US008247985B2

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

(10) **Patent No.: US 8,247,985 B2**
(45) **Date of Patent: *Aug. 21, 2012**

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

(75) Inventors: **Jos Timmermans**, Dearborn, MI (US); **Jean C. Raymond**, Montreal (CA)

(73) Assignee: **iLumisys, Inc.**, Troy, MI (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 1620 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **11/085,744**

(22) Filed: **Mar. 21, 2005**

(65) **Prior Publication Data**

US 2005/0162093 A1 Jul. 28, 2005

Related U.S. Application Data

(63) Continuation of application No. 09/782,375, filed on Feb. 12, 2001, now Pat. No. 7,049,761.

(60) Provisional application No. 60/181,744, filed on Feb. 11, 2000.

(51) **Int. Cl.**
H05B 41/10 (2006.01)
H05B 37/00 (2006.01)

(52) **U.S. Cl.** **315/246**; 315/312

(58) **Field of Classification Search** .... 315/200 R, 315/291, 246, 185 R, 209 R, 268, 269, 271–272, 315/312; 362/221, 225, 249, 659
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

3,612,855 A		10/1971	Juhnke	
3,993,386 A		11/1976	Rowe	
4,102,558 A		7/1978	Krachman	
4,107,581 A		8/1978	Abernethy	
4,189,663 A		2/1980	Schmutzer et al.	
4,211,955 A		7/1980	Ray	
4,581,687 A		4/1986	Nakanishi	362/226
4,597,033 A		6/1986	Meggs et al.	
4,607,317 A		8/1986	Lin	
4,661,890 A		4/1987	Watanabe et al.	
4,698,730 A		10/1987	Sakai et al.	
4,748,545 A	*	5/1988	Schmitt	362/219
4,758,173 A		7/1988	Northrop	
4,810,937 A		3/1989	Havel	
4,912,371 A		3/1990	Hamilton	
4,941,072 A		7/1990	Yasumoto et al.	
4,943,900 A		7/1990	Gartner	
5,018,054 A		5/1991	Ohashi et al.	
5,027,037 A		6/1991	Wei	
5,036,248 A		7/1991	McEwan et al.	
5,103,382 A		4/1992	Kondo et al.	
5,136,483 A		8/1992	Schoniger et al.	
5,140,220 A		8/1992	Hasegawa	
5,151,679 A		9/1992	Dimmick	
5,303,124 A		4/1994	Wrobel	
5,321,593 A		6/1994	Moates	
5,365,411 A		11/1994	Rycroft et al.	
D354,360 S		1/1995	Murata	
5,388,357 A		2/1995	Malita	40/570
5,404,094 A	*	4/1995	Green et al.	323/282
5,463,280 A	*	10/1995	Johnson	315/187
5,463,502 A		10/1995	Savage, Jr.	
5,561,346 A		10/1996	Byrne	
5,575,459 A		11/1996	Anderson	362/240
5,581,158 A		12/1996	Quazi	
5,607,227 A		3/1997	Yasumoto et al.	362/249
5,608,290 A		3/1997	Hutchisson et al.	
5,622,423 A		4/1997	Lee	
5,655,830 A		8/1997	Ruskouski	362/249
5,661,645 A		8/1997	Hochstein	
5,684,523 A		11/1997	Satoh et al.	
5,688,042 A	*	11/1997	Madadi et al.	362/240
5,697,695 A		12/1997	Lin et al.	362/184
5,726,535 A		3/1998	Yan	315/185 R
5,731,759 A		3/1998	Finucan	
5,803,579 A		9/1998	Turnbull et al.	
5,803,580 A		9/1998	Tseng	
5,803,729 A		9/1998	Tsimerman	
5,810,463 A		9/1998	Kawahara et al.	
5,813,751 A		9/1998	Shaffer	362/249
5,813,753 A		9/1998	Vriens et al.	
5,825,051 A		10/1998	Bauer et al.	
5,850,126 A		12/1998	Kanbar	
5,865,529 A		2/1999	Yan	

(Continued)

FOREIGN PATENT DOCUMENTS

DE 196 51 140 A1 6/1997

(Continued)

OTHER PUBLICATIONS

Web page at http://trucklite.com/leds 14.html printed on Jan. 13, 2000.

(Continued)

Primary Examiner — Douglas W Owens
Assistant Examiner — Minh D A
(74) *Attorney, Agent, or Firm* — Young Basile Hanlon & MacFarlane, P.C.

(57) **ABSTRACT**

The present invention provides a light tube for illumination by a power supply circuit including a bulb portion and a pair of end caps disposed at opposite ends of the bulb portion. A plurality of light emitting diodes are disposed inside the bulb portion and in electrical communication with the pair of end caps for illuminating in response to electrical current to be received from the power supply circuit.

18 Claims, 10 Drawing Sheets

U.S. PATENT DOCUMENTS

5,890,794	A	4/1999	Abtahi et al.	362/294
5,917,287	A	6/1999	Haederle et al.	
5,921,660	A	7/1999	Yu	
5,924,784	A	7/1999	Chliwnyj et al.	362/234
5,943,802	A	8/1999	Tijanic	
5,949,347	A	9/1999	Wu	340/815.45
5,998,928	A	12/1999	Hipp	
6,007,209	A	12/1999	Pelka	
6,028,694	A	2/2000	Schmidt	
6,030,099	A	2/2000	McDermott	
6,056,420	A	5/2000	Wilson et al.	
6,068,383	A	5/2000	Robertson et al.	
6,072,280	A *	6/2000	Allen	315/185 S
6,135,620	A	10/2000	Marsh	
6,149,283	A	11/2000	Conway et al.	
6,158,882	A *	12/2000	Bischoff, Jr.	362/488
6,217,190	B1	4/2001	Altman et al.	
6,227,679	B1	5/2001	Zhang et al.	
6,238,075	B1	5/2001	Dealey, Jr. et al.	
6,252,350	B1	6/2001	Alvarez	
6,268,600	B1	7/2001	Nakamura et al.	
6,305,109	B1	10/2001	Lee	40/546
6,305,821	B1	10/2001	Hsieh et al.	
6,325,651	B1	12/2001	Nishihara et al.	439/232
6,362,578	B1 *	3/2002	Swanson et al.	315/307
6,371,637	B1	4/2002	Atchinson et al.	362/555
6,471,388	B1	10/2002	Marsh	
6,528,954	B1	3/2003	Lys et al.	
6,568,834	B1	5/2003	Scianna	
6,577,072	B2	6/2003	Saito et al.	315/185 R
6,577,794	B1	6/2003	Currie et al.	
6,582,103	B1 *	6/2003	Popovich et al.	362/307
6,621,222	B1	9/2003	Hong	315/51
6,682,205	B2	1/2004	Lin	362/249
6,712,486	B1	3/2004	Popovich et al.	
6,762,562	B2	7/2004	Leong	318/51
6,853,151	B2	2/2005	Leong et al.	315/185 R
7,014,336	B1	3/2006	Ducharme et al.	
7,161,313	B2	1/2007	Piepgras et al.	
2002/0048174	A1	4/2002	Pederson	
2003/0076281	A1	4/2003	Morgan et al.	
2004/0085219	A1	5/2004	Pederson	
2004/0145490	A1	7/2004	Pederson	
2004/0212993	A1	10/2004	Morgan et al.	
2005/0041424	A1	2/2005	Ducharme	
2005/0099317	A1	5/2005	Pederson	
2007/0030683	A1	2/2007	Popovich et al.	

FOREIGN PATENT DOCUMENTS

DE	196 24 087	A1	12/1997
EP	0 632 511	A2	1/1995
JP	H6-54103		7/1994
JP	H8-162677		6/1996
JP	H11-135274		5/1999
WO	99/45312	A1	9/1999
WO	99/57945	A1	11/1999

OTHER PUBLICATIONS

Web page at http://trucklite.com/leds 2html printed on Jan. 13, 2000.

Web page at http://trucklite.com/leds 4.html printed on Jan. 13, 2000.

Web page at http://www/telecite.com/en/products/options_en.htm printed on Jan. 13, 2000.

Web page at http://www/dialight.com/trans.htm printed on Jan. 13, 2000.

Web page at http://www/ledlights.com/replac.htm printed on Jan. 13, 2000.

Ledtronics, apparently 1996 Catalog, apparently cover page and p. 10.

Defendant's Invalidity Contentions in *Altair Engineering, Inc.* v. *LEDS America, Inc.*, Civil Case No. 2:10-CV-13424 (E. D. Mich) (J. O'Meara).

Decision in *Altair Engineering, Inc.* v. *LEDdynamics* (Fed. Cir. Mar. 9, 2011).

* cited by examiner

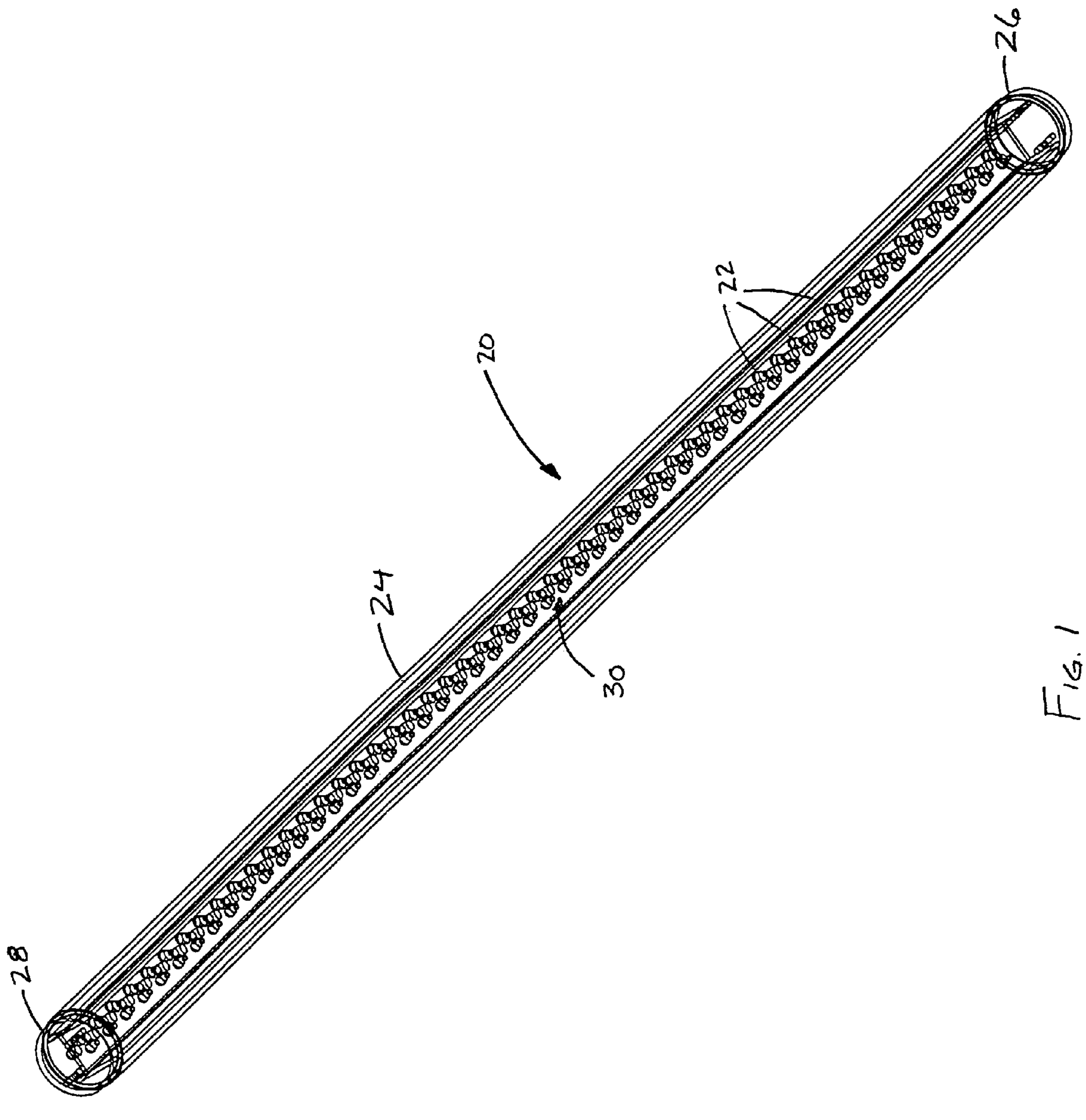

FIG. 1

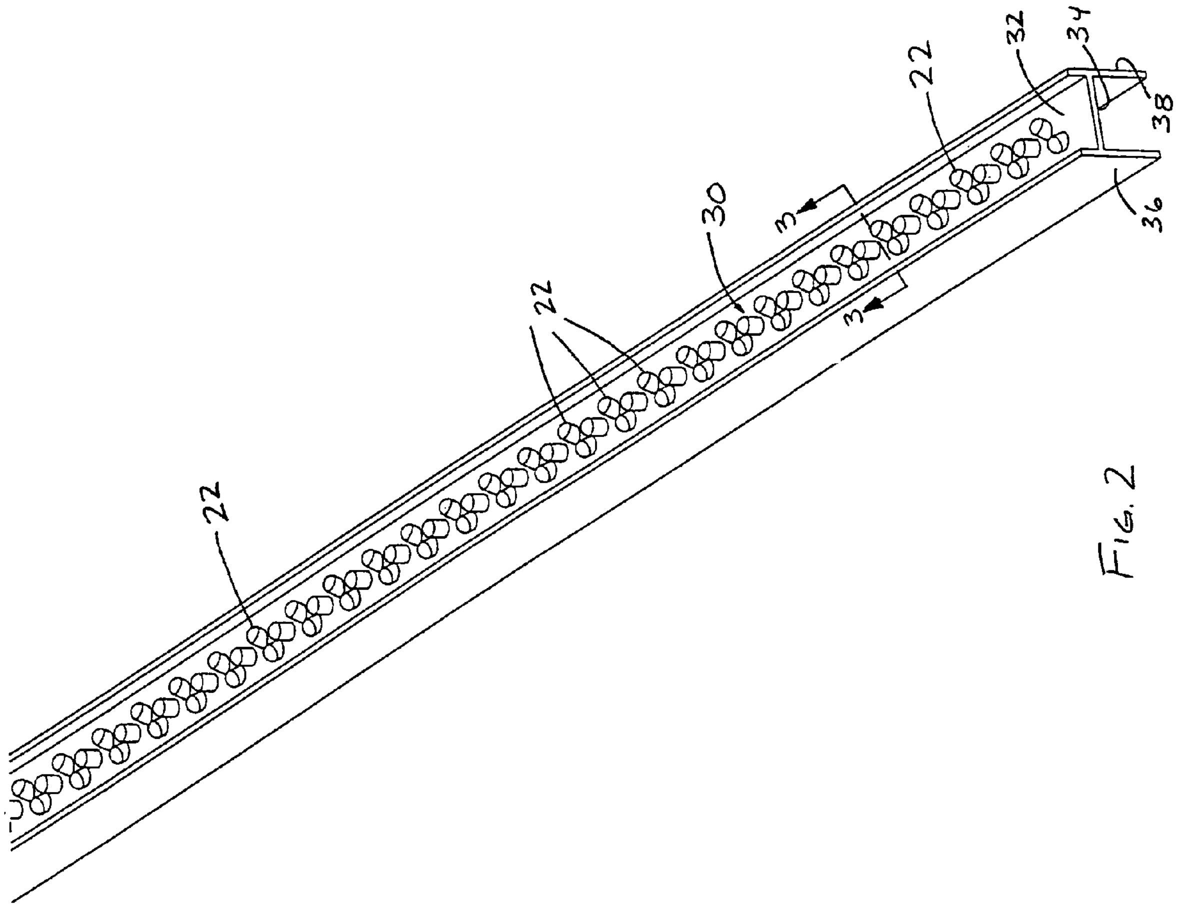

FIG. 2

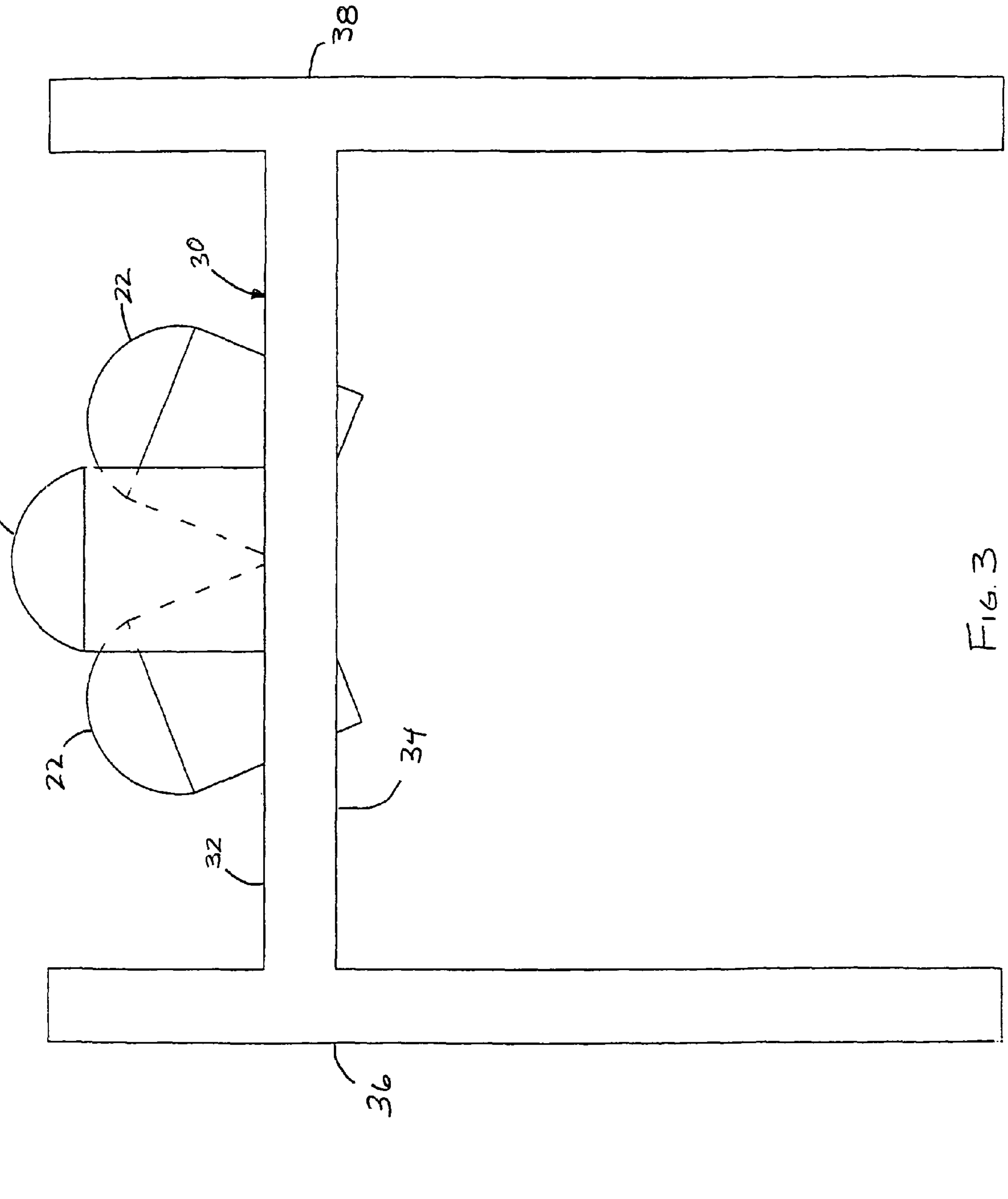

FIG. 3

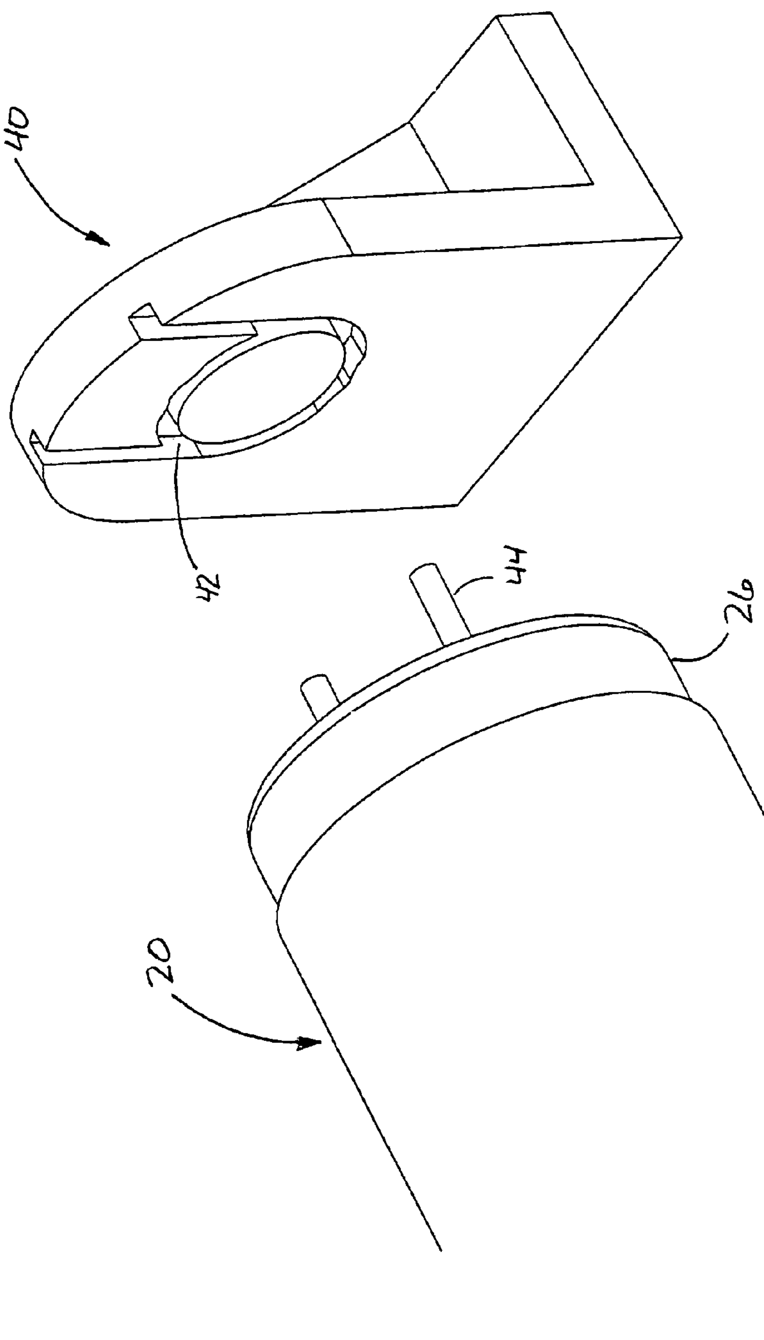

FIG. 4

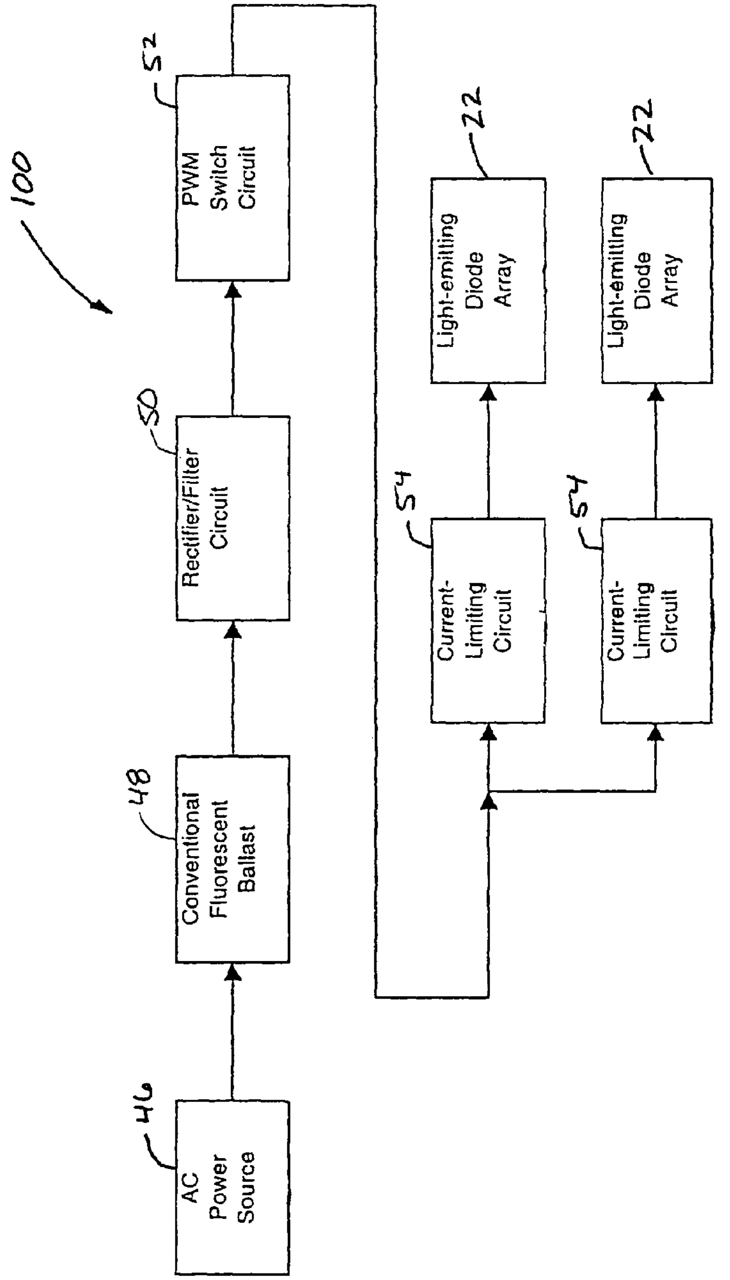
100
AC Power Source
46
Conventional Fluorescent Ballast
48
Rectifier/Filter Circuit
50
PWM Switch Circuit
52
Current-Limiting Circuit
54
Current-Limiting Circuit
54
Light-emitting Diode Array
22
Light-emitting Diode Array
22

FIG. 5

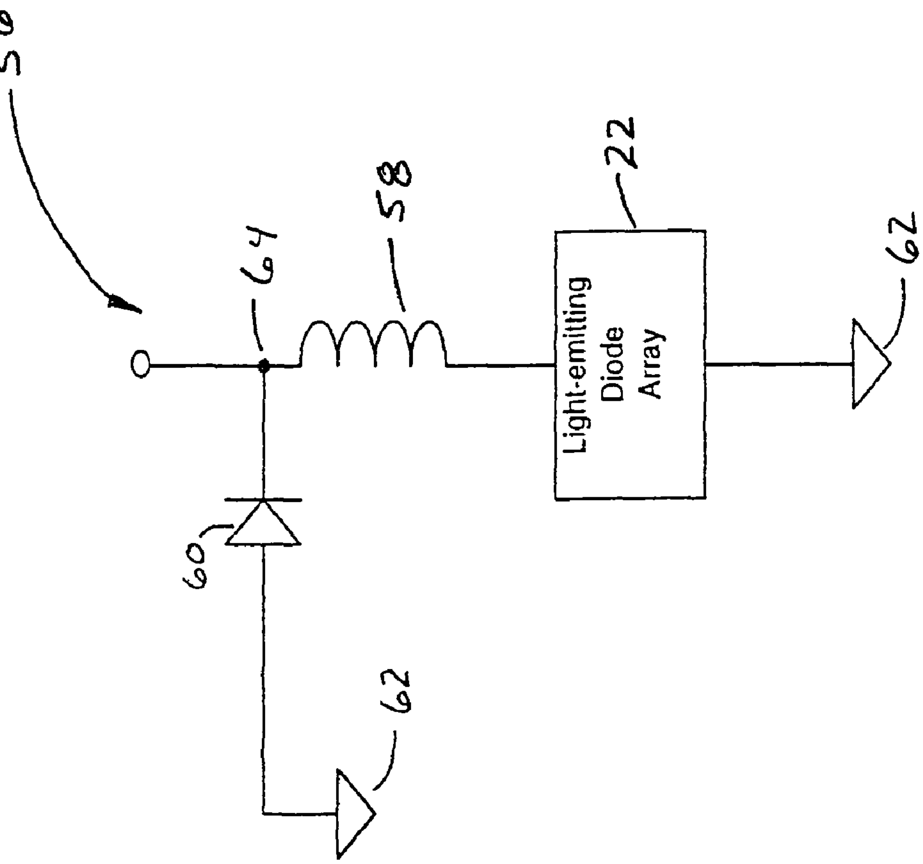

FIG. 6

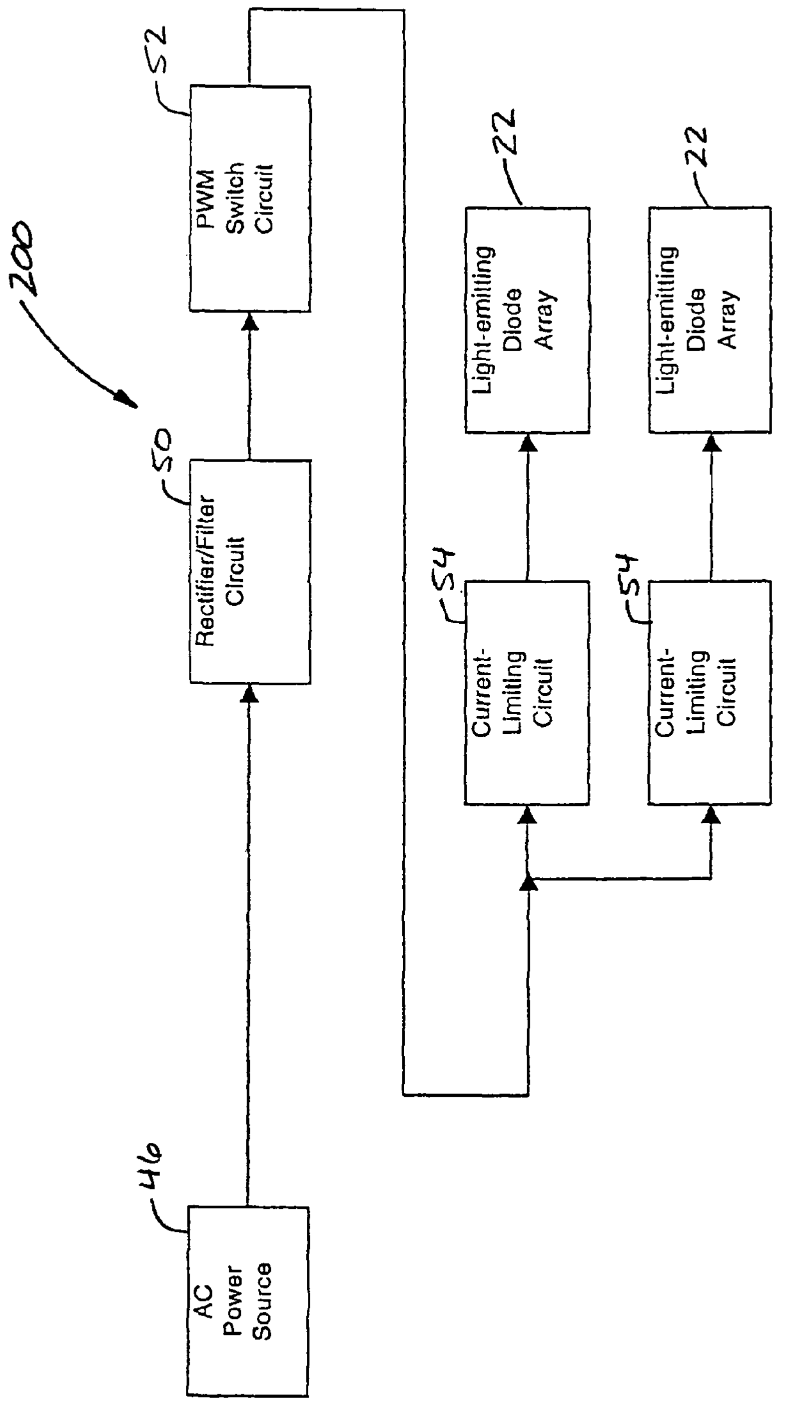
200
AC Power Source
46
Rectifier/Filter Circuit
50
PWM Switch Circuit
52
Current-Limiting Circuit
54
Current-Limiting Circuit
54
Light-emitting Diode Array
22
Light-emitting Diode Array
22

FIG. 7

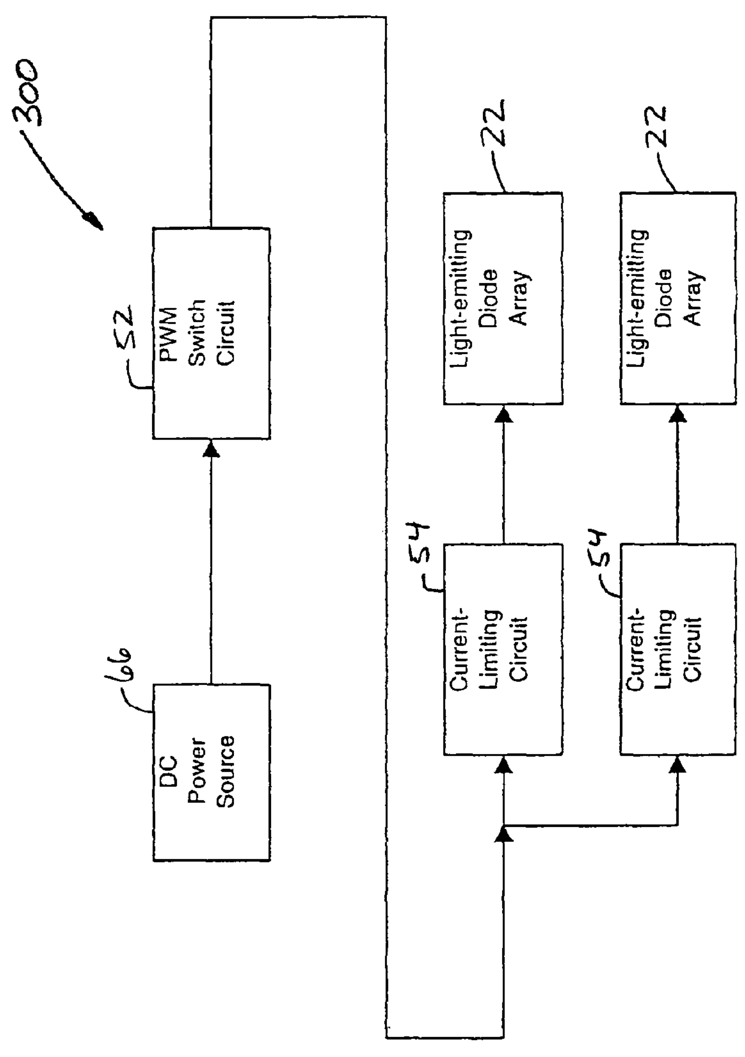
300
DC Power Source
66
PWM Switch Circuit
52
Current-Limiting Circuit
54
Current-Limiting Circuit
54
Light-emitting Diode Array
22
Light-emitting Diode Array
22

FIG. 8

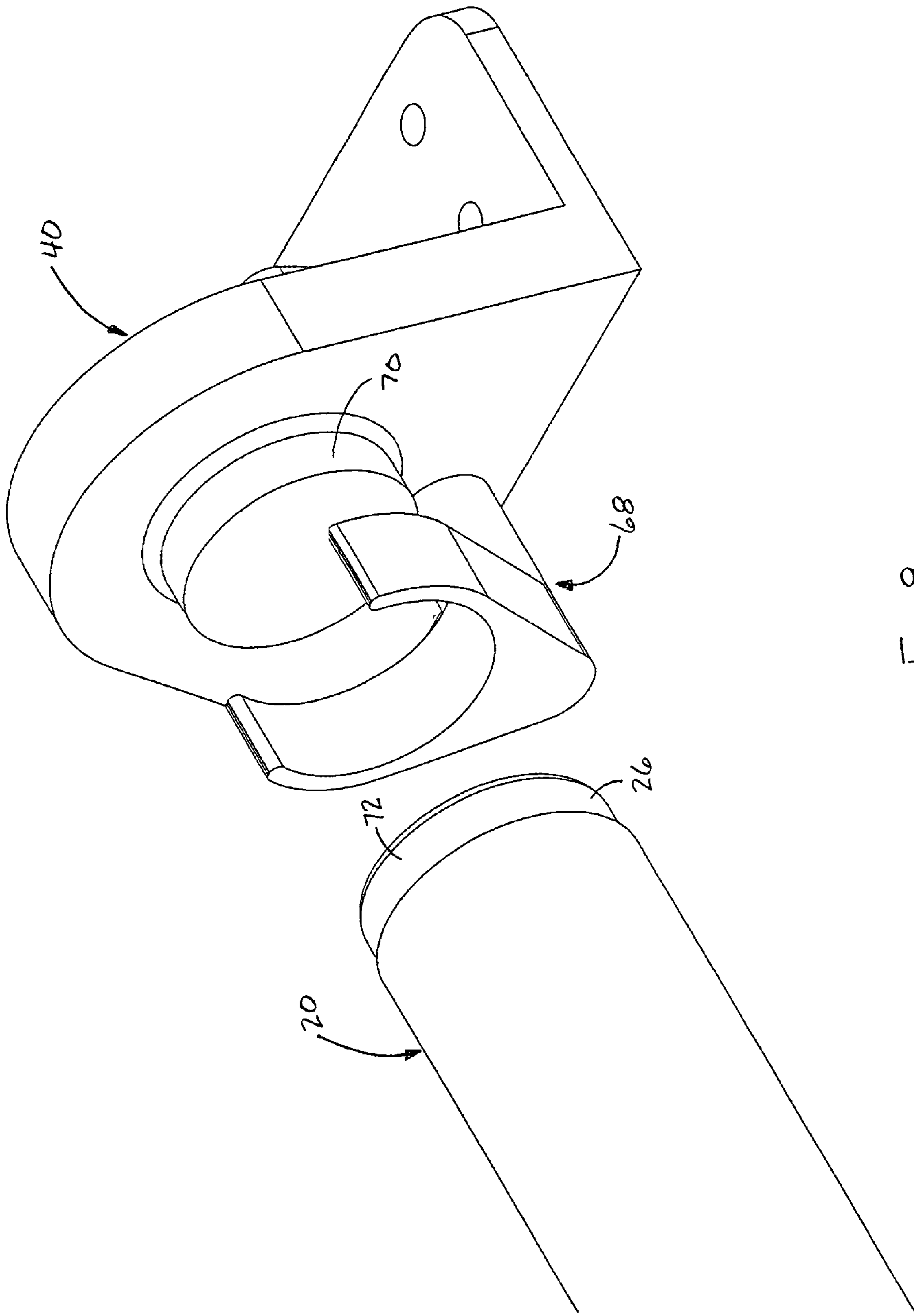

Fig. 9

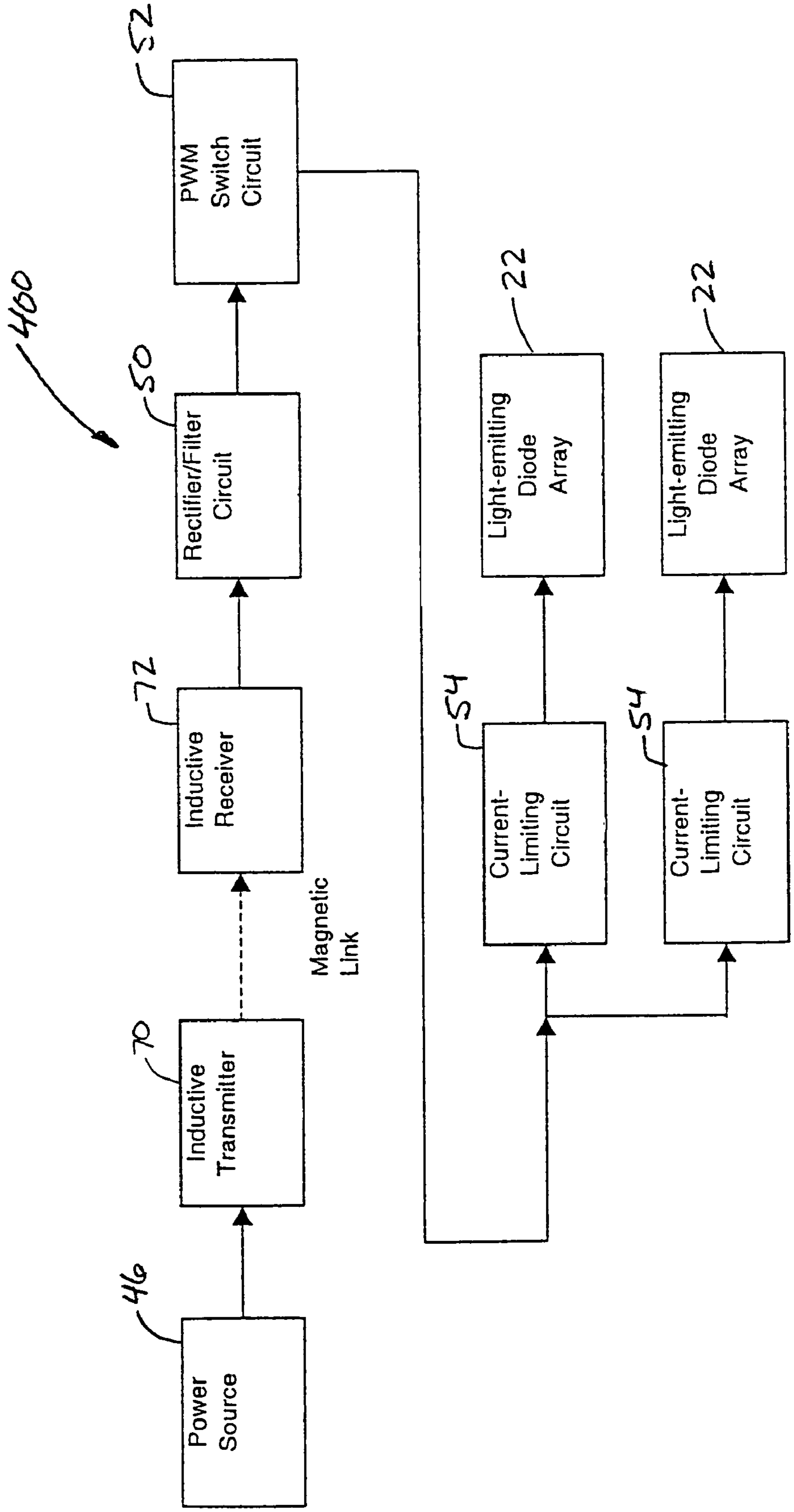
400
Power Source
46
Inductive Transmitter
70
Magnetic Link
Inductive Receiver
72
Rectifier/Filter Circuit
50
PWM Switch Circuit
52
Current-Limiting Circuit
54
Current-Limiting Circuit
54
Light-emitting Diode Array
22
Light-emitting Diode Array
22

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. 09/782,375 filed Feb. 12, 2001, now U.S. Pat. No. 7,049,761 issued 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

A light tube for illumination by a power supply circuit including a bulb portion and a pair of end caps disposed at opposite ends of the bulb portion. A plurality of light emitting diodes are disposed inside the bulb portion and in electrical communication with the pair of end caps for illuminating in response to electrical current to be received from the power supply circuit.

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.

DESCRIPTION OF THE PREFERRED EMBODIMENT

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 (not shown).

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 convention 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 which effect 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. An LED lighting unit for replacing a conventional fluorescent tube between the opposed electrical receptacles of a fluorescent lighting fixture, comprising:

an elongate support structure having a first end and a second end opposite said first end;

a first end cap disposed upon said first end of said elongate support structure;

a second end cap disposed upon said second end of said elongate support structure; wherein each of said first end cap and said second end cap includes a fluorescent light fixture receptacle connector extending from each said end cap and configured for installing within the opposed electrical receptacles of the fluorescent lighting fixture;

a plurality of LEDs disposed along said elongate support structure in an electrical circuit with one another;

a cover overlying the elongate support structure and forming a housing enclosing the plurality of LEDs;

a battery supplying power to the plurality of LEDs;

a pulse-width modulating circuit receiving DC power from said battery and supplying modulated power to said plurality of LEDs; and

one or more current-limiting circuits coupled between said pulse-width modulating circuit and said plurality of LEDs;

wherein said one or more current-limiting circuits comprises an inductor electrically connected in series between said pulse-width modulating circuit and said plurality of LEDs and a power diode electrically connected between ground and a node between said pulse-width modulating circuit and said inductor.

2. The LED lighting unit according to claim **1** wherein at least certain of said plurality of LEDs are electrically connected in series with one another.

3. The LED lighting unit according to claim **1** wherein at least certain of said plurality of LEDs are electrically connected in parallel.

4. The LED lighting unit according to claim **1** wherein said elongate support structure is a circuit board.

5. The LED lighting unit according to claim **1** wherein said plurality of LEDs are arranged in spaced-apart groups along one surface of said elongate support structure.

6. An LED lighting unit for replacing a conventional fluorescent tube between the opposed electrical receptacles of a fluorescent lighting fixture, comprising:

an elongate support structure having a first end and a second end opposite said first end;

a first end cap disposed upon said first end of said elongate support structure;

a second end cap disposed upon said second end of said elongate support structure; wherein each of said first end cap and said second end cap includes a fluorescent light fixture receptacle connector extending from each said end cap and configured for installing within the opposed electrical receptacles of the fluorescent lighting fixture;

a plurality of LEDs disposed along said elongate support structure in an electrical circuit with one another;

a cover overlying the elongate support structure and forming a housing enclosing the plurality of LEDs; and one or more current-limiting circuits coupled between said battery and said plurality of LEDs; wherein said one or more current-limiting circuits comprises an inductor electrically connected in series between said battery and said plurality of LEDs and a power diode electrically connected between ground and a node between said battery and said inductor;

a battery supplying power to the plurality of LEDs;

wherein said elongate support structure is a circuit board and said circuit board has an H-shaped cross-section.

7. The LED lighting unit according to claim **6**, further comprising:

a pulse-width modulating circuit receiving DC power from said battery and supplying modulated power to said plurality of LEDs.

8. The LED lighting unit according to claim **7**, further comprising:

one or more current-limiting circuits coupled between said pulse-width modulating circuit and said plurality of LEDs.

9. The LED lighting unit according to claim **8** wherein said one or more current-limiting circuits comprises one of a resistor, a current-limiting semiconductor circuit or a switching power supply type current limiter.

10. The LED lighting unit according to claim **8** wherein said one or more current-limiting circuits comprises an inductor electrically connected in series between said pulse-width modulating circuit and said plurality of LEDs and a power diode electrically connected between ground and a node between said pulse-width modulating circuit and said inductor.

11. The LED lighting unit according to claim **7** wherein said pulse-width modulating circuit is configured to modulate the plurality of LEDs to emit light at a frequency higher than 120 Hz.

12. The LED lighting unit according to claim **7** wherein said pulse-width modulating circuit is configured to modulate the plurality of LEDs to cyclically flash light from the LED lighting unit on and off.

13. The LED lighting unit according to claim **6** wherein said plurality of LEDs are arranged in spaced-apart groups along one surface of said elongate support structure.

14. An LED lighting unit for replacing a conventional fluorescent tube between the opposed electrical receptacles of a fluorescent lighting fixture, comprising:

an elongate support structure having a first end and a second end opposite said first end;

a first end cap disposed upon said first end of said elongate support structure;

a second end cap disposed upon said second end of said elongate support structure; wherein each of said first end cap and said second end cap includes a fluorescent light fixture receptacle connector extending from each said end cap and configured for installing within the opposed electrical receptacles of the fluorescent lighting fixture;

a plurality of LEDs disposed along said elongate support structure in an electrical circuit with one another;

a cover overlying the elongate support structure and forming a housing enclosing the plurality of LEDs; and one or more current-limiting circuits coupled between said battery and said plurality of LEDs; wherein said one or more current-limiting circuits comprises an inductor electrically connected in series between said battery and said plurality of LEDs and a power diode electrically connected between ground and a node between said battery and said inductor;

a battery supplying power to the plurality of LEDs;

wherein said plurality of LEDs are arranged in spaced-apart groups along one surface of said elongate support structure.

15. The LED lighting unit according to claim **14** wherein said cover is a hollow tube surrounding said elongate support structure.

16. The LED lighting unit according to claim **14** wherein said battery generates DC power for a power supply coupled to said plurality of LEDs and providing regulated power to said plurality of LEDs using said DC power.

17. The LED lighting unit according to claim **16** wherein said power supply is of a switching type.

18. The LED lighting unit according to claim **16** wherein said power supply is packaged at least in part within said cover or in either one of said first end cap or said second end cap.

* * * * *