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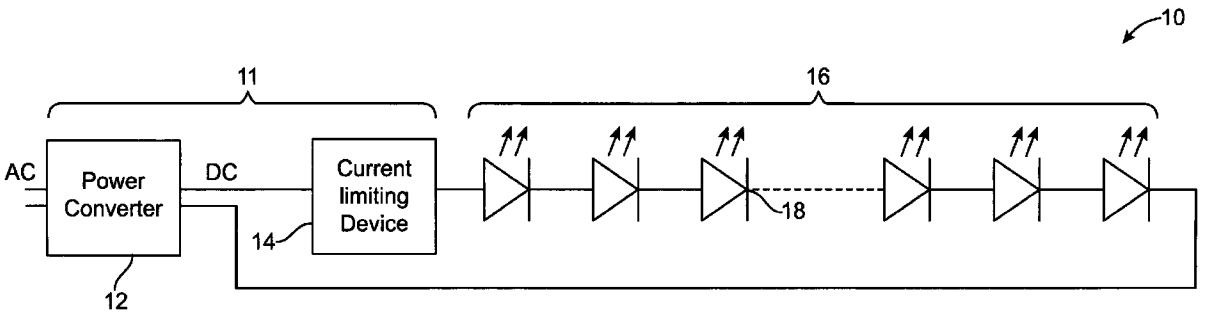

FIG. 1

(57) Abrégé/Abstract:
A lighting apparatus includes a solid state lamp including one or more solid state lighting elements, and a power circuit including a current limiting device electrically connected to the lamp. The current limiting device configured to impose a maximum threshold on the current delivered to the lamp, wherein the current limiting device functions as essentially a constant current source. The lighting apparatus includes a housing for the power circuit and lamp, as a module unit.

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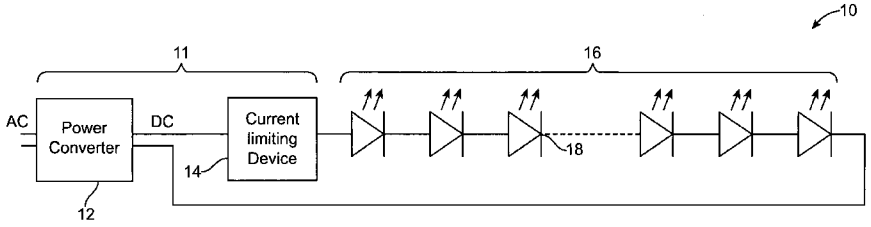

FIG. 1

(57) Abstract: A lighting apparatus includes a solid state lamp including one or more solid state lighting elements, and a power circuit including a current limiting device electrically connected to the lamp. The current limiting device configured to impose a maximum threshold on the current delivered to the lamp, wherein the current limiting device functions as essentially a constant current source. The lighting apparatus includes a housing for the power circuit and lamp, as a module unit.

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Solid State Lighting Apparatus

Related Application

This application claims priority from U.S. Provisional Patent Application Serial No. 60/926,140 filed April 25, 2007 incorporated herein by reference in its entirety. This application further claims priority from U.S. Provisional Patent Application Serial No. 60/926,476 filed April 27, 2007, incorporated herein by reference in its entirety.

Field of the Invention

The present invention relates to lighting applications, and in particular to solid state lighting.

Background of the Invention

There has been an ongoing global proliferation of lighting products. Typical lighting products use one or more incandescent bulbs. Incandescent bulbs are inexpensive to buy, but generate 90% heat and merely 10% of light, which makes them inefficient and expensive to operate. Further, incandescent bulbs have a very short product life (typically 1000 hours).

Fluorescent lamps are more efficient than incandescent bulbs, but utilize hazardous materials such as mercury. In addition, fluorescent lamps require bulky ballasts that are costly, and make the fluorescent lamps unsuitable for smaller spaces. Further, fluorescent lamps perform poorly in low temperatures. Though fluorescent lamps exhibit longer life than incandescent bulbs, fluorescent lamps are more expensive than incandescent bulbs and still require frequent maintenance, which is fulfilled by intensive labor.

Brief Summary of the Invention

The present invention provides a solid state lighting apparatus and assembly. In one embodiment, such a lighting apparatus includes a solid state lamp including one or more solid state lighting elements, and a power circuit including a current limiting device electrically connected to the lamp. The current limiting device is configured to impose a maximum threshold on the current delivered to the lamp, wherein the current limiting device functions as essentially a constant current source. The lighting apparatus includes a housing for the power circuit and lamp, as a module unit.

The power circuit further comprises a power converter electrically connected to the current limiting device, wherein the power converter is configured for converting AC power to DC power for the current limiting device. In one implementation, the power converter comprises a bridge rectifier for converting AC power to DC power for the current limiting device.

In one implementation, the power circuit is configured to deliver DC power to the lamp such that the lamp operates at less than 100% duty cycle from an AC line frequency. In an example, the power circuit is configured to deliver DC power to the solid state lamp such that the lamp operates at about 50% duty cycle from an AC line frequency.

At least one lighting element comprises an LED. Further, the lamp can comprise multiple LEDs chained as a single string circuit. The lamp can also comprise multiple LED string circuits chained in parallel, the apparatus comprising a current limiting device per LED string circuit, connected to the power circuit.

In another embodiment of the present invention provides a lighting assembly, comprising multiple solid state lighting apparatus units, as described. In another embodiment, the present invention provides a lighting assembly, comprising one or more solid state lighting apparatus units, each lighting apparatus unit comprising: a solid state lamp including one or more solid state lighting elements; a power circuit including a current limiting device electrically connected to the lamp, the current limiting device configured to impose a maximum threshold on the current delivered to the lamp, wherein the current limiting device functions as essentially a constant current source; bridge rectifier for converting AC power to DC power for the current limiting device; a circuit board including electrical traces such that the lamp and the power circuit are attached to the circuit board, and electrically connected via the circuit board; and a housing for one or more solid state lighting apparatus

units, forming a modular unit. The modular unit has a form factor to fit into an existing lighting environment using existing power lines.

These and other features, aspects and advantages of the present invention will become understood with reference to the following description, appended claims and accompanying figures.

Brief Description of the Drawings

Fig. 1 shows a functional block diagram of an example lighting apparatus according to an embodiment of the present invention.

Fig. 2 shows a functional block diagram of another example lighting apparatus according to the present invention.

Fig. 3 shows an example graph of the duty cycle for the lighting elements, such as LEDs, in a lighting apparatus according to an embodiment of the present invention.

Fig. 4 shows a modular lighting apparatus according to an embodiment of the present invention.

Fig. 5 shows a functional block diagram of a lighting assembly with multiple LED groups chained as a single string circuit, according to an embodiment of the present invention.

Fig. 6 shows a functional block diagram of a lighting assembly including multiple LED string circuits chained in parallel, according to an embodiment of the present invention.

Fig. 7 shows a functional block diagram of a lighting assembly including multiple lighting apparatus units connected to an AC line in parallel, according to an embodiment of the present invention.

Fig. 8 shows a fabricated modular lighting unit including a lighting apparatus, according to an embodiment of the present invention.

Fig. 9 shows a schematic of an example lighting assembly comprising a lighting module fabricated to fit into a typical fluorescent lamp housing, according to an embodiment of the present invention.

Detailed Description of the Preferred Embodiments

The present invention provides a lighting apparatus using solid state lighting elements, for such application as replacing incandescent bulbs and fluorescent lamps, while providing more efficient, longer life lighting (50,000 hours typical) that is also environmentally friendly and compact.

The lighting apparatus further allows for more compact fabrication than in conventional incandescent and fluorescent lighting. The lighting apparatus can further be fabricated to fit into existing incandescent or fluorescent bulb form factors, which in turn allows the lighting apparatus to be easily fit into existing housing and wiring for incandescent or fluorescent lighting.

Fig. 1 shows an example functional block diagram of a lighting apparatus 10, according to an embodiment of the present invention. The lighting apparatus 10 comprises a power circuit 11 including a power converter 12, such as bridge a rectifier, that converts alternating current (AC) to direct current (DC).

The power circuit 11 further includes a current limiting device (current limiter) 14 and a solid state lamp 16 which includes one or more solid state lighting elements such as LEDs 18. The power circuit 11 and the LEDs 18 are connected in series.

Fig. 2 shows another example lighting apparatus 20 according to the present invention, wherein the power circuit 11 further includes an AC line connection 19 to power lines such as an AC line in a typical home or office.

In either example, the current limiting device 14 imposes a maximum threshold on the current delivered to the lamp 16, thereby reducing the peak current that flows in the lamp 16. This reduces power consumption and/or prevents damage to the lighting elements 18 of the lamp 16.

The current limiting device 14 is preferably simple in design and compact in form, allowing modularization and space-saving form factors for the lighting apparatus it is used with. More preferably, the current limiting device 14 provides high voltage and functions as a constant current source, which is essentially unaffected by temperature variations.

Such a current limiting device for a lighting apparatus implementation according to the present invention, allows simplified power conversion steps in the power circuit, and provides overall size reduction. Therefore, the lighting apparatus allows a small/flexible form factor for modularization, and can be used for lighting in areas such as freezer cases, under-cabinet, display shelves, etc., wherein space is limited.

An example of the current limiting device 14 can be CL2 from Supertex, Inc., Sunnyvale, CA (specification published at http://www.supertex.com/pdf/datasheets/CL2.pdf). Yet another example of the current limiting device 14 can be regulator LM317 from Texas Instruments, Dallas, Texas (specification published at http://focus.ti.com/lit/ds/symlink/lm317.pdf).

The power circuit 11 can be connected to an AC line, or in another embodiment where suitable DC power is available, the power converter 12 of the circuit 11 becomes unnecessary, such that the available DC power can be electrically coupled to the current limiting device 14.

In an example implementation, the lighting apparatus 10 operates on 120V AC (a readily available household power source). The power converter 12 is implemented as a bridge rectifier that converts the 120V AC into a sine-wave 120V DC signal at 120 Hz, shown by an example graph 30 in **Fig. 3**. The current limiting device 14 has an operating range of 5 to 90V at 20mA.

The number of LEDs determines the applicable line voltage, where:

Number of LEDs = (Supply voltage - Voltage drop of the current limiting device) / Voltage drop per LED.

When the voltage drop across the current limiting device is 45V, then for a 120V AC input, the peak supply voltage is: 170 V (peak) = 120V AC x 1.414. When the voltage drop per LED is 3.5 V, then:

Number of LEDs = (170 V (peak) - 45V) / 3.5V, or

Number of LEDs = 125 V / 3.5V = 35.7 LEDs or 36 LEDs.

Since in this example the LEDs 18 operate at about 3.5V voltage drop for white LEDs, a total of 36 LEDs have a total voltage drop of 126V. Therefore, as shown by the example graph 30 in Fig. 3, the LEDs are turned ON only when the DC voltage applied to them is higher than 126V DC. The LEDs are connected in series to offset 75% of the line voltage, wherein a 50% duty cycle is achieved. With this simplified circuit, in a 120VAC application, a 50% duty cycle on the LEDs 18 from the AC line frequency prolongs the life of the LEDs and results in electrical energy savings. Other implementations with

less than 100% duty cycle are within the scope of the present invention are possible.

Such a simplified LED circuit design can be modularized, scaled, expanded, reconfigured or replaced individually. As shown by the schematic in **Fig. 4**, in an example lighting apparatus 40 the current limiting device 14 is embedded in a modular assembly for the LEDs 18 on a circuit board 42 (e.g., printed circuit board). Electrical traces 44 on the board 42 connect the LEDs 18 and the current limiting device 14. Therefore, external ballasts or transformers are not required, resulting in a compact form factor for the lighting apparatus 40. The power converter 12 can also be placed on the circuit board 42, while maintaining the compactness. The circuit board 42 can be attached to a backplane 46 for structural support.

Further, a lighting assembly according to an embodiment of the present includes multiple modularized lighting apparatus units 10, chained in various arrangements for different applications. As shown by example in **Fig. 5**, an example lighting assembly 50 according to the present invention includes multiple LEDs 18 that are chained as a single string circuit. Fig. 5 further shows the power converter 12 as a bridge rectifier with 4 diodes 15 connected for AC to DC conversion, per graph 30 in Fig. 3.

Referring to **Fig. 6**, another lighting assembly 60 according to an embodiment of the present includes multiple (e.g., two) string circuits 52 of LEDs 18, chained in parallel for form the solid state lamp. **Fig. 7** shows

another example lighting assembly 70 according to the present, including multiple lighting apparatus units 10 connected to an AC line in parallel.

Fig. 8 shows an example modular unit 80 including a solid state lighting apparatus, such as lighting apparatus 40 shown in Fig. 4, according to the present invention. In the modular unit 80, the lighting apparatus 40 is placed in a housing 82 that can be held by ends 84L, 84R of a holder 85, with power lines 86 connected to the power circuit of the lighting apparatus 40.

As shown in Fig. 8, essentially the entire lighting apparatus 40 (including the current limiter, LEDs and bridge rectifier) is placed in the housing 82 as modular unit, which can then be "dropped" into an existing holder 85 for making electrical contact with the power lines, or can be used in another manner. The housing 82 can have a form factor such as tubular (as in florescent applications), essentially spherical (as in incandescent bulb applications), etc. The housing 82 can be transparent, opaque, etc.

Fig. 9 shows an example lighting assembly 90 comprising a lighting module 92 according to the present invention, which is fabricated to fit into a typical fluorescent lamp housing 94, having holders 94L, 94R at opposing ends of a supporting member 93, for holding the corresponding ends of the lighting module 92. The lighting module 92 includes five lighting apparatus units 40 (Fig. 4), which can be electrically connected to AC power in a serial chain or parallel, and housed in a transparent housing 95. For example, the

lighting module 92 can be 60 inches long end-to-end (the tubular module 95 being 57 1/4 inches long), and 1 3/8 inches wide. Other examples are possible.

Without bulky ballasts, switching mode converters or transformers, a lighting apparatus according to the present invention can be applied in new installations or fit into existing lamp fixtures for replacing existing devices, without additional requirements or changes to the surrounding environment. While the SSL industry is still focused on high power LEDs (which makes the driving circuits and the finished product bulky), in one embodiment the present invention uses fewer number of low powered LEDs along with a current limiting device having a low current rating, as a combination that is low power generates essentially minimal heat.

The present invention has been described in considerable detail with reference to certain preferred versions thereof; however, other versions are possible. Therefore, the spirit and scope of the appended claims should not be limited to the description of the preferred versions contained herein.

What is claimed is:

1. A lighting apparatus, comprising:

a solid state lamp including one or more solid state lighting elements; and

a power circuit including a current limiting device electrically connected to the lamp, the current limiting device configured to impose a maximum threshold on the current delivered to the lamp, wherein the current limiting device functions as essentially a constant current source.

2. The apparatus of claim 1 wherein the power circuit further comprises a power converter electrically connected to the current limiting device, wherein the power converter is configured for converting AC power to DC power for the current limiting device.

3. The apparatus of claim 2 wherein the power converter comprises a bridge rectifier for converting AC power to DC power for the current limiting device.

4. The apparatus of claim 3 wherein a lighting element comprises an LED.

5. The apparatus of claim 3 wherein the bridge rectifier converts an AC signal into a sine-waved DC signal.

6. The apparatus of claim 3 wherein the power circuit is configured to deliver DC power to the lamp such that the lamp operates at less than 100% duty cycle from an AC line frequency.

7. The apparatus of claim 3 wherein the power circuit is configured to deliver DC power to the lamp such that the lamp operates at about 50% duty cycle from an AC line frequency.

8. The apparatus of claim 3 wherein the power circuit is configured to deliver DC power to the lamp such that the lamp operates at about 50% duty cycle from an 120VAC line frequency.

9. The apparatus of claim 4 wherein the one or more LEDs are connected in series to offset 75% of the line voltage, wherein a 50% duty cycle for the LEDs is achieved from an AC line frequency.

10. The apparatus of claim 1 further comprising a housing for the lamp and the power circuit, wherein the lamp and the power circuit form a modular unit with the housing.

11. The apparatus of claim 1 further comprising a circuit board including electrical traces such that the lamp and the power circuit are attached to the circuit board, and electrically connected via the circuit board.

12. The apparatus of claim 1 further comprising:

a circuit board including electrical traces such that the lamp and the power circuit are attached to the circuit board, and electrically connected via the circuit board;

a housing for the circuit board including the lamp and the power circuit, wherein the housing and circuit board carrying the power circuit and the lamp, form a modular unit.

13. The apparatus of claim 4 wherein the lamp comprises multiple LEDs chained as a single string circuit.

14. The apparatus of claim 4 wherein the lamp comprises multiple LED string circuits chained in parallel, the apparatus comprising a current limiting device per LED string circuit, connected to the power circuit.

15. A lighting assembly, comprising:

multiple solid state lighting apparatus units;

each lighting apparatus unit comprising:

a solid state lamp including one or more solid state lighting elements; and

a power circuit including a current limiting device electrically connected to the lamp, the current limiting device configured to impose a maximum threshold on the current delivered to the lamp.

16. The assembly of claim 15 wherein each power circuit further comprises a power converter electrically connected to the current limiting device,

wherein the power converter is configured for converting AC power to DC power for the current limiting device.

17. The assembly of claim 16 wherein each power converter comprises a bridge rectifier for converting AC power to DC power for the current limiting device.

18. The assembly of claim 17 wherein a lighting element comprises an LED.

19. The assembly of claim 17 wherein a bridge rectifier converts an AC signal into a sine-waved DC signal.

20. The assembly of claim 17 wherein a power circuit is configured to deliver DC power to the lamp such that the corresponding lamp operates at less than 100% duty cycle from an AC line frequency.

21. The assembly of claim 17 wherein a power circuit is configured to deliver DC power to the lamp such that the corresponding lamp operates at about 50% duty cycle from an AC line frequency.

22. The assembly of claim 17 wherein a power circuit is configured to deliver DC power to the lamp such that the corresponding lamp operates at about 50% duty cycle from an 120VAC line frequency.

23. The assembly of claim 21 wherein the one or more LEDs are connected in series to offset 75% of the line voltage, wherein a 50% duty cycle for the LEDs is achieved from an AC line frequency.

24. The assembly of claim 15 further comprising a housing for the lamps and the power circuits, wherein the lamps and the power circuits form a modular unit with the housing.

25. The assembly of claim 15 wherein each lighting apparatus unit further comprising a circuit board including electrical traces such that a corresponding lamp and the corresponding power circuit are attached to the circuit board, and electrically connected via the circuit board.

26. A lighting assembly, comprising:

one or more solid state lighting apparatus units;

each lighting apparatus unit comprising:

a solid state lamp including one or more solid state lighting elements;

a power circuit including a current limiting device electrically connected to the lamp, the current limiting device configured to impose a maximum threshold on the current delivered to the lamp, wherein the current limiting device functions as essentially a constant current source;

bridge rectifier for converting AC power to DC power for the current limiting device;

a circuit board including electrical traces such that the lamp and the power circuit are attached to the circuit board, and electrically connected via the circuit board; and

a housing for one or more solid state lighting apparatus units, forming a modular unit.

27. The assembly of claim 26 wherein the modular unit has a form factor to fit into an existing lighting environment using existing power lines.

28. The assembly of claim 26 wherein the housing is essentially transparent.

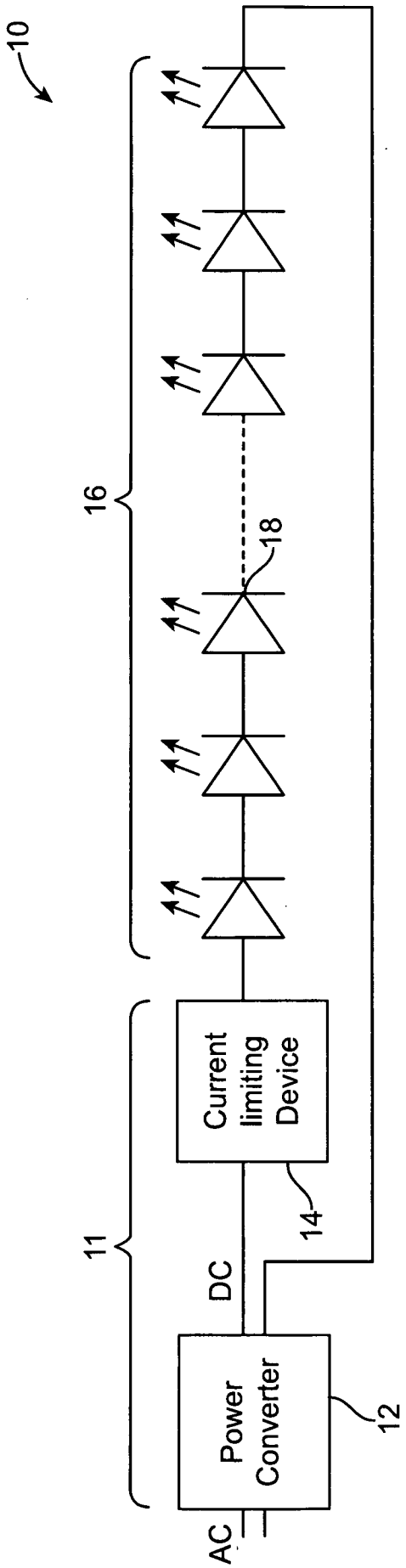

10
16
18
11
Current limiting Device
14
DC
Power Converter
12
AC

FIG. 1

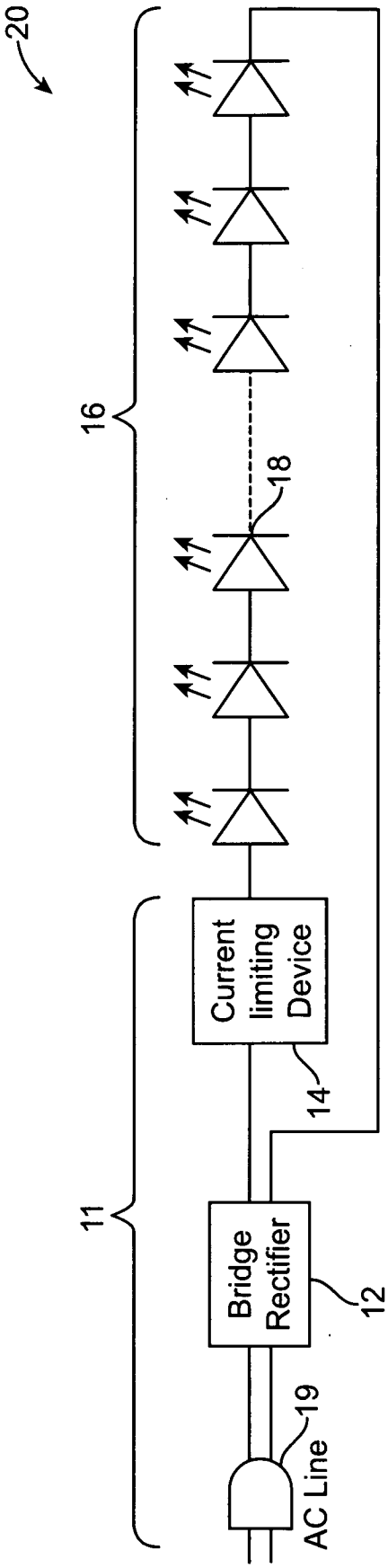

20
16
18
11
Current limiting Device
14
Bridge Rectifier
12
19
AC Line

FIG. 2

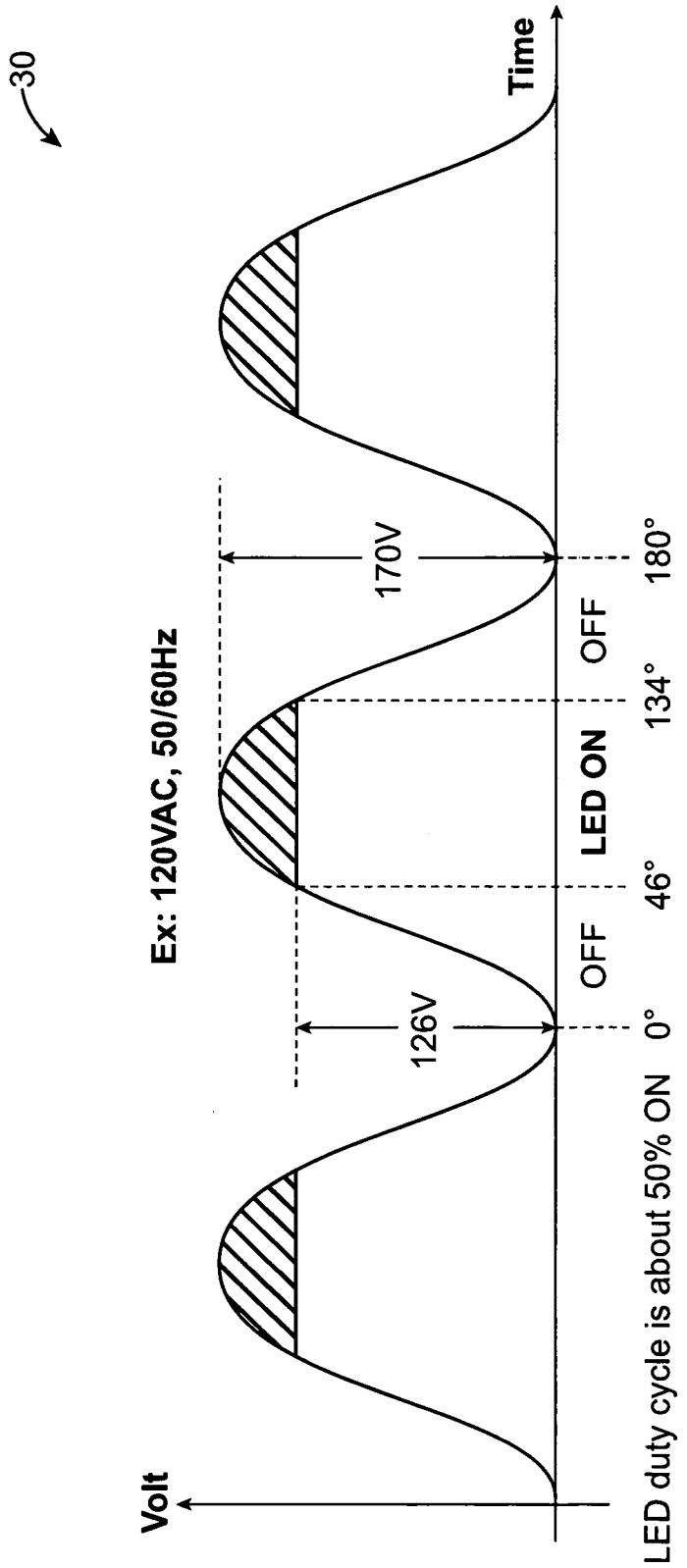

30
Time
Volt
Ex: 120VAC, 50/60Hz
170V
126V
OFF
LED ON
OFF
0°
46°
134°
180°
LED duty cycle is about 50% ON

FIG. 3

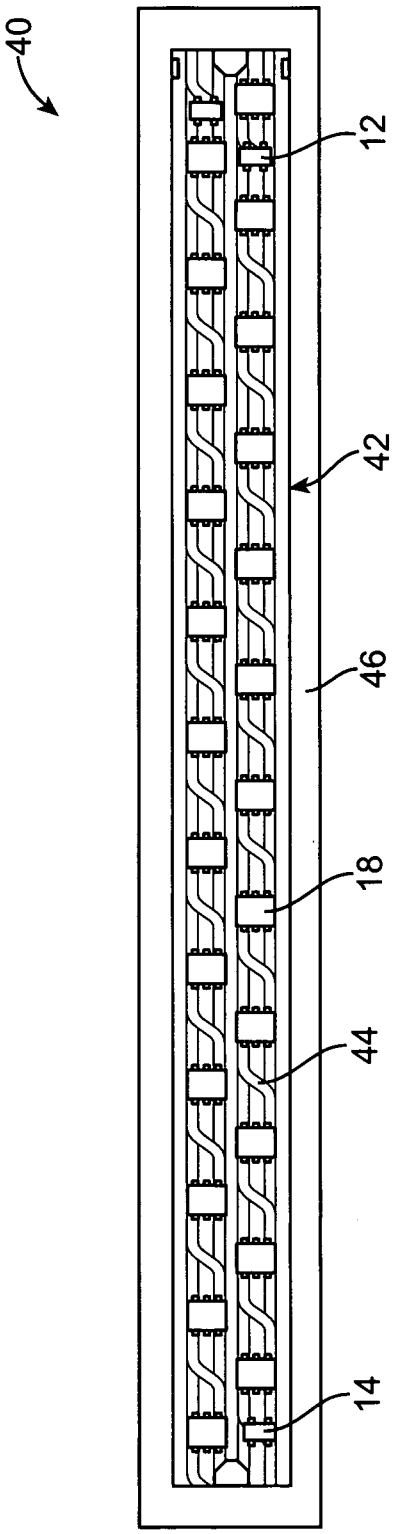
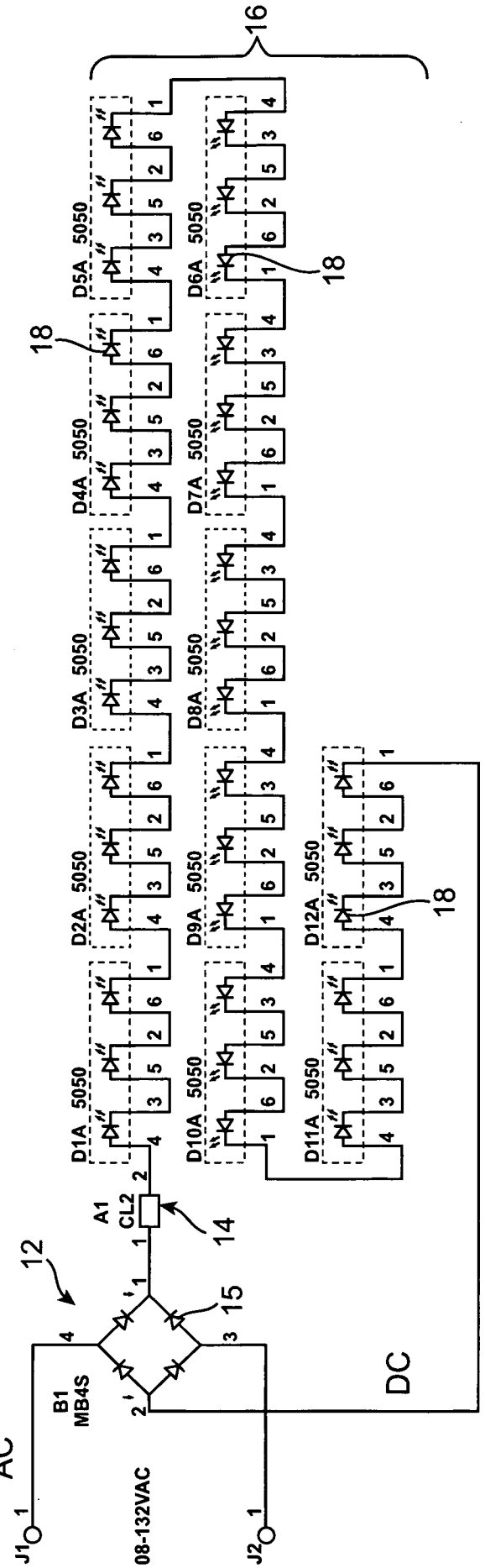


FIG. 4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18
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D2A 5050
D3A 5050
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D5A 5050
D6A 5050
D7A 5050
D8A 5050
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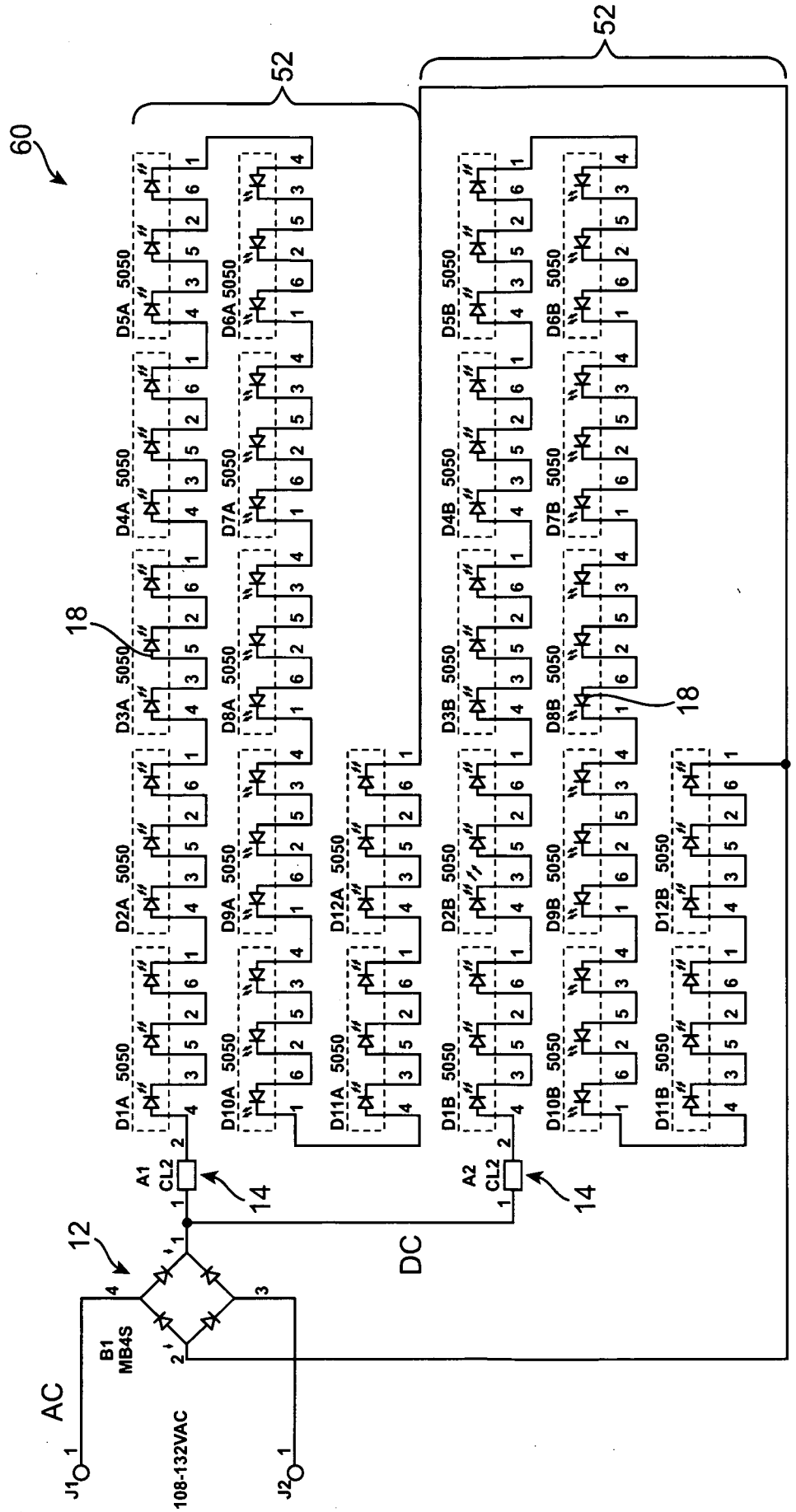
D10A 5050
D11A 5050
D12A 5050
A1
CL2
14
12
15
B1
MB4S
AC
08-132VAC
J1
J2
DC
50

FIG. 5


60
52
52
18
18
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D3A 5050
D4A 5050
D5A 5050
D6A 5050
D7A 5050
D8A 5050
D9A 5050
D10A 5050
D11A 5050
D12A 5050
D1B 5050
D2B 5050
D3B 5050
D4B 5050
D5B 5050
D6B 5050
D7B 5050
D8B 5050
D9B 5050
D10B 5050
D11B 5050
D12B 5050
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A2 CL2
14
14
12
B1 MB4S
AC
108-132VAC
J1
J2
DC

FIG. 6

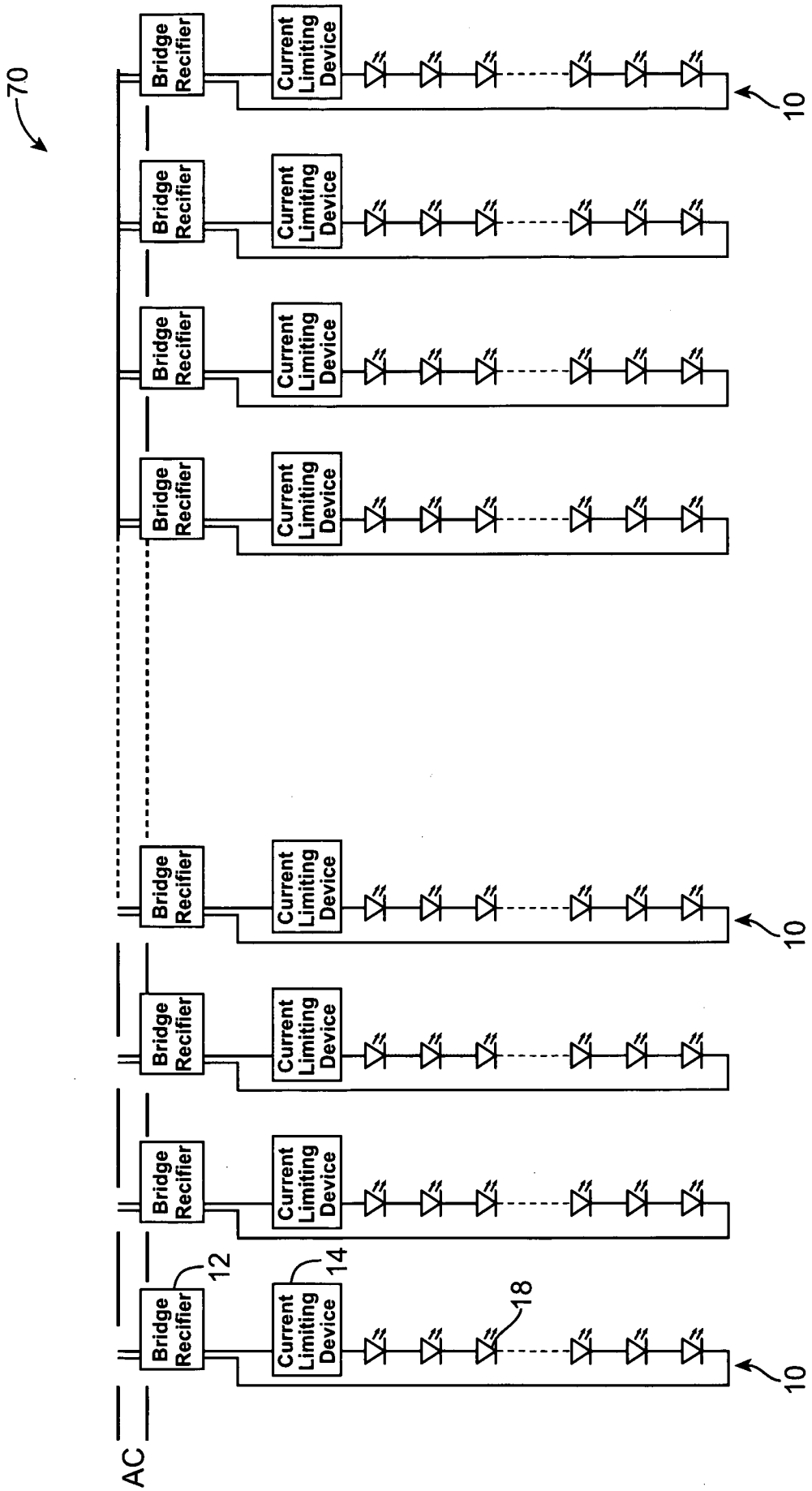

FIG. 7

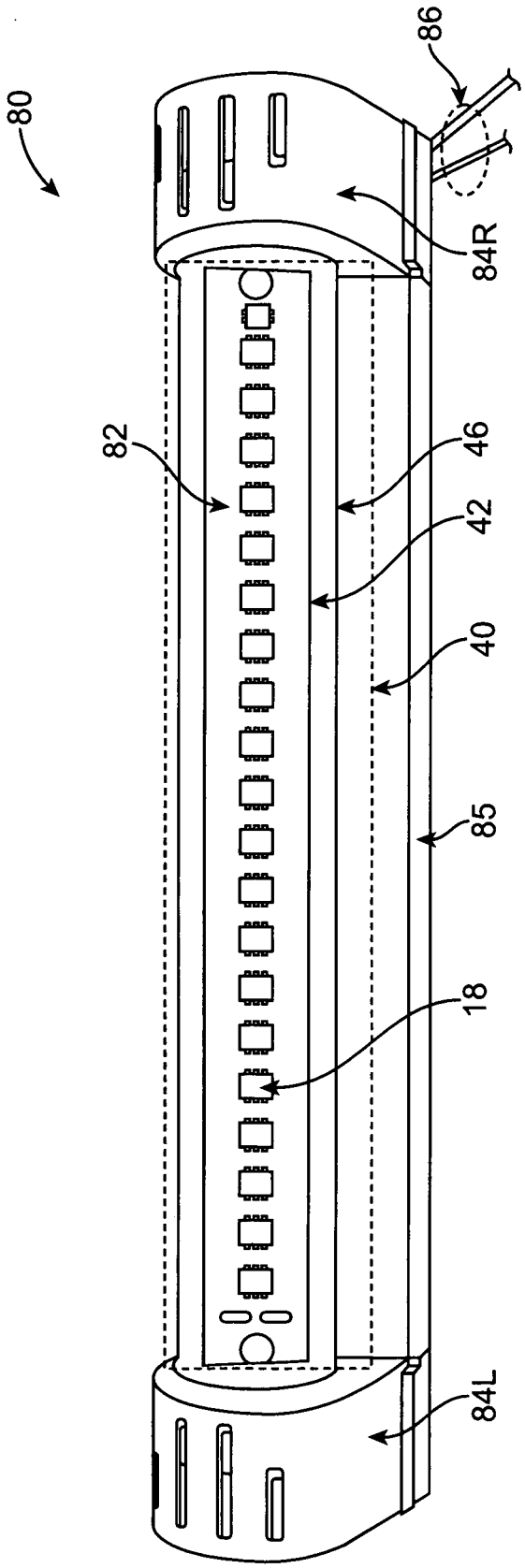

FIG. 8

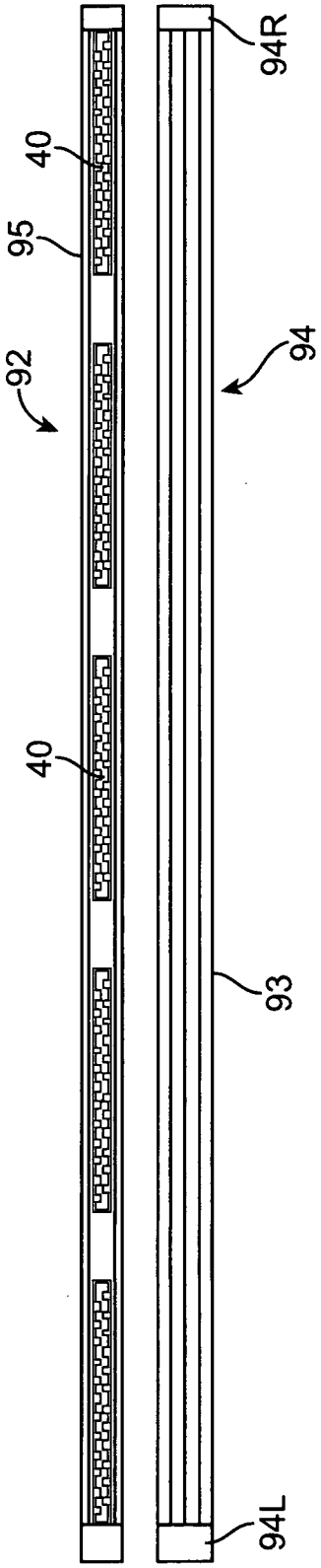

FIG. 9

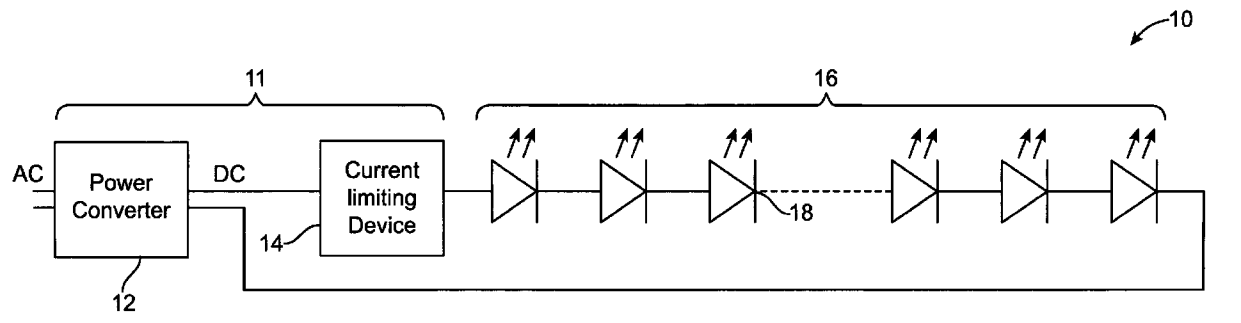
10
11
16
AC
Power Converter
DC
Current limiting Device
14
12
18

FIG. 1