**"), according to various embodiments. The system **100** may be located in any environment, such as an indoor environment, outdoor environment, or other environment types (e.g., blended indoor/outdoor environment, such as partially enclosed stadium). In certain embodiments, the system **100** may be used for a variety of entertainment applications, such as a themed entertainment attraction (e.g., line queue), theatrical/production stage, show set, and stage prop, as illustrative, non-limiting examples.

As shown, the system **100** includes a variety of lighting apparatuses **110-1** to **110-3** (collectively lighting apparatuses **110**) that may be used for various entertainment applications. Each lighting apparatus **110** is generally configured to create an illumination (or lighting) effect using one or more light devices **120**. The lighting apparatuses **110** may have various form factors, may be moveable or fixed, and may be deployed in various locations (e.g., floor, ceiling, wall, and other structures). In certain embodiments, each lighting apparatus **110** may provide structure (e.g., panel, board, etc.) for deploying (e.g., attaching) one or more of the light devices **120**, which may be (partially or fully) integrated within the lighting apparatus **110** or disposed on the lighting apparatus **110**. In the example depicted in FIG. **1**, the lighting apparatuses **110-1** to **110-3** include a display panel (e.g., lighting apparatus **110-1**), a stage lighting device (e.g., lighting apparatus **110-2**), and a field lighting device (e.g., lighting apparatus **110-3**). Each lighting apparatus **110** may include any number of light devices suitable for generating a desired illumination effect. In FIG. **1**, for example, lighting apparatus **110-1** includes a configuration of forty-two light devices (e.g., light devices **120-1** to **120-42**).

The light device(s) **120** may be flexible, modular, componentized, and highly reliable devices that can be deployed in multiple different configurations to create illumination effects for different applications. In some embodiments, one or more of the light devices **120** may be at least partially enclosed within a housing **125**. In lighting apparatus **110-1**, for example, light devices **120-1** to **120-42** may be (partially or fully) enclosed within respective housings **125-1** to **125-42**. Additionally, in certain embodiments, the form factors of the light devices **120** within a given lighting apparatus **110** may be the same or different. Using lighting apparatus **110-1** as an illustrative example, light device **120-1** may have a different form factor (or configuration) than at least one of the remaining light devices (e.g., light device **120-2**) and may have a same form factor as at least another one of the remaining light devices (e.g., light device **120-3**).

In certain embodiments, the light devices **120** may be deployed in a configuration without an enclosure. In the example depicted in FIG. **1**, multiple different sets of light devices **120** may be connected together to form different lighting configurations **140**, **170**, **180**, and **190**. Lighting configuration **180** includes a set of light devices **120** deployed at the bottom of a wall **160**, e.g., to create illumination effects such as uplighting. Similarly, lighting configuration **170** includes another set of light devices **120** deployed at the top of the wall **160**, e.g., to create illumination effects such as downlighting. In another example, lighting configurations **140** and **190** may be used to create a channel lighting effect on the walls **160** and **150**. Similar to illustrative example of lighting apparatus **110-1**, the form factors of the light devices **120** within a given lighting configuration **140**, **170**, **180**, and **190** may be the same or different.

Each light device **120** may include, without limitation, one or more light engines **130** and other components described in greater detail herein. Each light engine **130** may include one or more LEDs. The number of light engines **130** within a light device **120** may be based on the form factor of the light device **120**. For example, certain light devices **120** may include four light engines (e.g., light engine **130-1** to **130-4**), whereas other light devices **120** may include a single light engine **130**. Note, however, that these are merely examples, and that a light device **120** described herein may include any number of light engines **130**. As described in greater detail below, even in embodiments where different form factors of light devices **120** are used within a lighting configuration or lighting apparatus, the spacing between light engines **130** may be maintained, such that the light engines **130** are aligned with each other. By enabling a consistent line spacing throughout a given configuration/lighting apparatus, embodiments herein may allow light devices **120** to be used for lighting effects in which pixel alignment is crucial (e.g., LED displays).

The system **100** also includes a controller **105** which is communicatively coupled to the light devices **120** within the various lighting apparatuses **110** and lighting configurations **140**, **170**, **180**, and **190**. The controller **105** may be communicatively coupled to the light devices **120** via a wired or wireless interface. The controller **105** is generally representative of a computing system that can control the intensity, color, and other parameters of the light engines **130** within each light device **120**. As described in greater detail below, the controller **105** may use data signals in accordance with a lighting control protocol (e.g., Digital Multiplex (DMX) protocol, such as DMX512) to control the functionality of the light engines **130** within each light device **120**. Note the controller **105** is described in greater detail with respect to FIG. **2**.

Note that FIG. **1** depicts an illustrative example of an illumination system **100** in which one or more of the light devices **120** described herein can be implemented and that the light devices **120** described herein can be implemented in other systems and/or environments. For example, while the system **100** is shown with a certain number of lighting apparatuses, lighting configurations, light devices, and controllers, the system **100** may include any number of lighting apparatuses, lighting configurations, light devices, and controllers.

FIG. **2** further illustrates additional details of the light device **120** (a plurality of light devices **120-1** . . . N is shown) and the controller **105** of FIG. **1**, according to one embodiment. As shown, the controller **105** includes, without limitation, a processor **220**, a memory **222**, a storage **224**, and a network interface **226**.

The processor **220** represents any number of processing elements, which can include any number of processing cores. The memory **222** can include volatile memory, non-volatile memory, and combinations thereof. The memory **222** generally includes program code for performing various functions for controlling lighting via the light devices **120**. The program code is generally described as various functional "components" or "modules" within the memory **222**, although alternate implementations may have different functions or combinations of functions. Here, the memory **22** includes a lighting control component **240** (e.g., software component or logic), which may control the light devices **120-1** to **120**-N using one or more techniques described herein. In certain embodiments, the lighting control component **240** may perform lighting control in accordance with a lighting control protocol/standard, such as the United States Institute for Theatre Technology (USITT) DMX512-A defined by American National Standard (ANSI) Entertainment Technology.

The storage **224** may be a disk drive storage device. Although shown as a single unit, the storage **224** may be a combination of fixed and/or removable storage devices, such as fixed disc drives, removable memory cards, optical storage, network attached storage (NAS), or a storage area network (SAN). The network interface **226** may be any type of network communications interface (e.g., serial interface, such as serial recommended standard (RS) **232**) that allows the controller **105** to communicate with light devices **120** in the system **100**, e.g., via cabling (or cable or wire) **250**.

Each light device **120-1** to **120**-N may include, without limitation, one or more light engines **130**, a driver **206**, a regulator **208**, an input connector **210**, and an output connector **212**. In certain embodiments, the light engines **130**, driver **206**, regulator **208**, input connector **210**, and output connector **212** may be disposed on a single printed circuit board (PCB) **214**. The PCB **214** may be a metal core PCB and may provide thermal management for the light device **120**. In certain embodiments, the power level of each light device **120** may be 24 volts direct current (VDC), which may allow for a large number of light devices **120** to be used within a lighting configuration as well as improve voltage regulation on the light device **120**.

The light engine **130** may include one or more LEDs **204**, where each LED **204** is a single color emitter. In certain embodiments, the light engine **130** includes four LEDs **204** (e.g., red, green, blue, and white (RGBW) single color emitters). The LEDs **204** may be arranged in a manner that allows blending of the light emission from the LEDs **204** with or without optics, reduction of unintended phosphor excitation between LEDs **204**, thermal management of the LEDs **204**, or a combination thereof. For example, with four LEDs **204**, the LEDs **204** may be arranged in a quadrangle (or quad) (e.g., rectangular or square arrangement), an example of which is shown in further detail herein with respect to FIG. **6**. The light engine **130** may be a broad spectrum light engine or narrow spectrum light engine and may have any wavelength including infrared (IR) and ultraviolet (UV). Each light engine **130** may compose a single lighting pixel as part of a larger lighting configuration/lighting apparatus. In some examples, each LED **204** may emit light at 9000 Kelvin (K), have a CRI of approximately 90, and have a forward current target of approximately 100 milliamps (mA). Note, however, that this is an illustrative example and that the light engine **130** described herein may include LEDs with different parameters.

As noted, the number of light engines **130** included within each respective light device **120-1** to **120**-N may be different. As an illustrative example, light device **120-1** may include four light engines **130** (each including four LEDs **204**), and light device **120-2** may include a single light engine **130** (including four LEDs **204**). In certain embodiments, when multiple light devices **120** (with different numbers of light engines **130**) are used together in a lighting configuration and/or lighting apparatus, the light engine spacing between the light devices **120** may be maintained, notwithstanding the different numbers of light engines **130** used within the light devices **120**.

The driver **206** is generally configured to control each LED **204** within a light engine **130**, based on a data signal generated at the controller **105**. For example, the controller **105** is connected to a first light device (e.g., light device **120-1**) of the N light devices **120** via the cabling **250**. The controller **105** may send a data signal (e.g., DMX data signal) to the first light device (e.g., light device **120-1**) to control one or more of the N light devices **120**. The driver **206** of the first light device may accept the data signal and pass the signal to each light device **120** in the configuration. Note, the respective drivers **206** of the light devices **120** may be connected in parallel to the data signal chain, such that the failure of a single driver **206** does not interrupt the chain.

In certain embodiments, the driver **206** is a multiple channel (e.g., 4-channel) constant current LED driver integrated circuit (IC) with integrated lighting control and single-line auto-addressing functionality. The driver **206** may perform lighting control in accordance with a lighting control protocol/standard, such as the USITT DMX512-A defined by ANSI Entertainment Technology. The driver **206** may be configured to allow multiple light devices **120** to be connected in a chain, and pass power, data signals (e.g., DMX512 data signals), and single-line addressing between light devices **120** up to a predefined number of interconnected pixels (e.g., **128** interconnected pixels assuming the configuration of light devices includes **128** light engines **130**, each including four LEDs **204**).

The driver **206** may be configured to provide individual, discrete dimming control of each LED **204** within a light engine **130**, via data signals (e.g., DMX512 data signals). For example, the driver **206** may process data signals from the controller **105** to extract illumination level values for the LED(s) **204** of the light engine **130**. The driver **206** may also automatically configure the starting addresses of each LED **204** in a chain, such that each LED **204** can be controlled via a unique address (e.g., DMX512 address). For example, when light devices **120-1** to **120**-N are connected, each respective driver **206** may auto-address and assign each LED **204** within its respective light engine **130** a unique address. Additionally, in certain embodiments, power and data signals may be routed via the light devices **120**, such that the failure of a single driver **206** does not prevent downstream light devices **120** from operating. While a single driver **206** is depicted within the light device **120-1**, in certain embodiments, a respective driver **206** may be included within the light device **120-1** for each light engine **130**.

The regulator **208** (e.g., voltage regulator) is generally configured to provide voltage regulation for the light device **120**. The regulator **208** may protect the light device **120** to prevent circuit damage in scenarios where the power is switched, or light devices **120** are connected or disconnected. When the light device **120-1** is connected to at least one other light device (e.g., light device **120-2**), the regulator **208** may pass power (e.g., 24 VDC or some other voltage supply) between the light devices. Each light device **120** may be connected in parallel to a power supply chain such that failure of a single light device **120** does not interrupt the configuration of light devices.

The input connector **210** and the output connector **212** may allow two PCBs **214** (e.g., two light devices **120**) to be mated end-to-end. The input connector **210** and the output connector **212** may be electrically compatible with the controller **105**. For example, assuming the controller **105** is a DMX controller, the input connector **210** and the output connector **212** may be electrically compatible with the output of the DMX controller. In such examples, the input connector **210** may be a DMX IN connector and the output connector **212** may be a DMX OUT connector. The light device **120** (e.g., light device **120-1**) may use the input connector **210**, output connector **212**, or a combination thereof to receive addressing signals, data signals, power, or a combination thereof, from the controller **105** or another light device **120**. The light device **120** (e.g., light device **120-1**) may also use the input connector **210**, output connector **212**, or a combination thereof to forward addressing signals, data signals, power, or a combination thereof, to another light device **120** (e.g., light device **120-2**). In certain embodiments, the input connector **210** may have a plug configuration and the output connector **212** may have a socket configuration.

The input connector **210** and output connector **212** may enable the light device **120** to be used in different lighting configurations with other light devices **120**, including light devices **120** that have the same form factor, light devices **120** that have a different form factor, or a combination thereof. FIGS. **3** and **4**, for instance, depict example lighting configurations **300** and **400**, according to various embodiments. In the lighting configuration **300**, multiple light devices **120-1** to **120-4** are connected in a chain configuration. In the lighting configuration **400**, multiple light devices **120-1** to **120-5** are connected in a string configuration.

In a chain configuration, the light devices **120** may be directly connected together utilizing both the input connector **210** and output connector **212**. As shown in FIG. **3**, for example, the input connector **210-2** of light device **120-2** is directly connected to the output connector **212-1** of light device **120-1**, the input connector **210-3** of light device **120-3** is directly connected to the output connector **212-2** of light device **120-2**, and the input connector **210-4** of light device **120-4** is directly connected to the output connector **212-3** of light device **120-3**. The input connector **210-1** of light device **120-1** or the output connector **212-4** of light device **120-4** may be connected to the controller **105** via cabling (not shown in FIG. **3**). The input connector **210** and the output connector **212** may allow for the removal of a light device **120** (e.g., light device **120-3** or another light device) within the lighting configuration **300** without disturbing the other light devices **120**. For example, the input connector **210**, the output connector **212**, or a combination thereof, may be detachable components that can slide onto and/or slide away from the PCB **214** of the respective light device **120**. Note that while each light device **120** depicted in FIG. **3** has the same form factor, in certain embodiments, the lighting configuration **300** may include a chain configuration of light devices **120** with the same form factor, light devices **120** with different form factors, or a combination thereof.

In a string configuration, each individual light device **120** may be connected to a matching wiring harness via solely the input connector **210** of the light device **120** (e.g., the output connector **212** of each light device **120** may not be used). As shown in FIG. **4**, for example, input connector **210-1** of light device **120-1** is directly connected to connector **430-1** of wiring harness **402**, input connector **210-2** of light device **120-2** is directly connected to connector **430-2** of wiring harness **402**, input connector **210-3** of light device **120-3** is directly connected to connector **430-3** of wiring harness **402**, input connector **210-4** of light device **120-4** is directly connected to connector **430-4** of wiring harness **402**, and input connector **210-5** of light device **120-5** is directly connected to connector **430-5** of wiring harness **402**. In lighting configuration **400**, each input connector **210** may allow for the removal of a light device **120** within the lighting configuration **400** without disturbing the other light devices **120** (e.g., the input connector **210** may be a detachable component that can slide onto and/or slide away from the PCB **214** of the respective light device **120**. Note that while each light device **120** depicted in FIG. **4** has the same form factor, in certain embodiments, the lighting configuration **400** may include a chain configuration of light devices **120** with the same form factor, light devices **120** with different form factors, or a combination thereof.

In the lighting configuration **400**, the wiring harness **402** may pass control (e.g., addressing signals) and data signals (e.g., DMX512 data signals) and power to each light device **120-1** to **120-5** in the lighting configuration **400** via multiple cabling. FIG. **5** further illustrates the wiring harness **402** illustrated in FIG. **4**, according to one embodiment. In the depicted embodiment, the wiring harness **402** may include a respective connector **430-1** to **430-128** for each input connector **210-1** to **210-128** of a string configuration with **128** light devices **120**. Here, the wiring harness **402** may pass addressing signals (e.g., single-line addressing) between the light devices **120** via cabling **522**, pass data signals (e.g., DMX512 data signals) between the light devices **120** via cabling **526** and **528**, and pass power between the light devices **120** via cabling **524** and **530**. In certain embodiments, as shown in FIG. **5**, after a certain number of light devices **120** in the string (e.g., **32** light devices **120** in this example), the wiring harness **402** may allow for additional power to be injected into the string configuration via cabling **524** and **530**. In certain embodiments, the wiring harness **402** may include a cable sleeve **520** for organizing and protecting the cabling **522**, **524**, **526**, **528**, and **530** and preventing electrical hazards. In certain embodiments, the wiring harness **402** may include a termination component **510** (e.g., wire stop socket component) for terminating the data cabling **526** and **528** after the last light device **120-128** in the string configuration. In DMX implementations, the termination component **510** may be a resistor (e.g., 120 ohm resistor) coupled across the data cabling **526** and **528**.

FIG. **6** illustrates an example light device **620**, according to one embodiment. The light device **620** is an illustrative example implementation of the light device **120** described in FIGS. **1** and **2**. For example, the light device **620** is illustrative of an example form factor of the light devices **120** within the lighting configurations **300** and **400** illustrated in FIGS. **3** and **4**, respectively.

As shown, the light device **620** has a form factor that is rectangular in shape, includes a single light engine **130**, an input connector **210** disposed on one (short) side of the PCB **214**, an output connector **212** disposed on an opposite (short) side of the PCB **214**, a regulator **208** disposed between the input connector **210** and the light engine **130**, and a driver **206** disposed between the light engine **130** and the output connector **212**. Here, the light engine **130** may be disposed approximately at the center of the PCB **214**. Other components of the light device **620** may be placed such that the output from the light engine **130** is not adversely impacted (e.g., shadowed).

In certain embodiments, the light device **620** may include positioning holes that allow an optic or other component to be positioned and secured over the light engine **130**. In FIG. **6**, for example, the light device **620** includes four positioning holes **606-1** to **606-4** adjacent to the LEDs **204-1** to **204-4**, respectively, of the light engine **130**. The light device **620** also includes one or more mounting holes **604-1** to **604-2** and slots (or cutouts) **602-1** to **602-2** to allow for attaching the light device **620** to a surface or an enclosure.

FIG. **7** illustrates another example light device **720**, according to one embodiment. The light device **720** is an illustrative example implementation of the light device **120** described in FIGS. **1** and **2**. For example, the light device **720** is illustrative of another example form factor of the light devices **120** that can be used within the lighting configurations **300** and **400** illustrated in FIGS. **3** and **4**, respectively.

As shown, compared to the light device **620**, the light device **720** has a form factor that includes multiple (e.g., four) light engines **130-1** to **130-4**. Although not shown in FIG. **7**, in certain embodiments, the light device **720** may include a respective driver **206** disposed on the PCB **214** for each light engine **130-1** to **130-4**. In certain embodiments, the light device **720** may include a single driver **206** disposed on the PCB **214** for the light engines **130-1** to **130-4**.

As noted, in lighting configurations that include multiple light devices **120** with multiple different form factors, the spacing between the light engines **130** within the lighting configuration may be maintained (e.g., the spacing is the same). FIG. **8**, for example, depicts an example of the line spacing being maintained in a scenario where four light devices **620-1** to **620-4** are placed adjacent to a single light device **720**. As shown, the light engines within light devices **620** and light device **720** are arranged in a grid where the spacing (d) between line engines is consistent. As noted, enabling a consistent line spacing throughout a given configuration/lighting apparatus may allow light devices **120** to be used for lighting effects in which pixel alignment is crucial (e.g., LED displays).

In certain embodiments, one or more light devices **120** may be partially or fully enclosed within a housing (or enclosure) **125**. FIGS. **9A-9C** illustrate different views of an apparatus **900** that includes a light device **620** enclosed within a housing **125**, according to one embodiment. In particular, FIG. **9A** depicts a perspective view of the apparatus **900**, FIG. **9B** depicts a side view of the apparatus **900**, and FIG. **9C** depicts an exploded perspective view of the apparatus **900**, according to one embodiment.

As shown in FIGS. **9A-9C**, the apparatus **900** may include a single-piece housing (or enclosure) **125** that can be attached to the light device **620** via the mounting holes **604** and slots **602**. For example, as shown in FIG. **9C**, the housing **125** may include aligning pins **952-1** to **952-2** that can be inserted into the respective mounting holes **604-1** to **604-2**, and may include snap elements **950-1** to **950-2** that can lock onto the PCB **214** of the light device **620** via the respective slots **602-1** to **602-2**.

As shown in FIG. **9B**, the housing **125** may allow access to the input connector **210** of the light device **620** by another connector (e.g., output connector **212** of another light device or connector **430** of a wiring harness **402**). In embodiments where the input connector **210** is attached to a wiring harness **402**, the housing **125** may provide mechanical strain relief to the attached wiring harness **402** via the support member **920**. Opposite the input connector **210**, the housing **125** may include a key mount **912** that allows the light device **620** to lock into a lighting apparatus **110** (e.g., lighting apparatus **110-1**, such as a display panel).

As shown in FIGS. **9A-9C**, the apparatus **900** includes a light pipe **940** configured to pass light emitted from the light engine **130** from a portion **932** of the light pipe **940** to a portion **930** of the light pipe **940**. The light pipe **940** may be formed of any suitable material (e.g., polycarbonate) for passing emitted light. The positioning holes **606-1** to **606-4** of the light device **620** may be used to attach the portion **932** of the light pipe **940** to the light engine **130**, such that the total internal reflection (TIR) blending of the emitted light is maximized. The portion **930** of the light pipe **940** may be a diffused, semi-domed feature of the light pipe **940**. The light pipe **940** may be configured to provide illumination through the portion **930**, based on the emitted light received from the light engine **130** via the portion **932**. At least a portion (e.g., portion **930**) of the light pipe **940** may be inserted through an opening of the housing **125**.

In certain embodiments, at least a portion of the housing **125** may be sealed to form a watertight enclosure. For example, the opening of the housing **125** through which the portion **930** of the light pipe **940** extends may be sealed to prevent water, dust, and other foreign bodies from entering the housing **125**. In such embodiments, the apparatus **900** may be configured for a particular ingress protection (IP) rating.

Note that while FIGS. **9A-9C** depict a housing **125** being used to form an enclosure over light device **620**, in certain embodiments, a similar housing **125** may be used to form an enclosure over light device **720**.

FIG. **10** is a flowchart of a method **1000** for controlling one or more light devices **120** (e.g., light devices **620** and/or **720**), according to one embodiment. The method **1000** may be performed by a controller (e.g., controller **105**).

Method **1000** may enter at block **1002**, where the controller detects an error state associated with a lighting configuration. The lighting configuration may include multiple light devices (e.g., light devices **620**, light devices **720**, or a combination thereof). The lighting configuration may a single lighting configuration among multiple lighting configurations deployed in an environment.

In certain embodiments, detecting the error state (at block **1002**) may include determining a source of the error state (e.g., which light engine **130** is the source of the error state). For example, the controller may receive an indication from the driver (e.g., driver **206**) associated with the light engine (that is the source of error state) that the particular light engine has encountered an error state. In some embodiments, the driver associated with the light engine that is the source of the error state may generate the indication, which may then be passed upstream driver by driver until it reaches the controller.

In certain embodiments, detecting the error state (at block **1002**) may include: comparing a data output from a terminal (or ending) light device in the lighting configuration with a data input to an initial (or beginning) light device in the lighting configuration; and determining the error state has occurred when the data output is different from the data input.

At block **1004**, the controller may generate and transmit a command to turn off one or more light engines within the lighting configuration, in response to the detection at block **1002**. For example, in some cases, when the controller has determined the source of the error, the controller may turn off the light engine in the light device that is the source of the error. In some cases, the controller may turn off the entire lighting configuration, e.g., to prevent the lighting configuration from behaving in an unexpected manner.

As used herein, "a processor," "at least one processor," or "one or more processors" generally refers to a single processor configured to perform one or multiple operations or multiple processors configured to collectively perform one or more operations. In the case of multiple processors, performance of the one or more operations could be divided amongst different processors, though one processor may perform multiple operations, and multiple processors could collectively perform a single operation. Similarly, "a memory," "at least one memory," or "one or more memories" generally refers to a single memory configured to store data and/or instructions or multiple memories configured to collectively store data and/or instructions.

In the current disclosure, reference is made to various embodiments. However, it should be understood that the present disclosure is not limited to specific described embodiments. Instead, any combination of the following features and elements, whether related to different embodiments or not, is contemplated to implement and practice the teachings provided herein. Additionally, when elements of the embodiments are described in the form of "at least one of A and B," it will be understood that embodiments including element A exclusively, including element B exclusively, and including element A and B are each contemplated. Furthermore, although some embodiments may achieve advantages over other possible solutions or over the prior art, whether or not a particular advantage is achieved by a given embodiment is not limiting of the present disclosure. Thus, the aspects, features, embodiments and advantages disclosed herein are merely illustrative and are not considered elements or limitations of the appended claims except where explicitly recited in a claim(s). Likewise, reference to "the invention" shall not be construed as a generalization of any inventive subject matter disclosed herein and shall not be considered to be an element or limitation of the appended claims except where explicitly recited in a claim(s).

As will be appreciated by one skilled in the art, embodiments described herein may be embodied as a system, method or computer program product. Accordingly, embodiments may take the form of an entirely hardware embodiment, an entirely software embodiment (including firmware, resident software, micro-code, etc.) or an embodiment combining software and hardware aspects that may all generally be referred to herein as a "circuit," "module" or "system." Furthermore, embodiments described herein may take the form of a computer program product embodied in one or more computer readable medium(s) having computer readable program code embodied thereon.

Program code embodied on a computer readable medium may be transmitted using any appropriate medium, including but not limited to wireless, wireline, optical fiber cable, RF, etc., or any suitable combination of the foregoing.

Computer program code for carrying out operations for embodiments of the present disclosure may be written in any combination of one or more programming languages, including an object oriented programming language such as Java, Smalltalk, C++ or the like and conventional procedural programming languages, such as the "C" programming language or similar programming languages. The program code may execute entirely on the user's computer, partly on the user's computer, as a stand-alone software package, partly on the user's computer and partly on a remote computer or entirely on the remote computer or server. In the latter scenario, the remote computer may be connected to the user's computer through any type of network, including a local area network (LAN) or a wide area network (WAN), or the connection may be made to an external computer (for example, through the Internet using an Internet Service Provider).

Aspects of the present disclosure are described herein with reference to flowchart illustrations or block diagrams of methods, apparatuses (systems), and computer program products according to embodiments of the present disclosure. It will be understood that each block of the flowchart illustrations or block diagrams, and combinations of blocks in the flowchart illustrations or block diagrams, can be implemented by computer program instructions. These computer program instructions may be provided to a processor of a general purpose computer, special purpose computer, or other programmable data processing apparatus to produce a machine, such that the instructions, which execute via the processor of the computer or other programmable data processing apparatus, create means for implementing the functions/acts specified in the block(s) of the flowchart illustrations or block diagrams.

These computer program instructions may also be stored in a computer readable medium that can direct a computer, other programmable data processing apparatus, or other device to function in a particular manner, such that the instructions stored in the computer readable medium produce an article of manufacture including instructions which implement the function/act specified in the block(s) of the flowchart illustrations or block diagrams.

The computer program instructions may also be loaded onto a computer, other programmable data processing apparatus, or other device to cause a series of operational steps to be performed on the computer, other programmable apparatus or other device to produce a computer implemented process such that the instructions which execute on the computer, other programmable data processing apparatus, or other device provide processes for implementing the functions/acts specified in the block(s) of the flowchart illustrations or block diagrams.

The flowchart illustrations and block diagrams in the Figures illustrate the architecture, functionality, and operation of possible implementations of systems, methods, and computer program products according to various embodiments of the present disclosure. In this regard, each block in the flowchart illustrations or block diagrams may represent a module, segment, or portion of code, which comprises one or more executable instructions for implementing the specified logical function(s). It should also be noted that, in some alternative implementations, the functions noted in the block may occur out of the order noted in the Figures. For example, two blocks shown in succession may, in fact, be executed substantially concurrently, or the blocks may sometimes be executed in the reverse order or out of order, depending upon the functionality involved. It will also be noted that each block of the block diagrams or flowchart illustrations, and combinations of blocks in the block diagrams or flowchart illustrations, can be implemented by special purpose hardware-based systems that perform the specified functions or acts, or combinations of special purpose hardware and computer instructions.

While the foregoing is directed to embodiments of the present disclosure, other and further embodiments of the disclosure may be devised without departing from the basic scope thereof, and the scope thereof is determined by the claims that follow.

What is claimed is:

1. A lighting apparatus comprising:

a first light device and a second light device, each of the first light device and the second light device comprising:
- a printed circuit board (PCB);
- an input connector disposed at a first side of the PCB;
- an output connector disposed at second side of the PCB;
- one or more light engines disposed on the PCB between the input connector and the output connector, each light engine of the one or more light engines comprising a plurality of light emitting diodes (LEDs); and
- one or more drivers disposed on the PCB, each driver of the one or more drivers being configured to control illumination emitted from a respective light engine of the one or more light engines,

wherein the input connector of the first light device or the second light device is configured to directly connect to the output connector of the other of the first light device or the second light device.

2. The lighting apparatus of claim **1**, wherein each driver is configured to individually control illumination emitted from each LED of the plurality of LEDs within the respective light engine.

3. The lighting apparatus of claim **1**, wherein the input connector of the first light device or the second light device is directly connected to the output connector of the other of the first light device or the second light device.

4. The lighting apparatus of claim **1**, wherein the input connector of the first light device or the second light device is further configured to connect to a wiring harness.

5. The lighting apparatus of claim **1**, wherein the input connector of the first light device or the second light device is further configured to connect to a controller via at least one cable.

6. The lighting apparatus of claim **1**, wherein at least one of the first light device or the second light device further comprises a housing attached to the PCB, the housing forming an enclosure around the input connector, the output connector, the one or more light engines, and the one or more drivers.

7. The lighting apparatus of claim **6**, wherein the at least one of the first light device or the second light device further comprises one or more light pipes at least partially enclosed by the housing, each light pipe having (i) a first portion disposed on and aligned with a respective light engine of the one or more light engines and (ii) a second portion partially disposed outside of the housing at the first side of the PCB.

8. The lighting apparatus of claim **7**, wherein each of the one or more light pipes is configured to pass light emitted from the respective light engine from the first portion to the second portion.

9. The lighting apparatus of claim **1**, wherein a number of the one or more light engines in each of the first light device and the second light device is one.

10. The lighting apparatus of claim **1**, wherein a number of the one or more light engines in each of the first light device and the second light device is four.

11. A lighting apparatus comprising:

a plurality of light devices, wherein each light device of the plurality of light devices comprises:
- a printed circuit board (PCB);
- an input connector disposed at a first side of the PCB;
- an output connector disposed at second side of the PCB;
- a light engine disposed on the PCB between the input connector and the output connector, the light engine comprising a plurality of light emitting diodes (LEDs);
- a driver configured to control illumination emitted from the light engine; and
- a housing attached to the PCB and forming an enclosure around the input connector, the output connector, the light engine, and the driver,

wherein the input connector of a first light device of the plurality of light devices or a second light device of the plurality of light devices is configured to directly connect to the output connector of the other of the first light device or the second light device.

12. The lighting apparatus of claim **11**, wherein each light device of the plurality of light devices further comprises a light pipe configured to pass light emitted from the plurality of LEDs of the light engine from a first portion of the light pipe to a second portion of the light pipe, wherein the first portion of the light pipe is aligned with the light engine and the second portion of the light pipe partially extends through an opening of the housing at the second side of the PCB.

13. The lighting apparatus of claim **11**, further comprising a wiring harness comprising a plurality of connectors, each connector of the wiring harness being configured to connect to a respective input connector of a respective light device of the plurality of light devices.

14. The lighting apparatus of claim **13**, wherein the wiring harness is configured to provide power, data signals, and addressing signals to each of the plurality of light devices.

15. The lighting apparatus of claim **11**, wherein each light device of the plurality of light devices further comprises a voltage regulator disposed on the PCB between the input connector and the output connector.

16. The lighting apparatus of claim **11**, wherein an amount of spacing between each light engine within the plurality of light devices is the same.

17. A lighting apparatus comprising:

a first light device and a second light device, each of the first light device and the second light device comprising:

a printed circuit board (PCB);

an input connector disposed at a first side of the PCB;

an output connector disposed at second side of the PCB;

a first light engine coupled to the PCB comprising a first set of light emitting diodes (LEDs);

a second light engine coupled to the PCB comprising a second set of LEDs;

a first driver in communication with the first light engine and configured to control illumination emitted from the first set of LEDs; and

a second driver in communication with the second light engine and configured to control illumination emitted from the second set of LEDs,

wherein the input connector of the first light device or the second light device is configured to directly connect to the output connector of the other of the first light device or the second light device.

18. The lighting apparatus of claim **17**, wherein the first light engine and the second light engine are positioned between the first side and the second side.

19. The lighting apparatus of claim **17**, wherein at least one of the first light device or the second light device further comprises:

a first light pipe optically aligned with the first light engine and configured to direct light away from the PCB.

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