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Timmermans et al.

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(54) **LIGHT TUBE AND POWER SUPPLY CIRCUIT**

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(58) **Field of Classification Search**
CPC F21K 9/278; F21K 9/272; F21K 9/275; F21V 19/003; F21V 23/023
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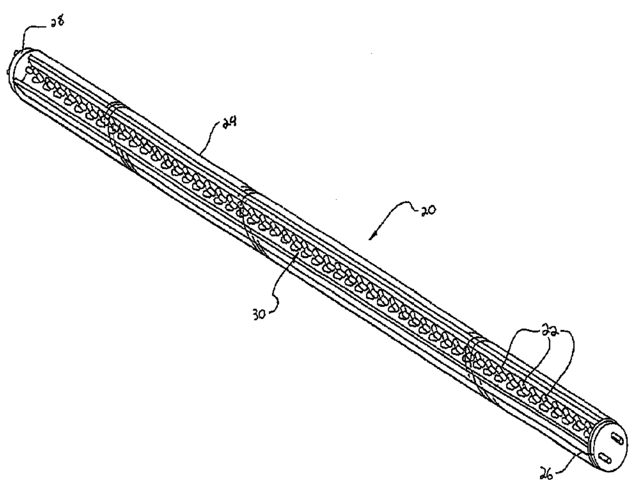
(57) **ABSTRACT**

A replacement light tube for replacing a fluorescent light tube includes a bulb portion extending between a first end and a second end, the bulb portion comprising a support structure, a plurality of white light emitting diodes (LEDs) and an elongate light-transmissive cover. The support structure has a first surface extending between the first end and the second end. The plurality of LEDs are supported by the first surface and arranged between the first end and the second end. The elongate light-transmissive cover extends between the first end and the second end and over the first surface of the support structure. A first end cap and a second end cap are disposed on the first end and the second end, respectively, each configured to fit with a socket for a fluorescent light tube. A power supply circuit is configured to provide power to the plurality of LEDs. The plurality of LEDs are arranged to emit light through the elongate light-transmissive cover and at least a portion of the power supply circuit is packaged inside at least one of the end caps.

48 Claims, 9 Drawing Sheets



Related U.S. Application Data

continuation of application No. 14/669,963, filed on Mar. 26, 2015, now Pat. No. 9,222,626, which is a continuation of application No. 14/299,909, filed on Jun. 9, 2014, now Pat. No. 9,006,990, and a continuation of application No. 14/299,915, filed on Jun. 9, 2014, now Pat. No. 9,006,993, said application No. 14/299,909 is a continuation of application No. 13/777,331, filed on Feb. 26, 2013, now Pat. No. 8,866,396, said application No. 14/299,915 is a continuation of application No. 13/777,331, which is a continuation of application No. 12/965,019, filed on Dec. 10, 2010, now Pat. No. 8,382,327, which is a continuation of application No. 11/085,744, filed on Mar. 21, 2005, now Pat. No. 8,247,985, which is a continuation of application No. 09/782,375, filed on Feb. 12, 2001, now Pat. No. 7,049,761.

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(58) **Field of Classification Search**
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See application file for complete search history.

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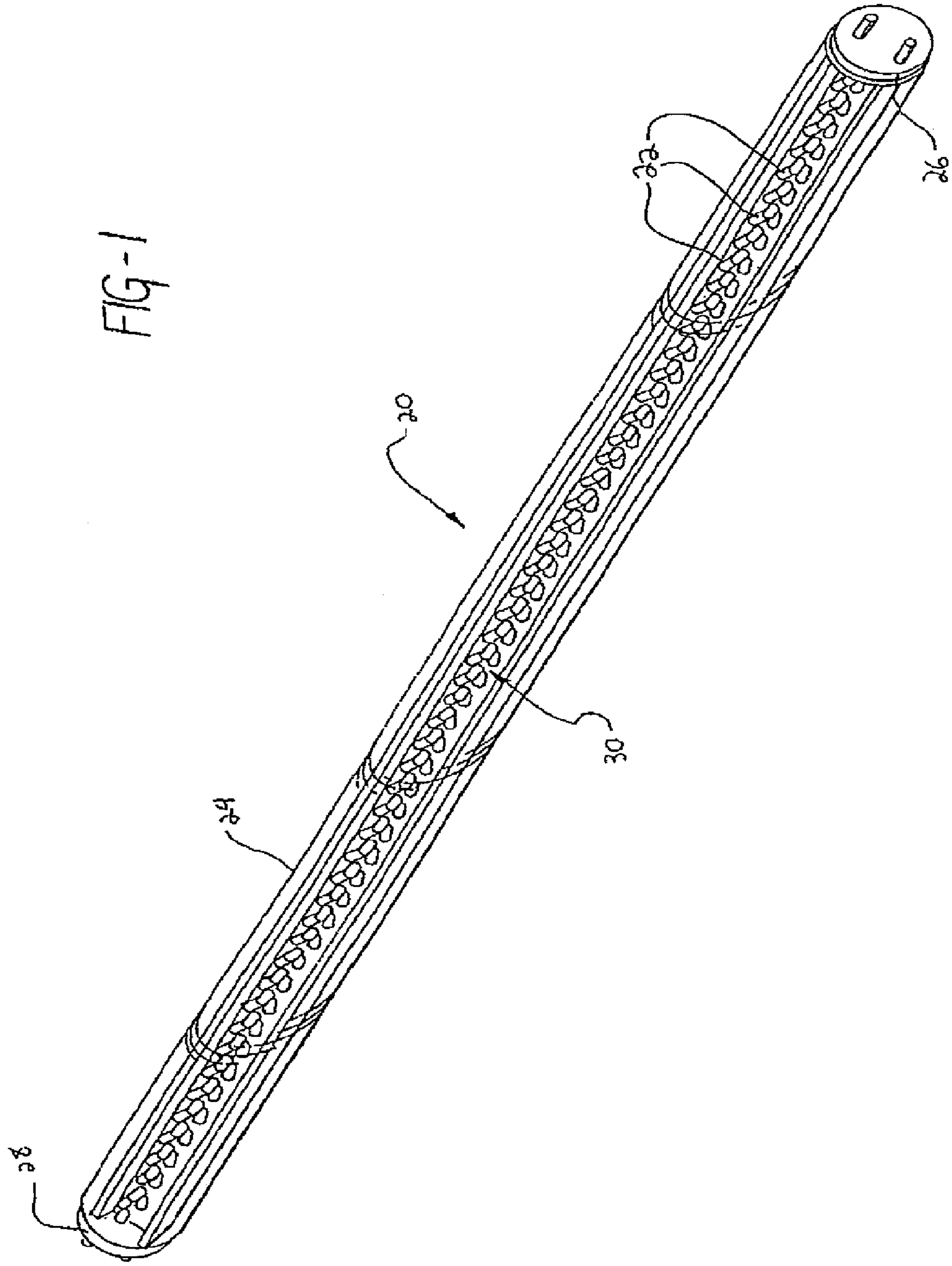
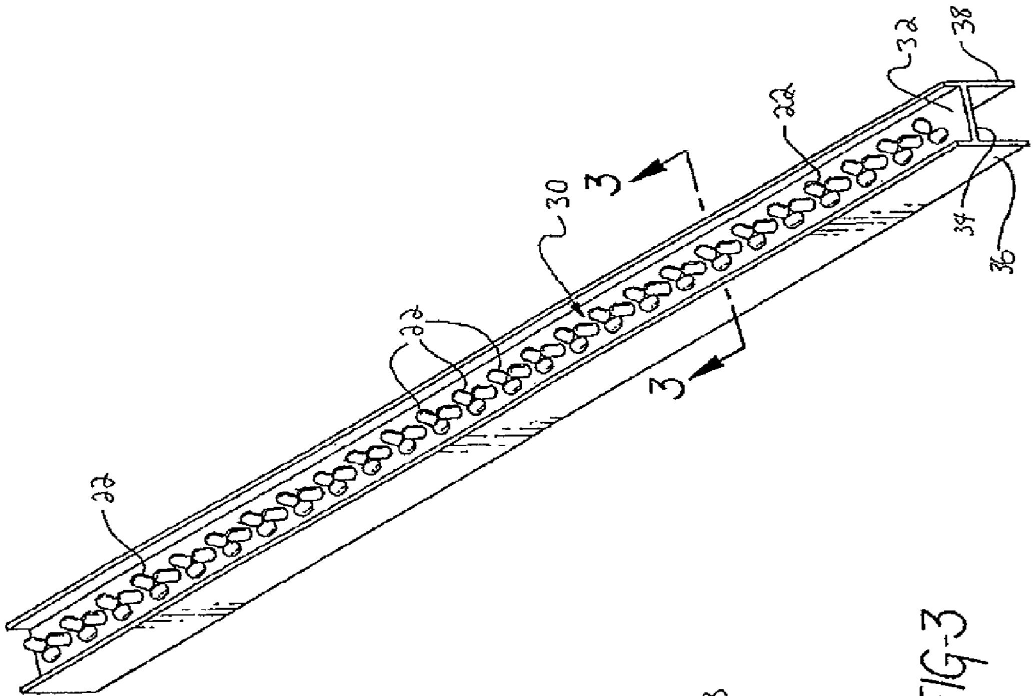
FIG-1





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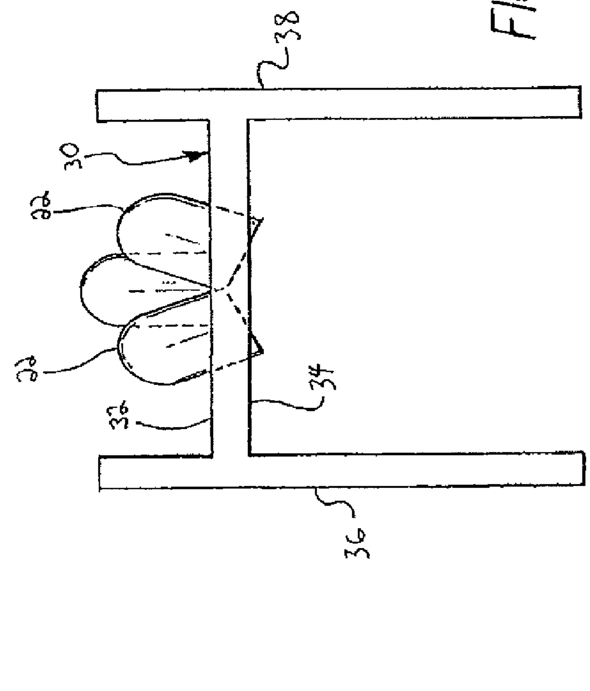


FIG-3

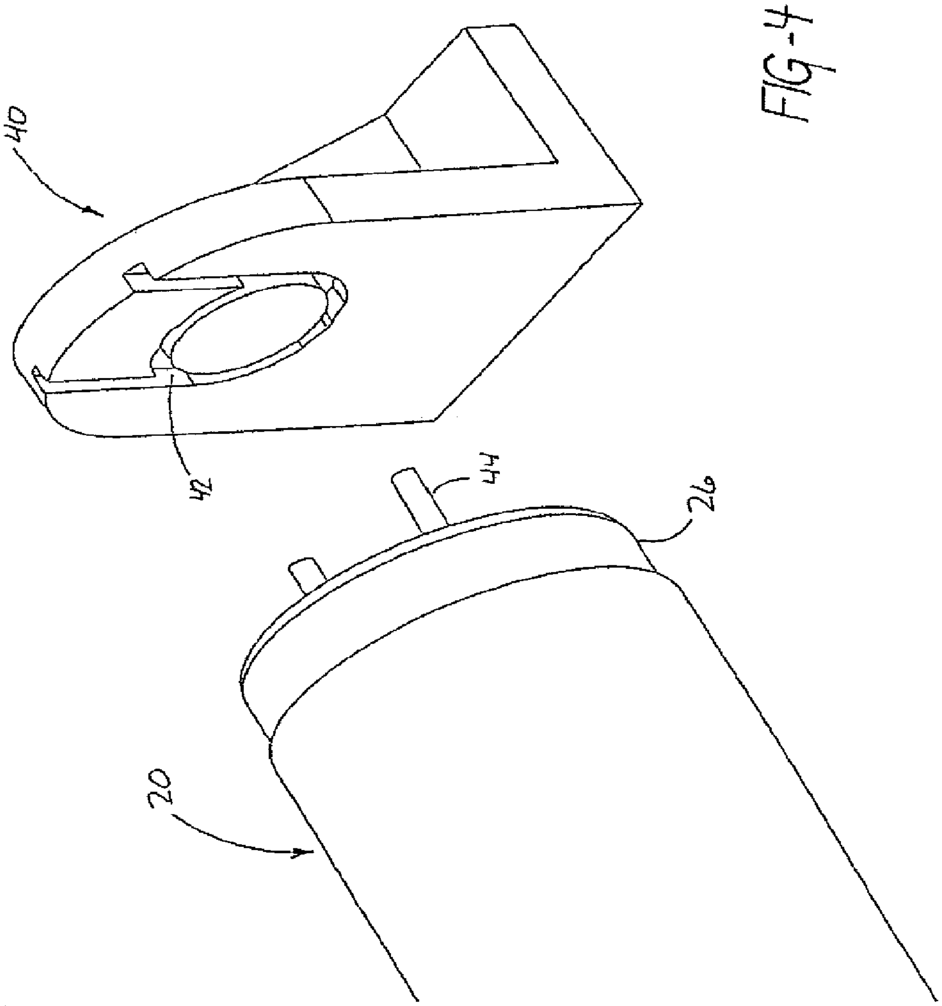
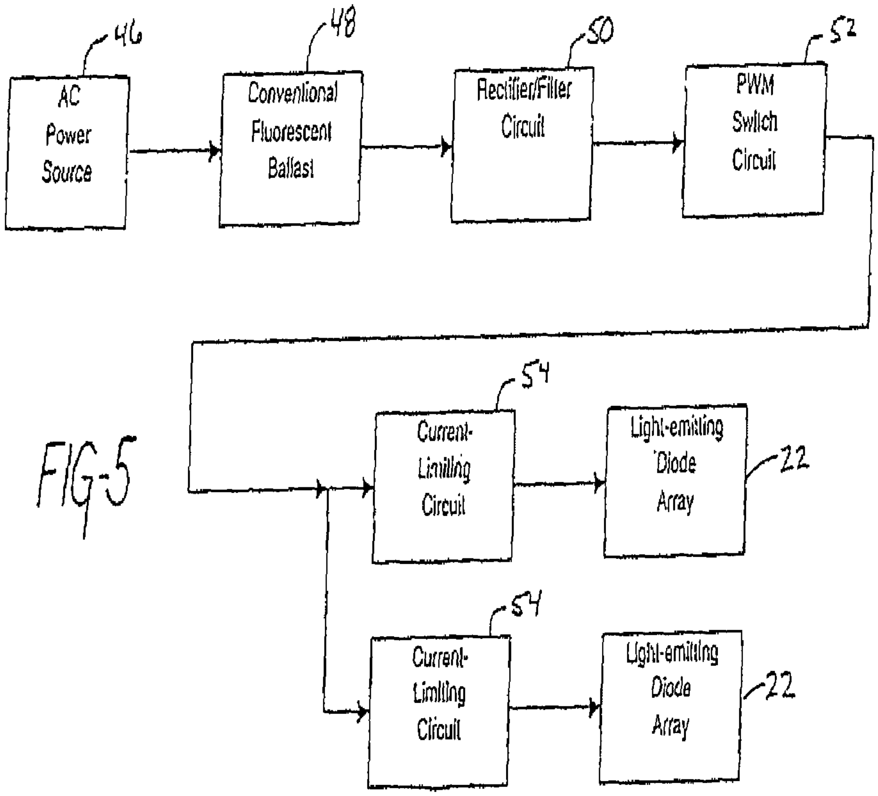


FIG-4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AC
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Source
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Conventional
Fluorescent
Ballast
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Rectifier/Filter
Circuit
52
PWM
Switch
Circuit
54
Current-
Limiting
Circuit
Light-emitting
Diode
Array
22
54
Current-
Limiting
Circuit
Light-emitting
Diode
Array
22

FIG-5

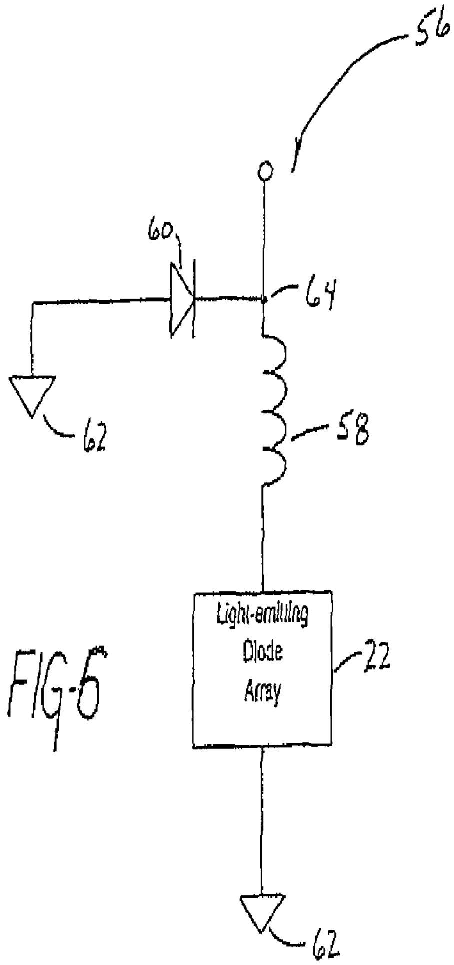
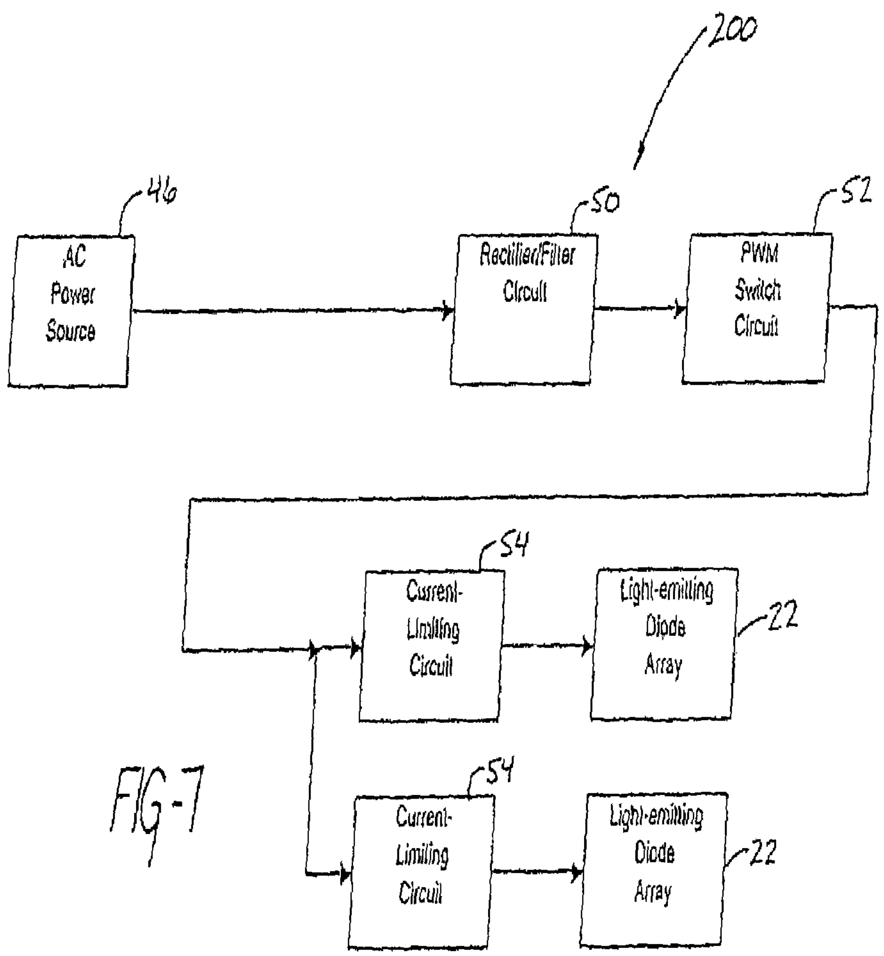


FIG-6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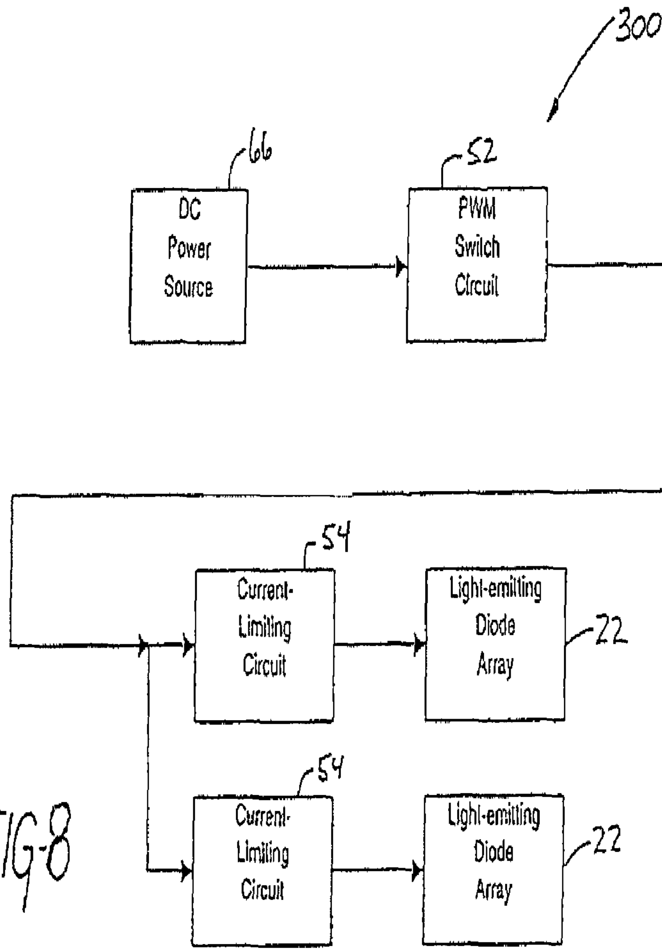
Diode
Array
22
54
Current-
Limiting
Circuit
Light-emitting
Diode
Array
22

FIG-7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54
Current-
Limiting
Circuit
Light-emitting
Diode
Array
22

FIG-8

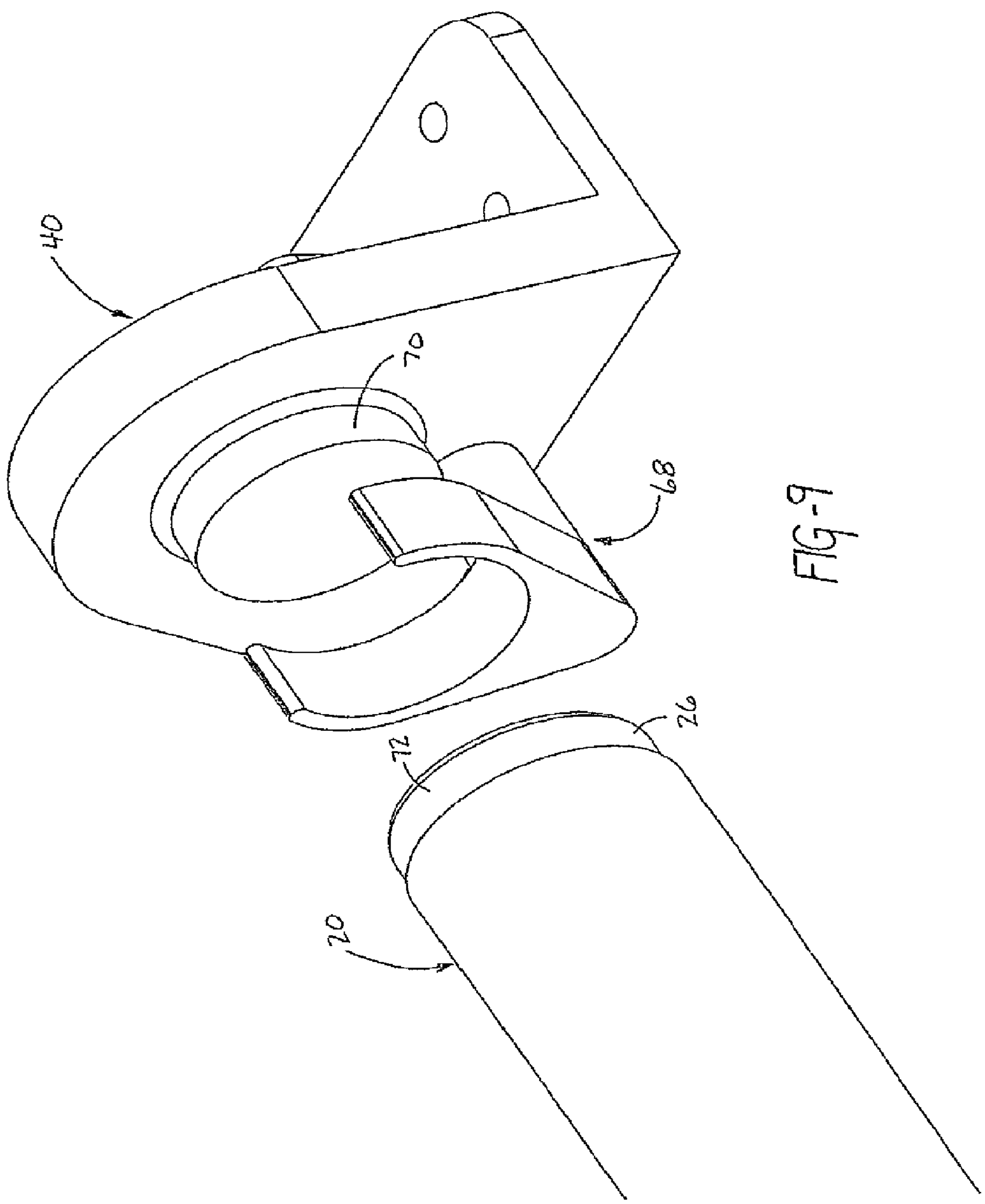

FIG-9

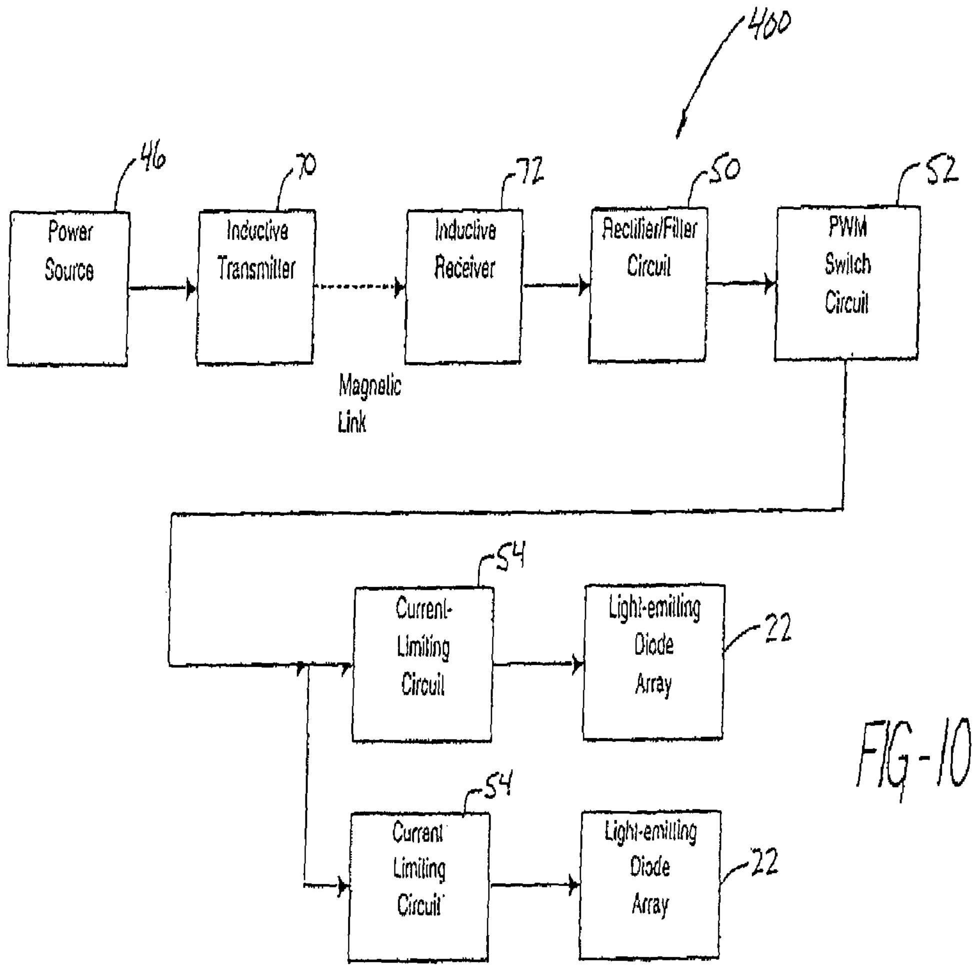
400
46
Power Source
70
Inductive Transmitter
72
Inductive Receiver
50
Rectifier/Filter Circuit
52
PWM Switch Circuit
Magnetic Link
54
Current-Limiting Circuit
Light-emitting Diode Array
22
54
Current Limiting Circuit
Light-emitting Diode Array
22

FIG-10

LIGHT TUBE AND POWER SUPPLY CIRCUIT

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a continuation of U.S. patent application Ser. No. 14/865,325, filed Sep. 25, 2015, which is a continuation of U.S. patent application Ser. No. 14/669,963, filed on Mar. 26, 2015 and issued as U.S. Pat. No. 9,222,626 on Dec. 29, 2015, which is a continuation of U.S. patent application Ser. No. 14/299,909, filed on Jun. 9, 2014 and issued as U.S. Pat. No. 9,006,990 on Apr. 14, 2015 and a continuation of U.S. patent application Ser. No. 14/299,915, filed Jun. 9, 2014 and issued as U.S. Pat. No. 9,006,993 on Apr. 14, 2015, which are continuations of U.S. patent application Ser. No. 13/777,331, filed Feb. 26, 2013 and issued as U.S. Pat. No. 8,866,396 on Oct. 21, 2014, which is a continuation of U.S. patent application Ser. No. 12/965,019, filed Dec. 10, 2010 and issued as U.S. Pat. No. 8,382,327 on Feb. 26, 2013, which is a continuation of U.S. patent application Ser. No. 11/085,744, filed Mar. 21, 2005 and issued as U.S. Pat. No. 8,247,985 on Aug. 21, 2012, which is a continuation of U.S. patent application Ser. No. 09/782,375, filed Feb. 12, 2001 and issued as U.S. Pat. No. 7,049,761 on May 23, 2006, which claims the benefit of U.S. Provisional Application No. 60/181,744 filed Feb. 11, 2000.

FIELD OF THE INVENTION

The present invention relates to a light tube illuminated by LEDs (light emitting diodes) which are packaged inside the light tube and powered by a power supply circuit.

BACKGROUND OF THE INVENTION

Conventional fluorescent lighting systems include fluorescent light tubes and ballasts. Such lighting systems are used in a variety of locations, such as buildings and transit buses, for a variety of lighting purposes, such as area lighting or backlighting. Although conventional fluorescent lighting systems have some advantages over known lighting options, such as incandescent lighting systems, conventional fluorescent light tubes and ballasts have several shortcomings. Conventional fluorescent light tubes have a short life expectancy, are prone to fail when subjected to excessive vibration, consume high amounts of power, require a high operating voltage, and include several electrical connections which reduce reliability. Conventional ballasts are highly prone to fail when subjected to excessive vibration. Accordingly, there is a desire to provide a light tube and power supply circuit which overcome the shortcomings of conventional fluorescent lighting systems. That is, there is a desire to provide a light tube and power supply circuit which have a long life expectancy, are resistant to vibration failure, consume low amounts of power, operate on a low voltage, and are highly reliable. It would also be desirable for such a light tube to mount within a conventional fluorescent light tube socket.

SUMMARY OF THE INVENTION

Embodiments of a replacement light tube for replacing a fluorescent light tube are disclosed herein. In one embodiment, the replacement light tube for replacing a fluorescent light tube includes a bulb portion extending between a first end and a second end, the bulb portion comprising a support

structure, a plurality of white light emitting diodes (LEDs) and an elongate light-transmissive cover. The support structure has a first surface extending between the first end and the second end. The plurality of LEDs are supported by the first surface and arranged between the first end and the second end. The elongate light-transmissive cover extends between the first end and the second end and over the first surface of the support structure. A first end cap and a second end cap are disposed on the first end and the second end, respectively, each configured to fit with a socket for a fluorescent light tube. A power supply circuit is configured to provide power to the plurality of LEDs. The plurality of LEDs are arranged to emit light through the elongate light-transmissive cover and at least a portion of the power supply circuit is packaged inside at least one of the end caps.

In another embodiment, the replacement light tube includes a bulb portion extending between a first end and a second end, the bulb portion comprising a support structure, a plurality of white light emitting diodes (LEDs) and an elongate light-transmissive cover. The support structure has a first surface extending between the first end and the second end. The plurality of LEDs are supported by the first surface and arranged between the first end and the second end, the LEDs being disposed along a base of a channel defined by the support structure. The elongate light-transmissive cover extends between the first end and the second end and over the first surface of the support structure. A first end cap and a second end cap are disposed on the first end and the second end, respectively, each configured to fit with a socket for a fluorescent light tube. A power supply circuit is configured to provide power to the plurality of LEDs, the power supply circuit comprising a rectifier configured to receive alternating current (AC) input from a ballast and to provide direct current (DC) output. The plurality of LEDs are arranged to emit light through the elongate light-transmissive cover and at least a portion of the power supply circuit is packaged inside at least one of the end caps.

These and other embodiments will be discussed in additional detail hereafter.

BRIEF DESCRIPTION OF THE DRAWINGS

The description herein makes reference to the accompanying drawings wherein like reference numerals refer to like parts throughout the several views, and wherein:

FIG. **1** is a line drawing showing a light tube, in perspective view, which in accordance with the present invention is illuminated by LEDs packaged inside the light tube;

FIG. **2** is a perspective view of the LEDs mounted on a circuit board;

FIG. **3** is a cross-sectional view of FIG. **2** taken along lines **3-3**;

FIG. **4** is a fragmentary, perspective view of one embodiment of the present invention showing one end of the light tube disconnected from one end of a light tube socket;

FIG. **5** is an electrical block diagram of a first power supply circuit for supplying power to the light tube;

FIG. **6** is an electrical schematic of a switching power supply type current limiter;

FIG. **7** is an electrical block diagram of a second power supply circuit for supplying power to the light tube;

FIG. **8** is an electrical block diagram of a third power supply circuit for supplying power to the light tube;

FIG. **9** is a fragmentary, perspective view of another embodiment of the present invention showing one end of the light tube disconnected from one end of the light tube socket; and

FIG. **10** is an electrical block diagram of a fourth power supply circuit for supplying power to the light tube.

DETAILED DESCRIPTION

FIG. **1** is a line drawing showing a light tube **20** in perspective view. In accordance with the present invention, the light tube **20** is illuminated by LEDs **22** packaged inside the light tube **20**. The light tube **20** includes a cylindrically shaped bulb portion **24** having a pair of end caps **26** and **28** disposed at opposite ends of the bulb portion. Preferably, the bulb portion **24** is made from a transparent or translucent material such as glass, plastic, or the like. As such, the bulb material may be either clear or frosted.

In a preferred embodiment of the present invention, the light tube **20** has the same dimensions and end caps **26** and **28** (e.g. electrical male bi-pin connectors, type G13) as a conventional fluorescent light tube. As such, the present invention can be mounted in a conventional fluorescent light tube socket.

The line drawing of FIG. **1** also reveals the internal components of the light tube **20**. The light tube **20** further includes a circuit board **30** with the LEDs **22** mounted thereon. The circuit board **30** and LEDs **22** are enclosed inside the bulb portion **24** and the end caps **26** and **28**.

FIG. **2** is a perspective view of the LEDs **22** mounted on the circuit board **30**. A group of LEDs **22**, as shown in FIG. **2**, is commonly referred to as a bank or array of LEDs. Within the scope of the present invention, the light tube **20** may include one or more banks or arrays of LEDs **22** mounted on one or more circuit boards **30**. In a preferred embodiment of the present invention, the LEDs **22** emit white light and, thus, are commonly referred to in the art as white LEDs. In FIGS. **1** and **2**, the LEDs **22** are mounted to one surface **32** of the circuit board **30**. In a preferred embodiment of the present invention, the LEDs **22** are arranged to emit or shine white light through only one side of the bulb portion **24**, thus directing the white light to a predetermined point of use. This arrangement reduces light losses due to imperfect reflection in a conventional lighting fixture. In alternative embodiments of the present invention, LEDs **22** may also be mounted, in any combination, to the other surfaces **34**, **36**, and/or **38** of the circuit board **30**.

FIG. **3** is a cross-sectional view of FIG. **2** taken along lines **3-3**. To provide structural strength along the length of the light tube **20**, the circuit board **30** is designed with a H-shaped cross-section. To produce a predetermined radiation pattern or dispersion of light from the light tube **20**, each LED **22** is mounted at an angle relative to adjacent LEDs and/or the mounting surface **32**. The total radiation pattern of light from the light tube **20** is effected by (1) the mounting angle of the LEDs **22** and (2) the radiation pattern of light from each LED. Currently, white LEDs having a viewing range between 6° and 45° are commercially available.

FIG. **4** is a fragmentary, perspective view of one embodiment of the present invention showing one end of the light tube **20** disconnected from one end of a light tube socket **40**. Similar to conventional fluorescent lighting systems and in this embodiment of the present invention, the light tube socket **40** includes a pair of electrical female connectors **42** and the light tube **20** includes a pair of mating electrical male connectors **44**.

Within the scope of the present invention, the light tube **20** may be powered by one of four power supply circuits **100**, **200**, **300**, and **400**. A first power supply circuit includes a power source and a conventional fluorescent ballast. A second power supply circuit includes a power source and a rectifier/filter circuit. A third power supply circuit includes a DC power source and a PWM (Pulse Width Modulation) circuit. A fourth power supply circuit powers the light tube **20** inductively.

FIG. **5** is an electrical block diagram of a first power supply circuit **100** for supplying power to the light tube **20**. The first power supply circuit **100** is particularly adapted to operate within an existing, conventional fluorescent lighting system. As such, the first power supply circuit **100** includes a conventional fluorescent light tube socket **40** having two electrical female connectors **42** disposed at opposite ends of the socket. Accordingly, a light tube **20** particularly adapted for use with the first power supply circuit **100** includes two end caps **26** and **28**, each end cap having the form of an electrical male connector **44** which mates with a corresponding electrical female connector **42** in the socket **40**.

The first power supply circuit **100** also includes a power source **46** and a conventional magnetic or electronic fluorescent ballast **48**. The power source **46** supplies power to the conventional fluorescent ballast **48**.

The first power supply circuit **100** further includes a rectifier/filter circuit **50**, a PWM circuit **52**, and one or more current-limiting circuits **54**. The rectifier/filter circuit **50**, the PWM circuit **52**, and the one or more current-limiting circuits **54** of the first power supply circuit **100** are packaged inside one of the two end caps **26** or **28** of the light tube **20**.

The rectifier/filter circuit **50** receives AC power from the ballast **48** and converts the AC power to DC power. The PWM circuit **52** receives the DC power from the rectifier/filter circuit **50** and pulse-width modulates the DC power to the one or more current-limiting circuits **54**. In a preferred embodiment of the present invention, the PWM circuit **52** receives the DC power from the rectifier/filter circuit **50** and cyclically switches the DC power on and off to the one or more current-limiting circuits **54**. The DC power is switched on and off by the PWM circuit **52** at a frequency which causes the white light emitted from the LEDs **22** to appear, when viewed with a "naked" human eye, to shine continuously. The PWM duty cycle can be adjusted or varied by control circuitry (not shown) to maintain the power consumption of the LEDs **22** at safe levels.

The DC power is modulated for several reasons. First, the DC power is modulated to adjust the brightness or intensity of the white light emitted from the LEDs **22** and, in turn, adjust the brightness or intensity of the white light emitted from the light tube **20**. Optionally, the brightness or intensity of the white light emitted from the light tube **20** may be adjusted by a user. Second, the DC power is modulated to improve the illumination efficiency of the light tube **20** by capitalizing upon a phenomenon in which short pulses of light at high brightness or intensity to appear brighter than a continuous, lower brightness or intensity of light having the same average power. Third, the DC power is modulated to regulate the intensity of light emitted from the light tube **20** to compensate for supply voltage fluctuations, ambient temperature changes, and other such factors that affect the intensity of white light emitted by the LEDs **22**. Fourth, the DC power is modulated to raise the variations of the frequency of light above the nominal variation of 120 to 100 Hz thereby reducing illumination artifacts caused by low frequency light variations, including interactions with video screens. Fifth, the DC power may optionally be modulated to provide an alarm function wherein light from the light tube **20** cyclically flashes on and off.

The one or more current-limiting circuits **54** receive the pulse-width modulated or switched DC power from the PWM circuit **52** and transmit a regulated amount of power to one or more arrays of LEDs **22**. Each current-limiting circuit **54** powers a bank of one or more white LEDs **22**. If a bank of LEDs **22** consists of more than one LED, the LEDs are electrically connected in series in an anode to cathode arrangement. If brightness or intensity variation between the LEDs **22** can be tolerated, the LEDs can be electrically connected in parallel.

The one or more current-limiting circuits **54** may include (1) a resistor, (2) a current-limiting semiconductor circuit, or (3) a switching power supply type current limiter.

FIG. **6** is an electrical schematic of a switching power supply type current limiter **56**. The limiter **56** includes an inductor **58**, electrically connected in series between the PWM circuit **52** and the array of LEDs **22**, and a power diode **60**, electrically connected between ground **62** and a PWM circuit/inductor node **64**. The diode **60** is designed to begin conduction after the PWM circuit **52** is switched off. In this case, the value of the inductor **58** is adjusted in conjunction with the PWM duty cycle to provide the benefits described above. The switching power supply type current limiter **56** provides higher power efficiency than the other types of current-limiting circuits listed above.

FIG. **7** is an electrical block diagram of a second power supply circuit **200** for supplying power to the light tube **20**. Similar to the first power supply circuit **100**, the second power supply circuit **200** includes a conventional fluorescent light tube socket **40** having two electrical female connectors **42** disposed at opposite ends of the socket **40**. Accordingly, a light tube **20** particularly adapted for use with the second power supply circuit **200** includes two end caps **26** and **28**, each end cap having the form of an electrical male connector **44** which mates with a corresponding electrical female connector **42** in the socket **40**.

In the second power supply circuit **200**, the power source **46** supplies power directly to the rectifier/filter circuit **50**. The rectifier/filter circuit **50**, the PWM circuit **52**, and the one or more current-limiting circuits **54** operate as described above to power the one or more arrays of LEDs **22**. The rectifier/filter circuit **50**, the PWM circuit **52**, and the one or more current-limiting circuits **54** of the second power supply circuit **200** are preferably packaged inside the end caps **26** and **28** or the bulb portion **24** of the light tube **20** or inside the light tube socket **40**.

FIG. **8** is an electrical block diagram of a third power supply circuit **300** for supplying power to the light tube **20**. Similar to the first and second power supply circuits **100** and **200**, the third power supply circuit **300** includes a conventional fluorescent light tube socket **40** having two electrical female connectors **42** disposed at opposite ends of the socket **40**. Accordingly, a light tube **20** particularly adapted for use with the third power supply circuit **300** includes two end caps **26** and **28**, each end cap having the form of an electrical male connector **44** which mates with a corresponding electrical female connector **42** in the socket **40**.

The third power supply circuit **300** includes a DC power source **66**, such as a vehicle battery. In the third power supply circuit **300**, the DC power source **66** supplies DC power directly to the PWM circuit **52**. The PWM circuit **52** and the one or more current-limiting circuits **54** operate as described above to power the one or more arrays of LEDs **22**. In the third power supply circuit **300**, the PWM circuit **52** is preferably packaged in physical location typically occupied by the ballast of a conventional fluorescent lighting system while the one or more current-limiting circuits **54** and LEDs **22** are preferably packaged inside the light tube **20**, in either one of the two end caps **26** or **28** or the bulb portion **24**.

FIG. **9** is a fragmentary, perspective view of another embodiment of the present invention showing one end of the light tube **20** disconnected from one end of the light tube socket **40**. In this embodiment of the present invention, the light tube socket **40** includes a pair of brackets **68** and the light tube **20** includes a pair of end caps **26** and **28** which mate with the brackets **68**.

FIG. **10** is an electrical block diagram of a fourth power supply circuit **400** for supplying power to the light tube **20**. Unlike the first, second, and third power supply circuits **100**, **200**, and **300** which are powered through direct electrical male and female connectors **44** and **42**, the fourth power supply circuit **400** is powered inductively. As such, the fourth power supply circuit **400** includes a light tube socket **40** having two brackets **68** disposed at opposite ends of the socket **40**. At least one bracket **68** includes an inductive transmitter **70**. Accordingly, a light tube **20** particularly adapted for use with the fourth power supply circuit **400** has two end caps **26** and **28** with at least one end cap including an inductive receiver or antenna **72**. When the light tube **20** is mounted in the light tube socket **40**, the at least one inductive receiver **72** in the light tube **20** is disposed adjacent to the at least one inductive transmitter **70** in the light tube socket **40**.

The fourth power supply circuit **400** includes the power source **46** which supplies power to the at least one inductive transmitter **70** in the light tube socket **40**. The at least one transmitter **70** inductively supplies power to the at least one receiver **72** in one of the end caps **26** and/or **28** of the light tube **20**. The at least one inductive receiver **72** supplies power to the rectifier/filter circuit **50**. The rectifier/filter circuit **50**, PWM circuit **52**, and the one or more current-limiting circuits **54** operate as described above to power the one or more arrays of LEDs **22**. In this manner, the light tube **20** is powered without direct electrical connection.

What is claimed is:

1. A method, comprising:

replacing a fluorescent light tube with an LED light tube in a socket for the fluorescent light tube,

the LED light tube comprising:

a pair of end caps each having a connector for connecting to the socket;

a bulb portion extending between the end caps, the bulb portion comprising a support, a light-transmissive cover, and a plurality of light emitting diodes (LEDs) disposed on the support at different locations between the end caps and arranged so that light emitted by the LEDs is emitted by the bulb portion through the light-transmissive cover; and

a power supply circuit; and

delivering power to the LED light tube in the socket via a ballast for the fluorescent light tube to provide area lighting using the LED light tube,

wherein one or more components of the power supply circuit are packaged in one of the end caps.

2. The method of claim **1**, wherein the power supply circuit comprises a rectifier circuit that receives AC power from the ballast and converts the AC power to DC power.

3. The method of claim **2**, wherein the power supply circuit comprises a current-limiting circuit that limits current from the rectifier to the LEDs.

4. The method of claim **3**, wherein the current-limiting circuit comprises a resistor.

5. The method of claim **3**, wherein the current-limiting circuit comprises an inductor.

6. The method of claim **3**, wherein the current-limiting circuit comprises a current-limiting semiconductor circuit.

7. The method of claim 2, wherein the power supply circuit further comprises a pulse width modulator (PWM) circuit that modulates power from the rectifier circuit to the LEDs.

8. The method of claim 1, wherein power from the ballast is modulated using a pulse width modulator (PWM) circuit.

9. The method of claim 8, wherein the power supply circuit comprises the PWM circuit.

10. The method of claim 8, wherein the power is modulated to adjust an intensity of the light from the light tube.

11. The method of claim 10, wherein the intensity of the light from the light tube is adjusted by a user.

12. The method of claim 8, wherein the power is modulated to improve an efficiency of the LED light tube relative to providing unmodulated power to the LED light tube.

13. The method of claim 8, wherein the power is modulated to regulate an intensity of light emitted from the LED light tube.

14. The method of claim 13, wherein the intensity is regulated to compensate for voltage fluctuations in the power delivered to the LED light tube.

15. The method of claim 13, wherein the intensity is regulated to compensate for temperature changes of the LED light tube.

16. The method of claim 8, wherein the power is modulated to increase a pulse frequency to the LEDs to a higher frequency than an AC frequency of power delivered to the ballast.

17. The method of claim 1, wherein the LEDs are white-light emitting LEDs.

18. The method of claim 1, wherein the support comprises a pair of sidewalls on opposing sides of a surface of the support supporting the LEDs, the sidewalls each extending between the end caps.

19. The method of claim 18, wherein the sidewalls extend from the surface of the support higher than at least some of the LEDs.

20. The method of claim 18, wherein the sidewalls and surface form a channel extending between the end caps.

21. The method of claim 1, wherein the ballast is an electronic ballast.

22. The method of claim 1, wherein the ballast is a magnetic ballast.

23. The method of claim 1, wherein the connectors are bi-pin connectors.

24. The method of claim 1, wherein the tube provides area lighting in a building.

25. The method of claim 1, wherein the tube provides area lighting in a vehicle.

26. A method, comprising:

replacing a fluorescent light tube with an LED light tube in a socket for the fluorescent light tube,

the LED light tube comprising:

a pair of end caps each having a connector for connecting to the socket;

a bulb portion extending between the end caps, the bulb portion comprising a support, a light-transmissive cover, and a plurality of light emitting diodes (LEDs) disposed on the support at different locations between the end caps and arranged so that light emitted by the LEDs is emitted by the bulb portion through the light-transmissive cover; and

a power supply circuit; and

delivering power to the LED light tube in the socket via a ballast for the fluorescent light tube to provide area lighting using the LED light tube,

wherein the support comprises a pair of sidewalls on opposing sides of a surface of the support supporting the LEDs, the sidewalls each extending between the end caps.

27. The method of claim 26, wherein the sidewalls extend above the surface of the support higher than at least some of the LEDs.

28. The method of claim 26, wherein the sidewalls and the surface form a channel extending between the end caps.

29. The method of claim 26, wherein the power supply circuit comprises a rectifier circuit that receives AC power from the ballast and converts the AC power to DC power.

30. The method of claim 29, wherein the power supply circuit comprises a current-limiting circuit that limits current from the rectifier to the LEDs.

31. The method of claim 30, wherein the current-limiting circuit comprises a component selected from the group consisting of a resistor and an inductor.

32. The method of claim 30, wherein the current-limiting circuit comprises a current-limiting semiconductor circuit.

33. The method of claim 29, wherein the power supply circuit further comprises a pulse width modulator (PWM) circuit that modulates power from the rectifier circuit to the LEDs.

34. The method of claim 26, wherein power from the ballast is modulated using a pulse width modulator (PWM) circuit.

35. The method of claim 34, wherein the power supply circuit comprises the PWM circuit.

36. The method of claim 34, wherein the power is modulated to adjust an intensity of the light from the light tube.

37. The method of claim 36, wherein the intensity of the light from the light tube is adjusted by a user.

38. The method of claim 34, wherein the power is modulated to improve an efficiency of the LED light tube relative to providing unmodulated power to the LED light tube.

39. The method of claim 34, wherein the power is modulated to regulate an intensity of light emitted from the LED light tube.

40. The method of claim 39, wherein the intensity is regulated to compensate for voltage fluctuations in the power delivered to the LED light tube.

41. The method of claim 39, wherein the intensity is regulated to compensate for temperature changes of the LED light tube.

42. The method of claim 34, wherein the power is modulated to increase a pulse frequency to the LEDs to a higher frequency than an AC frequency of power delivered to the ballast.

43. The method of claim 26, wherein the LEDs are white-light emitting LEDs.

44. The method of claim 26, wherein the connectors are bi-pin connectors.

45. The method of claim 26, wherein the support comprises a circuit board.

46. The method of claim 26, wherein the sidewalls extend perpendicularly to the surface of the support supporting the LEDs.

47. The method of claim 1, wherein the support comprises a circuit board.

48. The method of claim 18, wherein the sidewalls extend perpendicularly to the surface of the support supporting the LEDs.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE
CERTIFICATE OF CORRECTION

PATENT NO. : 9,739,428 B1
APPLICATION NO. : 15/187456
DATED : August 22, 2017
INVENTOR(S) : Jos Timmermans et al.

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

On the Title Page

Column 1, Item (72) Inventors, Second Inventor, Jean C. Raymond:
Delete "Nominique (CA)", and insert -- Nominingue, (CA) --, therefor.

Column 1, Item (56) FOREIGN PATENT DOCUMENTS:
Delete "96 51 140" and insert -- 196 51 140 --, therefor.

Signed and Sealed this
Seventeenth Day of October, 2017

Joseph Matal

Joseph Matal
Performing the Functions and Duties of the
Under Secretary of Commerce for Intellectual Property and
Director of the United States Patent and Trademark Office