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(54) Title: MULTI-COLOR LUMMAIRE

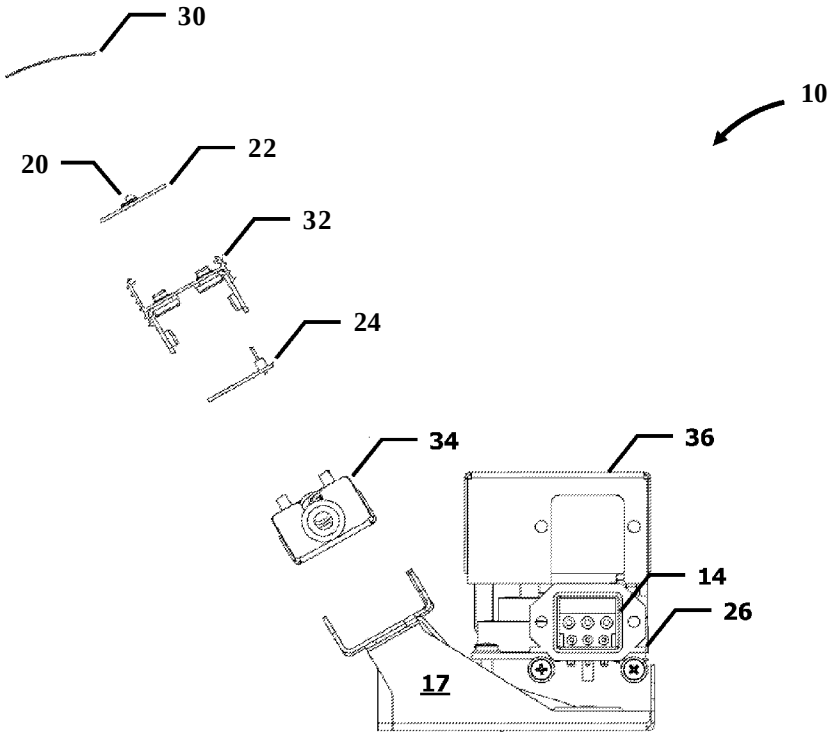

FIG. 2 (Exploded Side View)

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(57) Abstract: A multi-color light emitting diode (LED) luminaire is provided. The luminaire includes a power module and an LED module. The LED module includes a first LED string, a second LED and a microcontroller.

MULTI-COLOR LUMINAIRE

FIELD OF THE INVENTION

[0001] The present invention relates to a luminaire. More particularly, the present invention relates to multi-color luminaires.

BACKGROUND OF THE INVENTION

[0002] There are several approaches for designing light emitting diode (LED) or Solid State Lighting (SSL) luminaires capable of displaying two or more colors. In one approach, each luminaire includes two (or more) LED emitter strings that are commonly-controlled by a power signal (i.e., "ON" or "OFF"), so that each luminaire produces a fixed color spectrum as soon as the power signal is applied. In another approach, each luminaire is connected to a data network and includes three or four LED emitter strings (e.g., RGB or RGBA) that are independently-controlled by a system controller, so that each luminaire produces a particular color spectrum at a particular time.

[0003] Mood lighting systems for aircraft provide a significant enhancement to the cabin environment for commercial or general aviation, particularly on long distance flights, and include many LED or SSL luminaires that are connected to a data network and controlled by a system controller. However, retrofitting a mood lighting system to an existing aircraft suffers from many technical and other difficulties. For example, aircraft mood lighting systems are not "drop-in" replacements (i.e., physical mounting configuration, power and control signal connectors, etc.) for existing aircraft fluorescent lighting systems, and present higher cost, higher complexity and higher weight penalties than existing aircraft fluorescent lighting systems. Aircraft mood lighting systems also present complicated installation problems, and require additional operator training.

SUMMARY OF THE INVENTION

[0004] Embodiments of the present invention advantageously provide a multi-color light emitting diode (LED) luminaire.

[0005] In one embodiment, the multi-color light emitting diode (LED) luminaire includes a power module and an LED module. The LED module includes a first LED string, a second LED string and a microcontroller.

BRIEF DESCRIPTION OF THE DRAWINGS

[0006] FIGS. 1A, IB and 1C present top, front and right side views, respectively, of a multi-color luminaire, in accordance with an embodiment of the invention.

[0007] FIG. 2 presents an exploded right side view of the multi-color luminaire depicted in FIG. 1.

[0008] FIG. 3 presents an exploded isometric view of the multi-color luminaire depicted in FIG. 1.

[0009] FIGS. 4A to 4E present additional top, front, bottom, left and right side views, respectively, of the multi-color luminaire depicted in FIGS. 1A to 1C.

DETAILED DESCRIPTION

[0010] The invention will now be described with reference to the drawing figures, in which like reference numerals refer to like parts throughout.

[0011] Existing aircraft fluorescent lighting fixtures (hereinafter "legacy fixtures") are typically mounted within an aircraft cabin using a set of bolts, screws, etc., that are arranged in a predetermined pattern or footprint (hereinafter a "mounting arrangement"). Legacy fixtures generally include one or more fluorescent bulbs, an incandescent nightlight bulb, a ballast, power and/or signal conditioning circuitry, control logic, etc. The power/control signal connection typically includes six (6) signals, i.e., A/C_{IN}, A/CRETURN, chassis ground, nightlight control, MID DIM control, and LOW DIM control. From the powered-down (or "OFF" state), applying 115 V AC to A/CIN causes the legacy fixture to immediately transition to the powered-up (or "ON" state) of full brightness. When the MID DIM control signal is asserted, the legacy fixture immediately reduces the brightness to a level below full brightness; similarly, when the LOW DIM control signal is asserted, the legacy fixture immediately reduces the brightness to a level between the MID DIM level and

the OFF state. The MID DIM and LOW DIM signals may be asserted by connecting these signals to A/CRETURN- When the nightlight control signal is asserted, the incandescent nightlight bulb at the end of the fixture (or elsewhere) is powered-up, which provides a very low brightness level when the fluorescent light bulb is powered-down.

[0012] Embodiments of the present invention advantageously provide a multi-color luminaire 10 that is a physical and electrical drop-in replacement for legacy fixtures. In a preferred embodiment, multi-color luminaire 10 includes a physical mounting arrangement 12 and an electrical power/control signal connector 14 that comports with the mounting arrangement and electrical connections provided in the cabin for the legacy fixture. Advantageously, no additional modifications to the existing aircraft fluorescent lighting system (hereinafter "legacy system") are required, such as, for example, replacing the inverter module(s), the lamp control module(s), etc. In alternative embodiments, an adaptor bracket may used to provide a mechanical interface between the multi-color luminaire 10 and the existing mounting arrangement, or an additional connector or cable may be used to provide an electrical interface between the multi-color luminaire 10 and the existing power/control signal connections. In a further alternative embodiment, the multi-color luminaire 10 may be mounted within the cabin, in the approximate location of the legacy fixture, using a portion of the existing mounting arrangement in combination with a new mounting arrangement, using a completely new mounting arrangement, etc.

[0013] As depicted in FIGS. 1-4, the multi-color luminaire 10 includes a power module 16, an LED module 18 and a pair of mounting brackets 17. The power module 16 includes the electrical power/control signal connector 14 coupled to a power module board assembly 26 that is housed within the power module housing 36. The LED module 18 includes a rail assembly 32 on which one or more LED board assemblies 22 are mounted. The rail assembly 32 may be formed, for example, from extruded aluminum. In the depicted embodiment, two LED board assemblies 22 are provided; other configurations are also contemplated, such as one LED board assembly 22, three LED board assemblies 22, etc., depending on the overall length that is desired. Each LED board assembly 22 includes at least two strings of LEDs 20, and, in the depicted embodiment, the individual LEDs 20 of

each string are arranged in complementary pairs along the length of the LED board assembly 22. For an embodiment including three LED 20 strings (e.g., RGB), the individual LEDs 20 would be arranged in complementary triplets, etc. An LED driver board assembly 24 is provided for each LED board assembly 22, and an LED driver board housing 34 houses each LED driver board assembly 24. In a preferred embodiment, the LED driver board assembly 24 drives each LED 20 string independently. The LED driver board housings 34 are attached to the rail assembly 32, as well as to a respective mounting bracket 17. A lens 30 is attached to the rail assembly 32 and covers the entire length of the LED module 18. An LED cluster 38 is provided at one end of the LED module 18 which responds to the nightlight control signal from the legacy system.

[0014] Each LED driver board assembly 24 includes a microcontroller that independently controls each LED string provided on the respective LED board assembly 22 to produce a particular color spectrum and intensity, over a particular period of time, in response to the legacy system control signals. The microcontroller may be programmed during manufacture, or, alternatively, the microcontroller may be programmed, though an optional RJ-1 1 interface, just prior to installation, in-situ on the aircraft, etc. Because each LED driver board assembly 24 includes a microcontroller, a failure of one LED driver control board assembly 24 only affects the LED strings on the respective LED board assembly 22, which provides for graceful degradation of each multi-color luminaire 10.

[0015] Advantageously, the microcontroller uses pulse-width modulation (PWM) to independently control the brightness of the LED strings, and the resolution of the control parameter may be selected to provide very subtle changes in brightness. For example, 10-bit PWM control provides approximately 1,000 brightness steps between the "OFF" state and the "ON" state. Advantageously, the microcontroller may be programmed to transition from "OFF" to "ON" gradually over a particular period of time for each LED string, as well as to respond to the MID DIM and LOW DIM control signals by changing the brightness of each LED string independently, to predetermined levels over predetermined time periods. These transitions may be repeated over a much longer period of time, thereby creating lighting

scenes that repeat during the flight. Accordingly, a wide variety of durations, brightness levels and color intermix levels can be accommodated.

[0016] In one embodiment, the multi-color luminaire 10 includes a first LED string that includes white spectrum LED emitters in one of three color temperatures: 3000K (warm white), 4500K (neutral white), or 5700K (cool white). When the multi-color luminaire 10 is disposed in the "ON" state or "bright" mode of operation, the white LED emitters will be at 100% intensity level, providing a normal lighting environment for the aircraft cabin.

[0017] As discussed above, the legacy system provides either one (LOW DIM) or two (LOW DIM, MID DIM) control signals that are used to instantaneously switch the legacy system to a reduced lighting level. In this embodiment, these control signals activate a timed transition to an intermix color level utilizing a second LED string. Color choices for the second LED string may be the standard primary LED colors such as, for example, red, amber, green, or blue, with blue or amber being preferred. When the LOW DIM control signal is activated, the multi-color luminaire 10 transitions to a preset intermix color level somewhere between the primary white and the second color. This transition can be instantaneous or gradual, taking from seconds to several minutes in duration. As discussed above, the transition rate and target intermix levels are programmed into the microcontroller during manufacture, prior to installation, in-situ, etc. When both the LOW DIM and MID DIM control signals are available, two intermix lighting levels are available.

[0018] The primary white lighting channel (first LED string) and the secondary colored lighting channel (second LED string) are independently adjustable from 0 to 100% intensity or brightness. If so desired, the LOW DIM or MID DIM can be preset to forego any white lighting component (0%) at all and just display the secondary color channel (0 - 100%). In a preferred embodiment, with respect to the intermix levels, the additive percentage between the two lighting channels should not exceed 100%.

[0019] In another embodiment, a cool-white (5700K) LED string is installed as the primary white lighting channel, while the second LED string uses warm-white (3000K) emitters. The primary cool-white LED string will provide efficient high level illumination in the "ON" state or "bright" mode of operation. In the LOW DIM or MID DIM mode of

operation, a preset intermix level of cool-white and warm- white illumination is provided at a lower overall brightness level. This lighting environment promotes a restful condition and also enhances the appearance of foodstuffs. Once again the transition rate between the "ON" state and the LOW DIM and MID DIM modes of operation can be preset for an instantaneous or timed transition.

[0020] The many features and advantages of the invention are apparent from the detailed specification, and, thus, it is intended by the appended claims to cover all such features and advantages of the invention which fall within the true spirit and scope of the invention. Further, since numerous modifications and variations will readily occur to those skilled in the art, it is not desired to limit the invention to the exact construction and operation illustrated and described, and, accordingly, all suitable modifications and equivalents may be resorted to that fall within the scope of the invention.

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What is claimed is:

1. A multi-color light emitting diode (LED) luminaire, comprising:

a power module, including an electrical power / control signal connector to connect to an aircraft fluorescent lighting system, to convert VAC to VDC; and

an LED module, coupled to the power module, including:

a first LED string including a plurality of LEDs that emit the same color spectrum,

a second LED string including a plurality of LEDs that emit the same color spectrum, and

a microcontroller, coupled to the first and second LED strings, to independently control the brightness of the first and second LED strings based on control signals provided by the aircraft fluorescent lighting system.

2. The luminaire according to Claim 1, wherein the color spectrums emitted by the first and second LED strings are the same.

3. The luminaire according to Claim 1, wherein the color spectrums emitted by the first and second LED strings are different.

4. The luminaire according to Claim 3, further comprising a third LED string including a plurality of LEDs that emit the same color spectrum, wherein the color spectrums emitted by the first, second and third LED strings are different.

5. The luminaire according to Claim 4, wherein the color spectrums emitted by the first, second and third LED strings are red, green and blue, respectively.

6. The luminaire according to Claim 1, wherein the LED module includes at least one rail assembly to which the first and second LED strings are attached.

7. The luminaire according to Claim 6, wherein the LEDs of the first and second LED strings are arranged in complementary pairs along the LED rail assembly.

8. The luminaire according to Claim 1, wherein the LED module includes a plurality of LED board assemblies, wherein a portion of the first and second LED strings are arranged in complementary pairs along the length of each LED board assembly, and a microcontroller is provided on each LED board assembly.

9. The luminaire according to Claim 1, further comprising at least one lens extending along the length of the LED module.

10. The luminaire according to Claim 1, wherein the LED module includes an LED cluster, disposed at one end thereof, responsive to a nightlight control signal provided by the aircraft fluorescent lighting system.

11. The luminaire according to Claim 1, wherein the microcontroller is programmable via an RJ-11 interface after the luminaire has been installed in the aircraft.

12. The luminaire according to Claim 1, wherein the microcontroller uses pulse-width modulation to independently control the brightness of the first and second LED strings.

13. The luminaire according to Claim 1, wherein the first LED string includes white spectrum LED emitters having a color temperature of 3000K, 4500K or 5700K.

14. The luminaire according to Claim 1, wherein the second LED string includes color spectrum emitters including red, amber, green, or blue.

15. The luminaire according to Claim 1, wherein the first and second LED strings are independently adjustable from 0 to 100% intensity.

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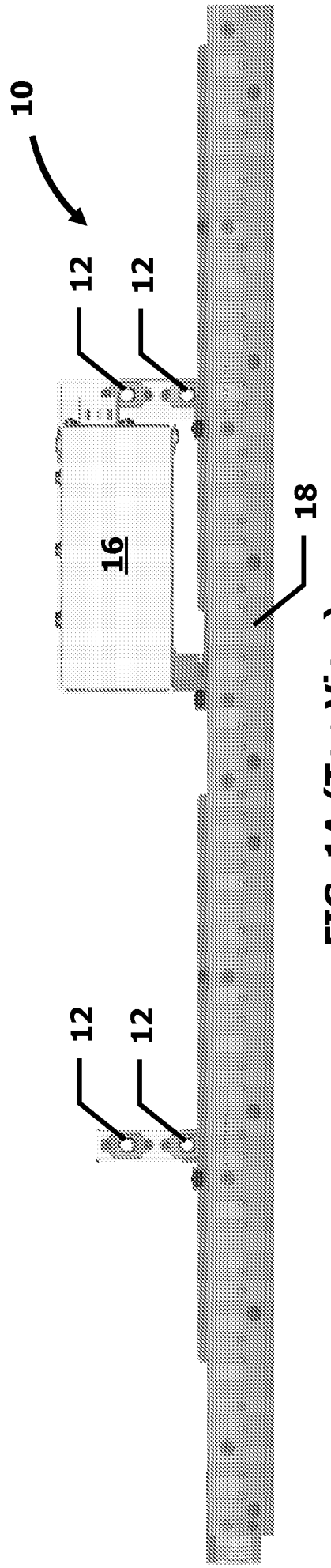

FIG. 1A (Top View)

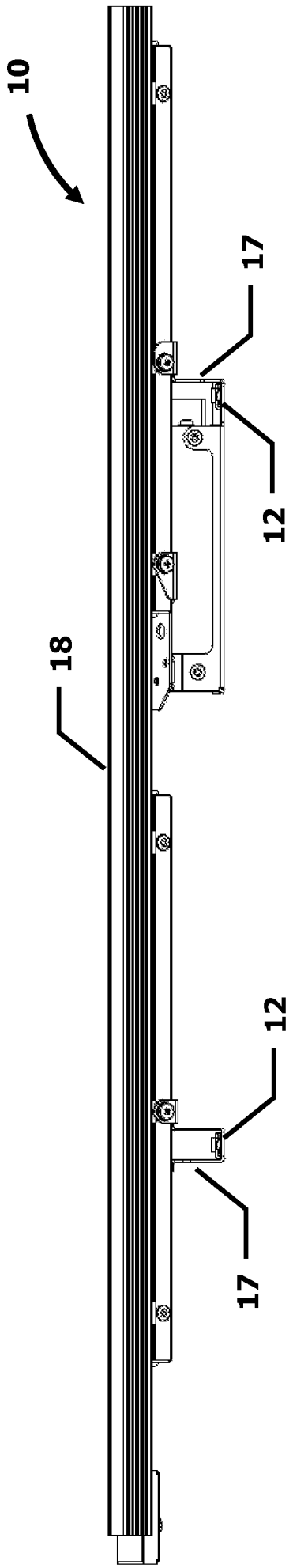

FIG. 1B (Front View)

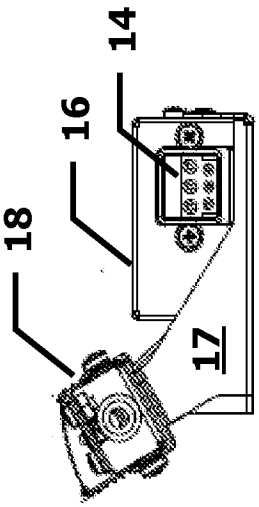

FIG. 1C (Side View)

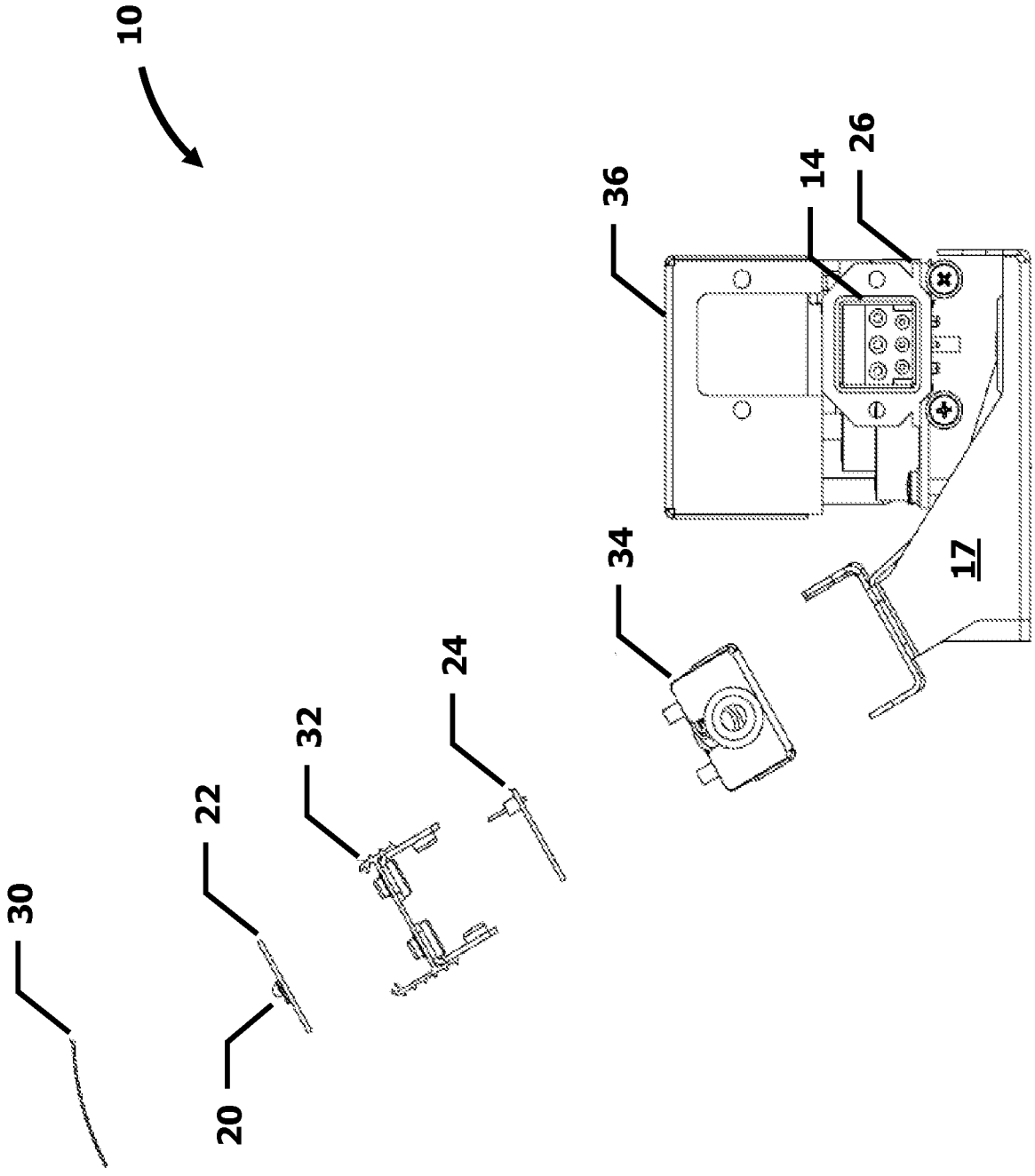

FIG. 2 (Exploded Side View)

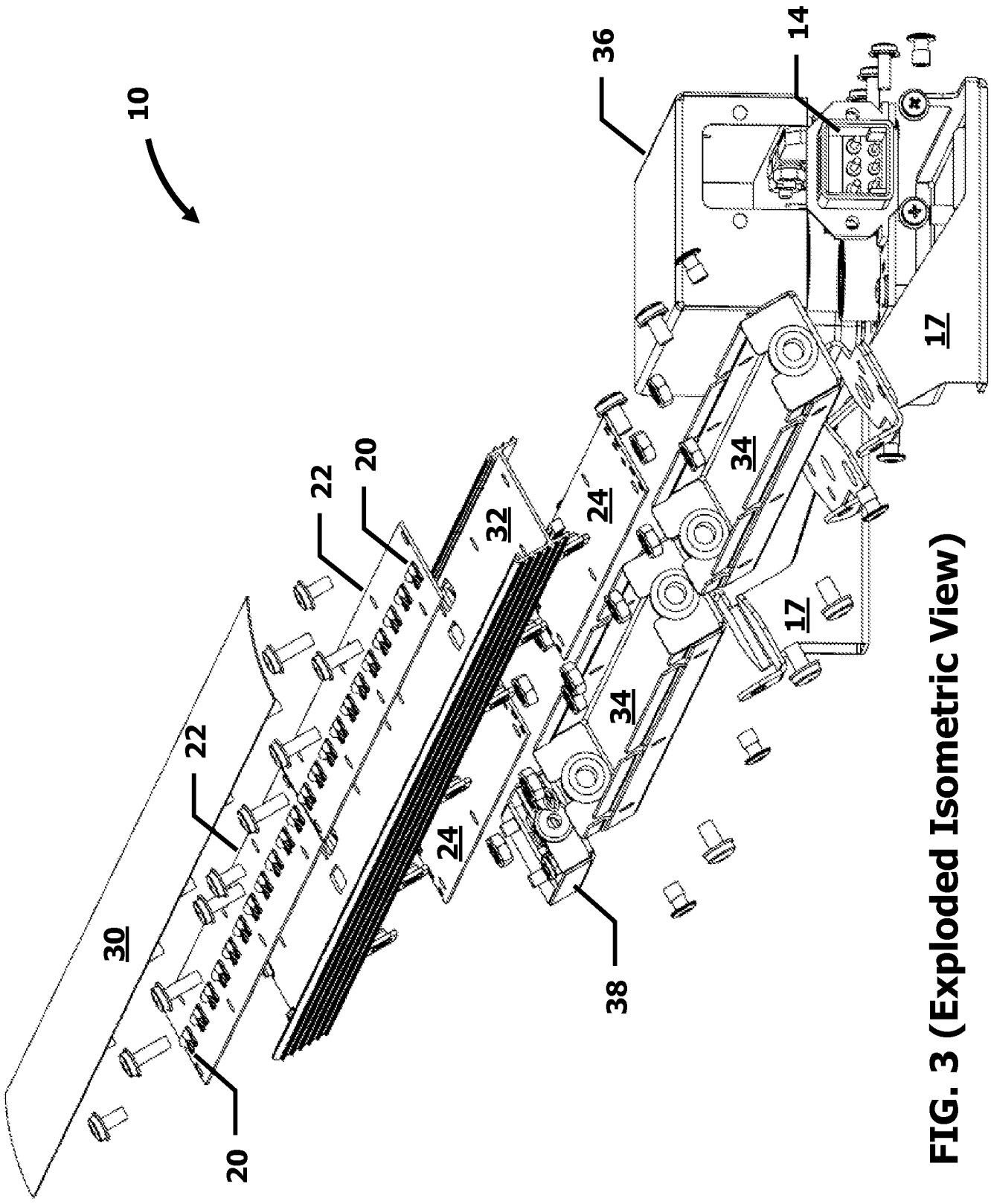

FIG. 3 (Exploded Isometric View)

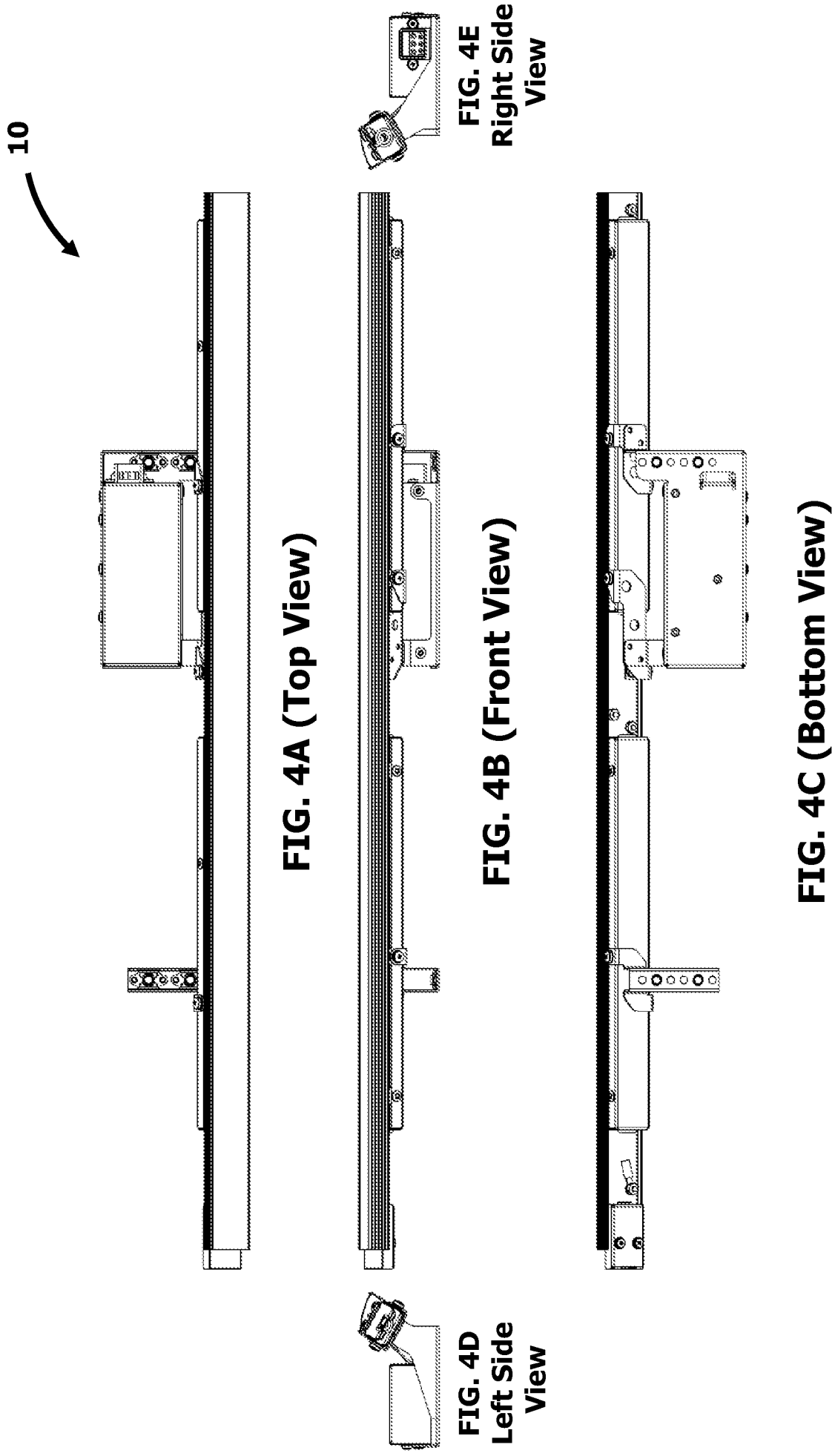
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FIG. 4A (Top View)
FIG. 4B (Front View)
FIG. 4C (Bottom View)
FIG. 4D Left Side View
FIG. 4E Right Side View

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US201 1/036893

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - H05B 37/00 (201 1.01)
USPC - 315/1 85R
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC(8) - F21 S 4/00; H05B 37/00, 37/02 (201 1.01)
USPC - 315/185R, 209R, 294; 362/249.03

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
MicroPatent, PatBase, Google Patent, Google

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2010/0072904 A1 (ECKEL et al) 25 March 2010 (25.03.2010) entire document	1-15
Y	US 2008/0253122 A1 (HANCOCK et al) 16 October 2008 (16.10.2008) entire document	1-15
Y	US 2003/0032426 A1 (GILBERT et al) 13 February 2003 (13.02.2003) entire document	11
A	US 7,333,01 1 B2 (SINGER et al) 19 February 2008 (19.02.2008) entire document	1-15
A	US 2004/0052076 A1 (MUELLER et al) 18 March 2004 (18.03.2004) entire document	1-15

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
24 August 2011	29 AUG 2011
Name and mailing address of the ISA/US Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-3201	Authorized officer: Blaine R. Copenheaver PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774

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