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[Continued on next page]

(54) **Title:** LED LIGHTING WITH INCANDESCENT LAMP COLOR TEMPERATURE BEHAVIOR

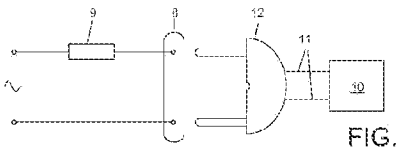


FIG. 1A

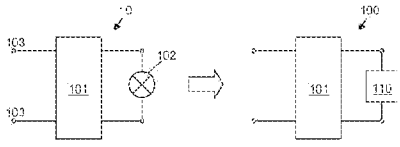


FIG. 1B

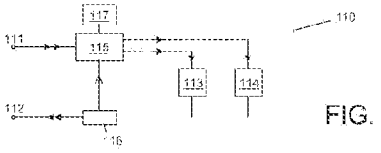


FIG. 1C

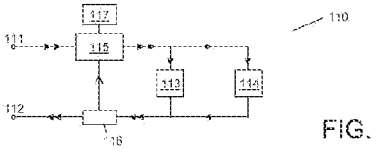


FIG. 1D

(57) **Abstract:** In a lighting device, sets of LEDs are employed using the natural characteristics of the LEDs to resemble incandescent lamp behavior when dimmed, thereby obviating the need for sophisticated controls. A first set of at least one LED produces light with a first color temperature, and a second set of at least one LED produces light with a second color temperature. The first set and the second set are connected in series, or the first set and the second set are connected in parallel, possibly with a resistive element in series with the first or the second set. The first set and the second set differ in temperature behavior, or have different dynamic electrical resistance. The light device produces light with a color point parallel and close to a blackbody curve.

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LED Lighting device with incandescent lamp color temperature behavior

FIELD OF THE INVENTION

The present invention relates in general to a lighting device comprising a plurality of LEDs as light sources and having only two terminals for receiving power, and more specifically to a LED lighting device having an incandescent lamp color temperature behavior when dimmed. The invention further relates to a kit of parts comprising a LED lighting device and a dimming device.

BACKGROUND OF THE INVENTION

A traditional light bulb is an example of a lighting device comprising a light source, i.e. the lamp filament, having two terminals for receiving power. When a voltage is applied to such light bulb, a current flows through the filament. The temperature of the filament rises due to Ohmic heating. The filament generates light, having a color temperature related to the temperature of the filament, which may be considered as being a black body. Normally, a lamp has a nominal rating corresponding to a nominal lamp power at nominal lamp voltage, for instance 230V AC in Europe, and corresponding to a certain nominal color of the emitted light.

Since many decades, people have been used to the light of incandescent lamps of different powers. The light of an incandescent lamp provides a general feeling of well-being. Generally, the lower the power of the incandescent lamp is, the lower the color temperature of the light emitted by the lamp is. As a characterization, the human perception of the light is "warmer" when the color temperature is lower. With one and the same incandescent lamp, the lower the power supplied to the lamp is, which occurs when the lamp is dimmed, the lower the color temperature of the emitted light is.

It is already known that it is possible to dim a lamp, i.e. to reduce the light output. This is done by reducing the average lamp power by reducing the average lamp voltage, for instance by phase cutting. As a result, also the temperature of the filament reduces, and consequently the color of the emitted light changes to a lower color temperature. For instance, in a standard incandescent lamp having 60W nominal rating, the color temperature is about 2700 K when the lamp is operated at 100% light output while the color

temperature is reduced to about 1700 K when the lamp is dimmed to a 4% light output. As is commonly known to a person skilled in the art, the color temperature follows the traditional black body line in a chromaticity diagram. A lower color temperature corresponds to a more reddish impression, and this is associated with a warmer, more cozy and pleasant atmosphere.

A relatively recent tendency is to replace incandescent light sources by lighting devices based on LED light sources, in view of the fact that LEDs are more efficient in converting electric energy to light and have a longer lifetime. Such lighting device comprises, apart from the actual LED light source(s), a driver that receives the mains voltage intended to operate an incandescent lamp and converts the input mains voltage to an operating LED current. LEDs are designed to provide a nominal light output when operated with a constant current having a nominal magnitude. An LED can also be dimmed. This can be done by reducing the current magnitude, but this typically results in a change of the color of the light output. In order to keep the color temperature of the generated light as constant as possible, dimming an LED is typically done by Pulse Width Modulation, also indicated as duty cycle dimming, wherein the LED current is switched ON and OFF at a relatively high frequency, wherein the current magnitude in the ON periods is equal to the nominal design magnitude, and wherein the ratio between ON time and switching period determines the light output.

It is desirable to have a lighting device having one or more LEDs as light source, wherein the dimming behavior of the traditional incandescent lamp is simulated so that, on dimming, the color temperature of the output light also follows a path (preferably close to the black body line) from a higher color temperature to a lower temperature.

Lighting devices capable of such functionality have already been proposed, for instance in US-2006/0273331. Such prior art devices comprise at least two LEDs of mutually different colors, each provided with a corresponding current source, and an intelligent control device, such as a microprocessor, controlling the individual current sources to change the relative light outputs of the respective LEDs. The known device receives an input voltage signal that carries power and a control signal. In the device, the control signal is taken from the input signal and transferred to the intelligent control device, that controls the individual current sources on the basis of the received control data. By changing the ratio between the respective light outputs, the relative contributions to the overall light output is changed and hence the overall color of the overall light output, as perceived by an observer, is changed. Such lighting device, therefore, requires a separate control input signal.

In LED lighting devices, a behavior of the color temperature of the LED light can be obtained which, in dimming conditions, is similar to that of an incandescent lamp, but until now only at the expense of extensive current control, such as e.g. known from DE 10230 105. The necessity of adding controls to the LED lighting device for the desired color temperature behavior increases the number of components, increases the complexity of the lighting device, and increases costs. These effects are undesirable.

SUMMARY OF THE INVENTION

The present invention aims to provide a LED circuit for such LED lighting device, and a LED lighting device comprising such LED circuit, wherein an intelligent control can be omitted and wherein a feedback sensor can be omitted.

It would be desirable to provide an LED lighting device having a color temperature behavior, when dimmed, resembling or approaching the color temperature behavior of an incandescent lamp, when dimmed. It would also be desirable to provide an LED lighting device having an incandescent lamp color temperature behavior, when dimmed, without the need of extensive controls.

According to an aspect of the present invention, an LED lighting device comprises a single dimmable current source and an LED module receiving current from the current source. The LED module behaves as a load to the current source, similar to an array existing of LEDs only. Within the LED module, an electronic circuit senses the current magnitude of the input current, and distributes the current to different LED sections of the LED module on the basis of the sensed current magnitude. No intelligent current control is needed in the current source.

To better address one or more of these concerns, in an aspect of the invention an LED lighting device is provided, comprising a plurality of LEDs, and two terminals for supplying current to the lighting device. The lighting device comprises a first set of at least one LED of a first type producing light having a first color temperature, and a second set of at least one LED of a second type producing light having a second color temperature different from the first color temperature. The first set and the second set are connected in series or in parallel between the terminals. The lighting device is configured to produce light with a color point varying in accordance with a blackbody curve at a variation of an average current supplied to the terminals.

A color temperature behavior of an incandescent lamp may be described by the following relationship:

$$CT(x\%) = CT(100\%) * (x/100)^{\frac{1}{9.5}}$$

where CT(100%) is the color temperature of the light at full power (100% current) of the lamp, CT(x%) is the color temperature of the light at x% dimming of the lamp (x% current, with $0 < x < 100$).

In an embodiment, the first set has a varying first luminous flux output as a function of junction temperature of the LED of the first type, and the second set has a varying second luminous flux output as a function of junction temperature of the LED of the second type, and wherein, at varying junction temperatures, the ratio of the first luminous flux output to the second luminous flux output varies. In particular, when the first color temperature is lower than the second color temperature, the lighting device is configured such that, at decreasing junction temperatures, the ratio of the first luminous flux output to the second luminous flux output increases, and vice versa. In such a configuration, e.g. having the first set connected in series with the second set, the first luminous flux output increases relative to the second flux output when the lighting device is dimmed, thereby producing light having a lower color temperature.

In an embodiment, the first set has a first dynamic electrical resistance, and the second set has a second dynamic electrical resistance. When e.g. the first set is connected in parallel with the second set, different luminous flux outputs of the first set and the second set result, which can be designed to produce light having a lower color temperature when dimmed.

In another aspect of the present invention, a lighting kit of parts is provided, comprising a dimmer having input terminals adapted to be connected to an electrical power supply, and having output terminals adapted to provide a variable electrical power. An embodiment of the lighting device according to the present invention has terminals configured to be connected to the output terminals of the dimmer.

Further advantageous elaborations are mentioned in the dependent claims.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other aspects, features and advantages of the present invention will be further explained by the following description of one or more preferred embodiments with reference to the drawings, in which same reference numerals indicate same or similar parts, and in

which:

figures IA- ID are block diagrams schematically illustrating the present invention;

figures 2A and 2B are graphs illustrating the current division behavior of a division circuit according to the present invention;

figure 3A is a diagram illustrating a first possible embodiment of a division circuit according to the present invention;

figure 3B is a diagram illustrating a variation of the first possible embodiment of a division circuit according to the present invention;

figure 4A is a diagram illustrating a second possible embodiment of a division circuit according to the present invention;

figure 4B is a diagram illustrating a third possible embodiment of a division circuit according to the present invention;

figure 5 is a diagram illustrating a fourth possible embodiment of a division circuit according to the present invention;

figure 6 depicts an LED lighting device in a fifth embodiment of the present invention, powered by a current source;

figure 7 illustrates relationships between luminous flux and temperature for different types of LEDs;

figure 8 illustrates further relationships between luminous flux and temperature for different types of LEDs;

figure 9 illustrates a relationship between a luminous flux ratio and a dimming ratio for different types of LEDs;

figure 10 depicts a LED lighting device in a sixth embodiment of the present invention, powered by a current source;

figure 11 illustrates relationships between LED current and forward voltage for different types of LEDs, as well as a ratio of current through the first and second sets of LEDs of figure 10.

DETAILED DESCRIPTION OF THE INVENTION

Figure IA schematically shows a lighting device 10, having a power cord 11 and power plug 12 connected to a wall socket 8, that receives dimmed mains voltage from a dimmer 9 connected to mains M, for instance 230 VAC @ 50 Hz in Europe. It is noted that instead of a wall socket 8 and power plug 12, the lighting device 10 may also be connected

through fixed wiring directly. Conventionally, the lighting device 10 comprises one or more incandescent lamps.

Figure 1B at the lefthand side shows the conventional layout of a lighting device 10 having LEDs as a light source. Such device comprises a driver 101 that generates current for an LED array 102. The driver 101 has input terminals 103 for receiving mains power. In conventional systems, the driver can only be switched on or off. In a more sophisticated system, the driver 101 is adapted to receive dimmed mains voltage from the dimmer 9, and to generate pulsed output current for the LEDs, the pulse height being equal to a nominal current level while the average current level is reduced on the basis of the dim information contained in the dimmed mains voltage. At the righthand side, figure 1B shows a lighting device 100 according to the present invention in which the LED array 102 is replaced by an LED module 110; as seen from the driver 101, the LED module 110 behaves as an LED array, i.e. the load characteristics of the LED module are the same as or similar to the load characteristics of an LED array.

Figure 1C is a block diagram schematically illustrating the basic concept of the LED module 110 according to the present invention. The module 110 has two input terminals 111, 112 for receiving the LED current from the driver 101. The module 110 comprises at least two LED arrays 113, 114. Each LED array may consist of one single LED or may comprise two or more LEDs. In the case of an LED array comprising a plurality of LEDs, such LEDs may be all connected in series but it is also possible to have LEDs connected in parallel. Further, in the case of an LED array comprising a plurality of LEDs, such LEDs may all be of the same type and/or the same color, but it is also possible that the plurality involves LEDs of mutually different colors. It is seen that in the schematic drawing of figure 1C only two LED arrays are shown, but it is noted that the LED module may comprise more than two LED arrays. It is further noted that such arrays may be connected in series and/or in parallel. The module 110 further comprises a division circuit 115 providing drive current to the LED arrays 113, 114, these drive currents being derived from the input LED current as received from the driver 101. The division circuit 115 is provided with a current sensor means 116, sensing the input LED current and providing the division circuit 115 with information representing the momentary average input current. This sensor means 116 may be a separate sensor external to the division circuit 115, as shown, but it may also be an integral part of the division circuit 115. The magnitudes of the individual drive currents for the respective LED arrays 113, 114 depend on the momentary average input current, and more particularly the ratio between the individual drive currents in the respective LED arrays

113, 114 depends on the momentary average input current. To this end, the division circuit 115 may be provided with a memory 117, either external to the division circuit 115, as shown, or an integral part of the division circuit 115, containing information defining a relationship between total input current and current division ratio. The information may for instance be in the form of a function or look-up table, where the division circuit 115 includes an intelligent control means such as for instance a microprocessor. However, in a cost-efficient embodiment preferred by the present invention, the division circuit 115 consists of an electronic circuit with passive and/or active electronic components, supplied by the voltage drop over the LEDs, and the memory function is implemented in the design of the electronic circuit.

Figures 2A and 2B are graphs illustrating an example of the current division behavior of a possible embodiment of the division circuit 115, where the formulas I1 = pTin and I2 = q-Iin apply, with I1 denoting the current in the first LEDs (white) and I2 denoting the current in the second LEDs (amber). Neglecting the current consumption in the division circuit itself, p + q = 1 at all times. The horizontal axis represents the input current Iin received from the driver 101. The vertical axis represents the output current provided to the LED arrays 113, 114. Assume that the LEDs in one string, for instance the first string 113, are white LEDs and that the LEDs in the other string are amber LEDs. Curve W represents the current in the white LEDs and curve A represents the current in the amber LEDs. Figure 2A illustrates a linear behavior, while figure 2B illustrates an example of a non-linear behavior; it should be clear that other embodiments are also possible. In all cases, the summation of the currents in both strings is almost equal to the input current Iin, represented by a straight line, although the division circuit itself may also consume a small amount of current but this is neglected for sake of discussion. The figures show that when the input current Iin is maximal, all current goes to the white LEDs and the amber LEDs are off. When the input current Iin is reduced, the percentage of the current in the white LEDs reduces and the current through the amber LEDs increases. As from a certain input current level, all current goes to the amber LEDs and the white LEDs are off. Since the color point of the output light is determined by the overall contribution of all LEDs in all strings, it should be clear that the color point is white when the input current Iin is maximal, and that the color point gets warmer with reducing input current.

More generally, when Iin is zero or close to zero, p is equal to a minimum value Pmin which may be equal to zero and q is equal to a maximum value Qmax which may be equal to one. When Iin is at a predetermined nominal (or maximum) level, q is equal to a

minimum value Qmin which may be equal to zero and p is equal to a maximum value Pmax which may be equal to one. There is at least a range of input currents where dp/d(Iin) is always positive and dq/d(Iin) is always negative. There may be a range of input currents where p and q are constant. There may be a range of input currents where p=0. There may be a range of input currents where q=0.

In accordance with the present invention, the important issue is that the division circuit is capable of individually changing the current in at least one LED array. There are several ways possible for doing so. For instance, it may be that the two arrays 113, 114 are arranged in parallel, and that the input current is split into a first portion going to first array 113 and a second portion going to second array 114, as illustrated in figure 1D. The summation of the first and second portion may always be equal to the input current. Splitting the current may be done on a magnitude basis, so that each array receives constant current yet of a variable magnitude; this can for instance be achieved if the division circuit comprises at least one controllable resistance or at least one controllable current source in series with an LED array concerned. Splitting the current may also be done on a temporal basis, so that each array receives current pulses with constant magnitude yet of a variable pulse duration; this can for instance be achieved if the division circuit comprises at least one controllable switch in series with an LED array. It may be that a third load (for instance a resistor) is used for dissipating a third portion of the input current bypassing an LED array. It may be that one current portion is kept constant.

The following contains illustrative examples of exemplary implementations embodying the present invention, but it is noted that these examples are not considered to be limiting for the invention. It is noted that in the following only the LED module will be shown; the driver 101 will be omitted for sake of simplicity, since the driver 101 may be implemented by a standard LED driver.

Figure 3A is a diagram illustrating a first possible embodiment of the division circuit 115. This embodiment of the LED module will be indicated by reference numeral 300, and its division circuit will be indicated by reference numeral 315. The division circuit 315 comprises an opamp 310 and a transistor 320 having its base terminal coupled to the output of opamp 310, possibly via a resistor not shown. The opamp 310 has a non-inverting input 301 set at a reference voltage level determined by a voltage divider 330 consisting of a series arrangement of two resistors 331, 332 connected between the input terminals 111, 112, said non-inverting input 301 being coupled to the node between said two resistors 331, 332. The LED module 300 further comprises a string of three white LEDs 341, 342, 343 arranged in

series between the input terminals 111, 112, with a resistor acting as current sensor 350 arranged in series with the string of white LEDs. A feedback resistor 360 has one terminal connected to the node between current sensor resistor 350 and the string of white LEDs 341, 342, 343, and has its second terminal connected to an inverting input of the opamp 310. The transistor 320 has its emitter terminal connected to the inverting input of the opamp 310. The collector terminal of the transistor 320 is connected to a point of the LED string 341, 342, 343, in this case a node between a first LED 341 and a second LED 342, with an amber LED 371 in this collector line.

Thus, in the embodiment shown, the collector-emitter path of the transistor 320 is connected in parallel to a portion of the string of white LEDs 341, 342, 343; this can be considered as constituting a total of three strings, one string containing two white LEDs 342, 343 parallel to on string containing one amber LED 371, and these two strings being connected in series to a third string containing one white LED 341. Alternatively the collector-emitter path of the transistor 320 could be connected in parallel to the entire string of white LEDs 341, 342, 343, in which case there would be only two strings. In the example, there are three white LEDs 341, 342, 343 in series, but his could be two or four or more. In this example, the collector line contains only one amber LED, but this line might contain a series arrangement of two or more amber LEDs. In general, it is preferred that the number of amber LEDs connected in series in the collector line is less than the number of series-connected white LEDs in the string parallel to the collector-emitter path of the transistor 320.

The operation is as follows. With increasing input current, the voltage drop over the current sensor resistor 350 rises, thus the voltage between input terminals 111, 112 rises, thus the voltage at the opamp's non-inverting input rises. Since the voltage drop over the string of white LEDs 341, 342, 343 is substantially constant, the voltage rise between input terminals 111, 112 is substantially equal to the rise of voltage drop over the current sensor resistor 350 while the voltage rise at the opamp's non-inverting input is smaller than the voltage rise between input terminals 111, 112, the ratio being defined by the resistors 331, 332 of the voltage divider 320. Thus, the voltage drop over the feedback resistor 360 should be reduced, and hence the current in the collector-emitter path of the transistor 320 is reduced.

Figure 3B is a diagram illustrating a second possible embodiment of the division circuit 115. This embodiment of the LED module will be indicated by reference numeral 400, and its division circuit will be indicated by reference numeral 415. The division circuit 415 is substantially identical to the division circuit 315, with the exception that the

opamp 310 has its non-inverting input 301 set at a reference voltage level Vref determined by a reference voltage source 430, providing a reference voltage of for instance 200 mV, while further the base terminal of the transistor 320 is coupled to the positive input terminal 111 through a resistor 440. One important advantage of this division circuit 415 over the division circuit 315 of figure 3A is that it is more stable, i.e. less sensitive to variations of the forward voltages of the individual LEDs. The operation is comparable: with increasing input current, the voltage drop over the current sensor resistor 350 rises, thus the voltage at the opamp's inverting input 302 rises, reducing the base voltage of the transistor and hence reducing the current in the collector-emitter path of the transistor 320.

Figure 4A is a block diagram, comparable to figure 1D, illustrating a second embodiment of an LED module 500, where the input current Iin is divided over two LED strings 113, 114 on a temporal basis. The division circuit of this embodiment will be indicated by reference numeral 515. The module 500 comprises a controllable switch 501, having an input terminal receiving the input current Iin, and having two output terminals coupled to the LED strings 113, 114, respectively. The controllable switch 501 has two operative conditions, one where the first output terminal is connected to its input terminal and one where the second output terminal is connected to its input terminal. A control circuit 520 controls the controllable switch 501 to switch between these two operative conditions at a relatively high frequency. Thus, each LED string 113, 114 receives current pulses having a certain duration t1, t2, respectively, the current pulses having magnitude Iin. If the switching period is indicated as T, the ratio t1/T determines the average current in the first LED string 113 and the ratio t2/T determines the average current in the second LED string 114, with t1+t2=T. The control circuit 520 sets the duty cycle (or ratio t1/t2) on the basis of the input current Iin as sensed by current sensor 116: if the input current level Iin decreases, t1 is reduced and t2 is increased so that the average light output of the first LED string 113 (for instance white) is reduced and the average light output of the second LED string 114 (for instance amber) is increased.

Figure 4B is a block diagram illustrating a third embodiment of an LED module 600, where the amount of current in the second group of LEDs 114 (for instance amber) is controlled by a Buck current converter 601 connected in parallel to the first group of LEDs 113 (for instance white). The division circuit of this embodiment will be indicated by reference numeral 615. The first LED string 113 is connected in parallel to the input terminals 111, 112. A filter capacitor Cb is connected in parallel to the first LED string 113. The second LED string 114 is connected in series with an inductor L, with a diode D

connected in parallel to this series arrangement. A controllable switch S is connected in series to this parallel arrangement, controlled by the control circuit 115, wherein a control circuit 620 sets the duty cycle δ of the switch S on the basis of the input current Iin as sensed by current sensor 116. The resulting current in the second LED string 114 is indicated as Ia, and the resulting current in the first LED string 113 is indicated as Iw.

The Buck converter is operated in CCM (continuous conduction mode), such that the ripple in Ia is small compared to its average value. The input current Is'of the Buck converter is a switched current, having a peak value equal to Ia and a duty cycle δ. The switched current Is' is supplied from the filter capacitor Cb, and the input current Is to this filter capacitor Cb is in fact the average value of Is'. For the Buck converter operating in CCM and neglecting the current ripple, we can derive Is = δIa. It should be clear that the current in the first LED string 113 is reduced by the input current Is to the filter capacitor Cb, or

$$Iw = Iin - Is = Iin - \delta Ia.$$

So, if δ is changed to adapt the amber current Ia, the current Iw through the white LED' s also changes. The current source Iin has the same linear dependency on the dim setting as shown in fig 2A/B. The input current Iin is monitored by current sensor 116, generating a sense signal Vctrl, and the control circuit 620 changes the duty cycle δ of the Buck converter, and as such changes both the currents Iw and Ia.

In principle, the same white/amber current divisions as shown in fig. 2A/B can be realized with this embodiment. The advantage compared to the other embodiments is the higher efficiency. The Buck converter inherently has a higher efficiency than a linear current regulator, as the other embodiments of figures 3A-3B in fact are. Also, via a suitable current sense network (pre-biased current mirror), the sense resistor Rs can be kept very small.

It is noted that the Buck converter regulating the amber LED current Ia is preferably a hysteretic mode controlled Buck converter.

Figure 5 is a block diagram illustrating a fourth embodiment of an LED module 700, where each individual LED string 113, 114 is driven by a corresponding current converter 730, 740, respectively. The division circuit of this embodiment will be indicated by reference numeral 715. In this case, the two current converters 730, 740 are connected in series. In the embodiment shown, the converters are depicted as being of Buck type, but it is noted that different types are also possible, for instance boost, buck-boost, sepic, cuk, zeta. A control circuit 720 has two control output terminals, for individually controlling the switches S of the converters, on the basis of the input current Iin as sensed by the current sensor 116.

Each current converter 730, 740 generates an output current depending on the duty cycle of the switching of the corresponding switch S, as should be clear to a person skilled in the art. In this embodiment, it is possible for the control circuit 720 to implement the same current dependency as shown in figures 2A-2B, but it is also possible to control the individual currents for the individual LED strings 113, 114 independently from each other; so, in fact, it is possible for both LED strings 113, 114 to be driven at maximum light output or at minimum light output simultaneously.

It is also possible to obtain the desired behavior on the basis of intrinsic characteristics of the LEDs itself.

Figure 6 depicts a lighting device 1 comprising at least one LED 11 of a first type, such as an AlInGaP type LED, and producing light having a first color temperature. The at least one LED 11 is connected in series with at least one LED 12 of a second type different from the first type, such as an InGaN type LED, and producing light having a second color temperature which is higher than the color temperature of an AlInGaP type LED. The lighting device 1 has two terminals 14, 16 for supplying a current IS from a current source 18 to the series connection of LEDs 11, 12. The lighting device 1 has no active components. As indicated by a dashed line, the series connection LEDs of the lighting device 1 may comprise further LEDs 11 of the first type and/or LEDs 12 of the second type, such that the lighting device 1 comprises a plurality of LEDs 11 of the first type and/or a plurality of LEDs 12 of the second type. The lighting device 1 may further comprise one or more of any other type of LEDs of a third type different from the first type and the second type.

The one or more LEDs 11 of the first type are selected to have a first luminous flux output as a function of temperature having a gradient which is different from the gradient of a second luminous flux output as a function of temperature of the one or more LEDs 12 of the second type. In practice, the luminous flux output FO variation may be characterized by a so-called hot-coldfactor, indicating a percentage of luminous flux loss from 25 ^{0}C to 100 ^{0}C junction temperature of the LED. This is illustrated by reference to figures 7, 8 and 9.

Figure 7 illustrates graphs of a luminous flux output FO (vertical axis, lumen/mW) as a function of temperature T (horizontal axis, ^{0}C) of different LEDs 11 of a first type. A first graph 21 illustrates a luminous flux output FO decrease at a temperature increase for a red photometric LED. A second graph 22 illustrates a steeper luminous flux output FO decrease than the graph 21 at a temperature increase for a red-orange photometric

LED. A third graph 23 illustrates a still steeper luminous flux output FO decrease than the graphs 21 and 22 at a temperature increase for an amber photometric LED.

Figure 8 illustrates graphs of a luminous flux output FO (vertical axis, lumen/mW) as a function of temperature T (horizontal axis, ^{0}C) of different LEDs 12 of a second type. A first graph 31 illustrates a luminous flux output FO decrease at a temperature increase for a cyan photometric LED. A second graph 32 illustrates a slightly steeper luminous flux output FO decrease than the graph 31 at a temperature increase for a green photometric LED. A third graph 33 illustrates a still steeper luminous flux output FO decrease than the graphs 31 and 32 at a temperature increase for a royal-blue radiometric LED. A fourth graph 34 illustrates a yet steeper luminous flux output FO decrease than the graphs 31, 32 or 33 at a temperature increase for a white photometric LED. A fifth graph 35 illustrates a still slightly steeper luminous flux output FO decrease than the graphs 31, 32, 33 or 34 at a temperature increase for a blue photometric LED.

Figures 7 and 8 show that an LED 11 of a first type has a higher hot-coldfactor than an LED 12 of a second type, indicating that the gradient of the luminous flux output as a function of temperature of the LED 11 is higher than the gradient of the luminous flux output as a function of temperature of the LED 12.

Figure 9 illustrates a graph 41 of a luminous flux output ratio FR (vertical axis, dimensionless) of a string of LEDs 11 of the first type (red, orange, amber) having a relatively low color temperature, and a string of LEDs 12 of the second type (cyan, blue, white) having a relatively high color temperature, as a function of a dimming ratio DR (horizontal axis, dimensionless), where the temperature of all LED dies is 100 ^{0}C at 100% power (no dimming, i.e. dimming ratio = 1), and ambient temperature is 25 ^{0}C. The graph 41 illustrates a luminous flux output ratio FR decrease at a dimming ratio increase. Thus, according to Figure 9, a lighting device 1 having the luminous flux ratio of the first and second sets of LEDs as shown will show a color temperature decrease when the lighting device 1 is dimmed. A particular luminous flux output ratio at a particular dimming ratio may be designed without undue experimentation by selecting appropriate types of LEDs in appropriate amounts, and selecting an appropriate thermal resistance to ambient of each LED of set of LEDs to obtain desired temperatures for the LED at particular dimming ratios. For example, the one or more LEDs of the first type, such as AlInGaP LEDs, may be mounted with a higher thermal resistance to ambient than the one or more LEDs of the second type, such as InGaN LEDs. In an appropriate design, the LED lighting device 1 will show a color

temperature behavior like a color temperature behavior of an incandescent lamp, without additional controls.

Figure 10 depicts a lighting device 50 comprising at least one LED 51 of a first type, such as an AlInGaP type LED, connected in parallel with at least one LED 52 of a second type different from the first type, such as an InGaN type LED. The lighting device 50 has two terminals 54, 56 for supplying a current IS from a current source 58 to the parallel connection of LEDs 51, 52. In series with the at least one LED 52, a resistor 59 is provided. The resistor 59 may also be connected in series with the at least one LED 51 instead of in series with the at least one LED 52. Alternatively, a resistor may be connected in series with the at least one LED 51 and another resistor may be connected in series with the at least one LED 52. The lighting device 50 has no active components. As indicated by dashed lines, the at least one LED 51 and the at least one LED 52 of the lighting device 50 may comprise further LEDs 51 and/or 52 such that the lighting device 50 comprises a plurality of LEDs 51 of the first type and/or a plurality of LEDs 52 of the second type. The lighting device 50 may further comprise one or more of any other type of LEDs of a third type different from the first type and the second type.

The resistor 59 is a negative temperature coefficient, NTC, type resistor, which will compensate relatively slow temperature variations by the variation of its resistance value.

The one or more LEDs 51 of the first type are selected to have a first dynamic resistance (measured as a ratio of a forward voltage across the LED(s) and a current through the LED(s)) which is different from a second dynamic resistance of the one or more LEDs 52 of the second type connected in series with the resistor 59. As a result, a ratio of the current through the one or more LEDs 51 of the first type and the current through the one or more LEDs 52 will be variable. This is illustrated by reference to Figure 11.

Figure 11 illustrates graphs of currents ILED1, ILED2 (left vertical axis, A) as a function of forward voltage FV (horizontal axis, V) for LED(s) of a first and second type. Referring also to Figure 10, a first graph 61 illustrates a current ILED1 in InGaN LED(s) 51 as a function of forward voltage across the LED(s) 51. A second graph 62 illustrates a current ILED2 in AlInGaP LED(s) 52 and resistor 59 as a function of forward voltage across the LED(s) 52 and resistor 59. In the illustrated example, the resistor 59 has a value of 8 ohm.

Figure 11 further shows a graph 63 of the current ratio ILED1/ILED2 (right vertical axis, dimensionless) as a function of forward voltage FV. As can be seen in graph 63, for forward voltages FV higher than ca. 2.9 V, a higher current ILED1 flows through the

LED(s) 51 than the current ILED2 through the LED(s) 52 and resistor 59, whereas below a forward voltage FV of about 2.9 V, the current ILED1 is lower than ILED2. Accordingly, when the current provided by the current source 58 is lowered in a dimming operation, the luminous flux output from the LED(s) 51, will decrease at a higher rate than the decrease of the luminous flux output from the LED(s) 52, such that the color temperature of the lighting device 50 will tend more towards the color temperature of the LED(s) 52 than at a higher current provided by the current source 58, where the color temperature of the lighting device 50 will tend towards the color temperature of the LED(s) 51. In an appropriate design, the LED lighting device 50 will thus show a color temperature behavior like a color temperature behavior of an incandescent lamp, without additional controls.

The current sources 18, 58 are configured to provide a DC current which may have a low current ripple. For dimming purposes, the current sources 18, 58 may be pulse width modulated. In case of the current source 18 feeding the lighting device 10, the junction temperatures of the LEDs will decrease when dimming. In case of current source 58, the average current during the time that a current flows in the lighting device 50, should be decreased during dimming. Thus, each current source 18, 58 is to be considered as a dimmer having output terminals which are adapted to provide a variable electrical power, in particular a variable current, and the terminals 14, 16 and 54, 56, respectively, are configured to be connected to the output terminals of the dimmer.

In the above it has been explained that in a lighting device sets of LEDs are employed using the natural characteristics of the LEDs to resemble incandescent lamp behavior when dimmed, thereby obviating the need for sophisticated controls. A first set of at least one LED produces light with a first color temperature, and a second set of at least one LED produces light with a second color temperature. The first set and the second set are connected in series, or the first set and the second set are connected in parallel, possibly with a resistive element in series with the first or the second set. The first set and the second set differ in temperature behavior, or have different dynamic electrical resistance. The light device produces light with a color point parallel and close to a blackbody curve.

As required, detailed embodiments of the present invention are disclosed herein; however, it is to be understood that the disclosed embodiments are merely exemplary of the invention, which can be embodied in various forms. Therefore, specific structural and functional details disclosed herein are not to be interpreted as limiting, but merely as a basis for the claims and as a representative basis for teaching one skilled in the art to variously employ the present invention in virtually any appropriately detailed structure. Further, the

terms and phrases used herein are not intended to be limiting, but rather, to provide an understandable description of the invention.

The terms "a" or "an", as used herein, are defined as one or more than one. The term plurality, as used herein, is defined as two or more than two. The term another, as used herein, is defined as at least a second or more. The terms including and/or having, as used herein, are defined as comprising (i.e., open language, not excluding other elements or steps). Any reference signs in the claims should not be construed as limiting the scope of the claims or the invention.

The mere fact that certain measures are recited in mutually different dependent claims does not indicate that a combination of these measures cannot be used to advantage.

The term coupled, as used herein, is defined as connected, although not necessarily directly, and not necessarily mechanically.

Summarizing, in a lighting device, the present invention provides that sets of LEDs are employed using the natural characteristics of the LEDs to resemble incandescent lamp behavior when dimmed, thereby obviating the need for sophisticated controls. A first set of at least one LED produces light with a first color temperature, and a second set of at least one LED produces light with a second color temperature. The first set and the second set are connected in series, or the first set and the second set are connected in parallel, possibly with a resistive element in series with the first or the second set. The first set and the second set differ in temperature behavior, or have different dynamic electrical resistance. The light device produces light with a color point parallel and close to a blackbody curve.

The present invention also relates to a lighting kit of parts, comprising:

a dimmer having input terminals adapted to be connected to an electrical power supply, and having output terminals adapted to provide a variable electrical power; and

a lighting device according to any of the attached claims, wherein the terminals of the lighting device are configured to be connected to the output terminals of the dimmer.

While the invention has been illustrated and described in detail in the drawings and foregoing description, it should be clear to a person skilled in the art that such illustration and description are to be considered illustrative or exemplary and not restrictive. The invention is not limited to the disclosed embodiments; rather, several variations and modifications are possible within the protective scope of the invention as defined in the appending claims.

For instance, different colors can be used. For instance, instead of amber, it would be possible to use yellow or red. Further, it is noted that in the example the contribution of the white LEDs reduces to zero with reducing input current, but this is not necessary.

Further, while in the above the driver 101 has been described as being capable of receiving dimmed mains from a dimmer 9, it is also possible that the driver 101 is designed for being dimmed by remote control while receiving normal mains voltage. The important aspect is that the driver 101 is acting as a current source and is capable of generating dimmed output current, which is received by the LED module as input current. Thus, the light output level is determined by the driver 101 by generating a certain output current to the LED module, and the color of the light output is determined by the LED module in dependency of the current received from the driver 101.

Other variations to the disclosed embodiments can be understood and effected by those skilled in the art in practicing the claimed invention, from a study of the drawings, the disclosure, and the appended claims. In the claims, the word "comprising" does not exclude other elements or steps, and the indefinite article "a" or "an" does not exclude a plurality. A single processor or other unit may fulfill the functions of several items recited in the claims. The mere fact that certain measures are recited in mutually different dependent claims does not indicate that a combination of these measures cannot be used to advantage. Any reference signs in the claims should not be construed as limiting the scope.

In the above, the present invention has been explained with reference to block diagrams, which illustrate functional blocks of the device according to the present invention. It is to be understood that one or more of these functional blocks may be implemented in hardware, where the function of such functional block is performed by individual hardware components, but it is also possible that one or more of these functional blocks are implemented in software, so that the function of such functional block is performed by one or more program lines of a computer program or a programmable device such as a microprocessor, microcontroller, digital signal processor, etc.

CLAIMS:

1. Lighting device (100), comprising:

an LED driver (101) capable of generating dimmed LED current;

a two-terminal LED module (110; 300; 400; 500; 600), having two input terminals (111, 112) for receiving an input current (Iin) from the LED driver (101) and comprising:

a first LED group (113) comprising at least one first type LED for producing light having a first color temperature;

a second LED group (114) comprising at least one second type LED for producing light having a second color temperature different from the first color temperature;

wherein the module is capable of supplying LED currents to the LED groups, these LED currents being derived from the input current (Iin);

wherein the LED module produces a light output having at least a light output contributions from the first LED group (113) and from the second LED group (114);

and wherein the module is designed to vary the individual LED currents in the individual LED groups in dependency of the average magnitude of the received input current (Iin), such that the color point of the light output of the module varies as a function of the input current magnitude.

2. Lighting device according to claim 1, wherein the LED module is designed to vary the individual LED currents in the individual LED groups such that the color point of the light output of the module on dimming follows a black body curve.

3. Lighting device according to claim 1, wherein the LED module is designed to vary the individual LED currents in the individual LED groups such that the color behavior of the light output of the module on dimming resembles the color behavior of an incandescent lamp.

4. Lighting device according to claim 1, wherein the lighting device is configured to produce light with a color temperature CT at an average current of x%, CT(x%), supplied to the terminals following the relationship:

$$CT(x\%) = CT(100\%) * (x/100)^{\frac{1}{9.5}}$$

5. Lighting device according to claim 1, wherein the first group of LEDs has a varying first luminous flux output as a function of junction temperature of the first type LED, and the second group of LEDs has a varying second luminous flux output as a function of junction temperature of the second type LED, and wherein, at varying junction temperatures, the ratio of the first luminous flux output to the second luminous flux output varies;

and wherein preferably the first color temperature is lower than the second color temperature, while, at decreasing junction temperatures, the ratio of the first luminous flux output to the second luminous flux output increases, and vice versa.

6. Lighting device according to claim 1, wherein a gradient of the first luminous flux output as a function of junction temperature of the first type LED differs from a gradient of the second luminous flux output as a function of junction temperature of the second type LED;

and wherein preferably the first color temperature is lower than the second color temperature, while the absolute value of the gradient of the first luminous flux output as a function of temperature of the first type LED is higher than the gradient of the second luminous flux output as a function of temperature of the second type LED.

7. Lighting device according to claim 1, wherein a thermal resistance to ambient of the first group of LEDs differs from the thermal resistance to ambient of the second group ofLEDs;

and wherein preferably the first color temperature is lower than the second color temperature, while the thermal resistance to ambient of the first group ofLEDs is higher than the thermal resistance to ambient of the second group ofLEDs.

8. Lighting device according to claim 1, wherein the first group ofLEDs has a first dynamic electrical resistance, and the second group ofLEDs has a second dynamic electrical resistance.

9. Lighting device according to claim 1, wherein one of the first group ofLEDs and the second group ofLEDs is connected in series with a resistor, and wherein this series

arrangement is connected in parallel to the other one of the first group of LEDs and the second group of LEDs, and wherein this parallel arrangement is connected between the two input terminals (111, 112) of the LED module;

and wherein preferably the resistor is a negative temperature coefficient, NTC, type resistor.

10. Lighting device according to any of the preceding claims, wherein the first type LED is an AlInGaP type LED, and/or wherein the second type LED is an InGaN type LED.

11. Lighting device according to claim 1, wherein the LED module comprises an electronic division circuit (115) capable of controlling the LED currents (II, 12) in said two groups (113, 114) of LEDs as a function of the input current level received at the input of the LED module.

12. Lighting device according to claim 11, wherein the electronic division circuit is capable of supplying the two groups of LEDs with constant current and of controlling the LED currents (II, 12) such that the following formulas apply:

$I1 = p \cdot Iin$ and $I2 = q \cdot Iin$, and $p + q = 1$

with Iin denoting the input current magnitude,

I1 denoting the current magnitude in the first group of LEDs,

I2 denoting the current magnitude in the second group of LEDs;

wherein there is at least a range of input current magnitudes where dp/d(Iin) is always positive and dq/d(Iin) is always negative.

13. Lighting device according to claim 12, wherein the LED module comprises:

a current regulating element (320) arranged in series with one of said groups of LEDs, this series arrangement being coupled in parallel to another of said groups of LEDs;

a current sensing element (350) arranged for sensing the input current received at the input terminals of the LED module;

and a regulator driver (310) receiving a sense output signal from the sensing element and driving the current regulating element on the basis of this sense output signal.

14. Lighting device according to claim 11, wherein the electronic division circuit (515) comprises a controllable switch (501) for temporally dividing de received input current (Iin) between the two groups of LEDs;

a control device (520) for controlling the switch (501) at a switching period T such that the input current is passed on to the first group of LEDs for a first time duration t1 and the input current is passed on to the second group of LEDs for a second time duration t2, with t1+t2=T;

a current sensing element (116) arranged for sensing the input current received at the input terminals of the LED module;

the control device being coupled to receive a sense output signal from the sensing element and being designed to vary the ratio t1/t2 of the switching of the switch on the basis of said sense output signal, such that there is at least a range of input current magnitudes where dt1(Iin) is always positive and dt2(Iin) is always negative.

15. Lighting device according to claim 11, wherein the second group of LEDs (114) is supplied by a current converter (601) having its input terminals connected in parallel to the first group of LEDs (113);

wherein the current converter comprises a control circuit (620) receiving a sense output signal from a current sensing element (116) sensing the input current of the LED module;

and wherein this control circuit (620) is designed to control the current converter (601) on the basis of the sense output signal received from the current sensing element (116).

16. Lighting device according to claim 11, wherein the first group of LEDs (113) is supplied by a first current converter (730) and the second group of LEDs (114) is supplied by a second current converter (740), and wherein these two current converter have their input terminals connected in series;

wherein the LED module comprises a control circuit (720) receiving a sense output signal from a current sensing element (116) sensing the input current of the LED module;

and wherein this control circuit (720) is designed to control the current converters (730, 740) on the basis of the sense output signal received from the current sensing element (116).

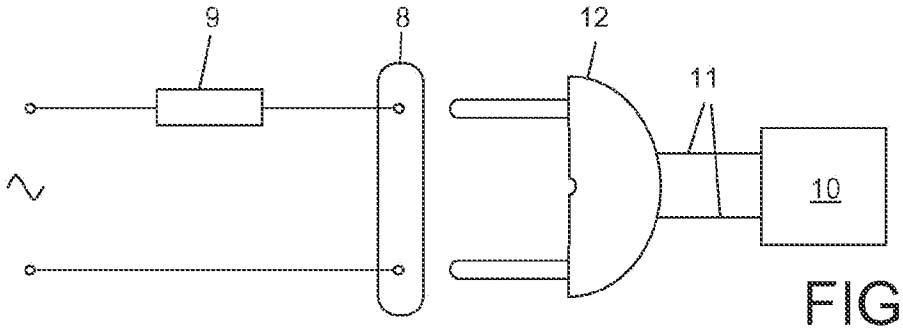


FIG. 1A

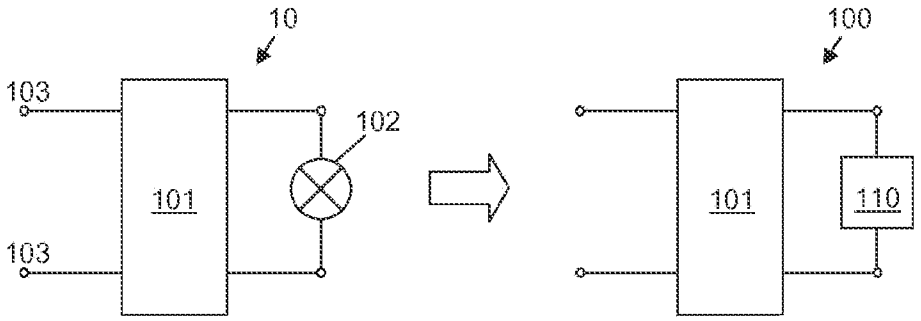


FIG. 1B

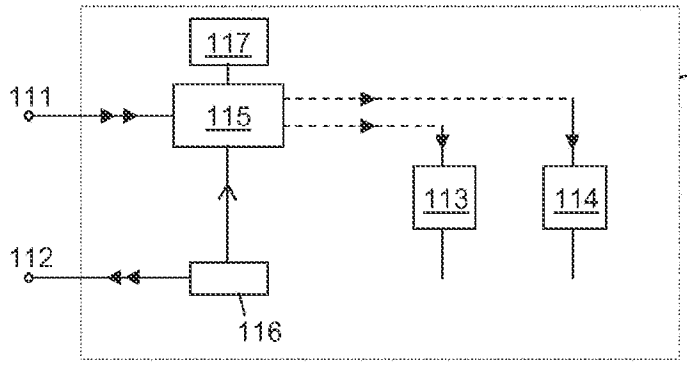


FIG. 1C

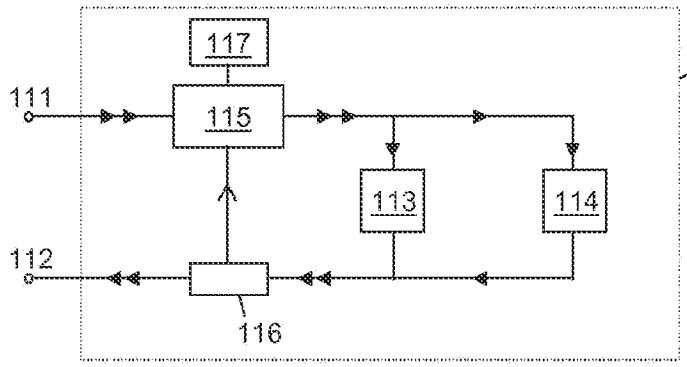


FIG. 1D

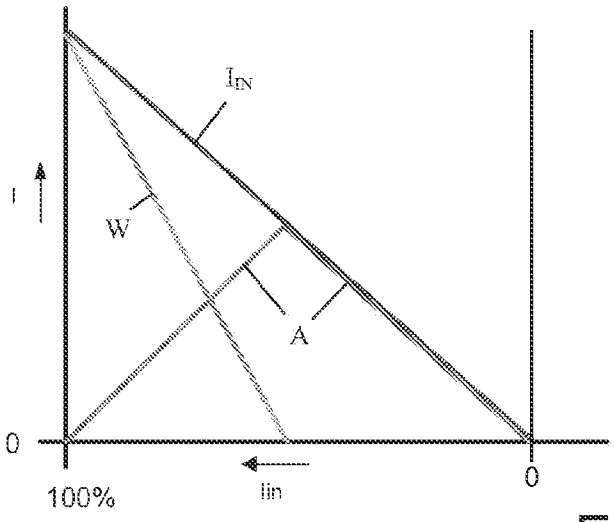


FIG. 2A

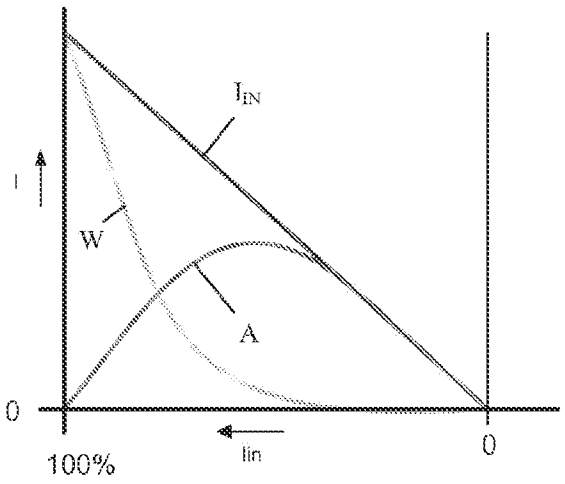


FIG. 2B

Home Depot
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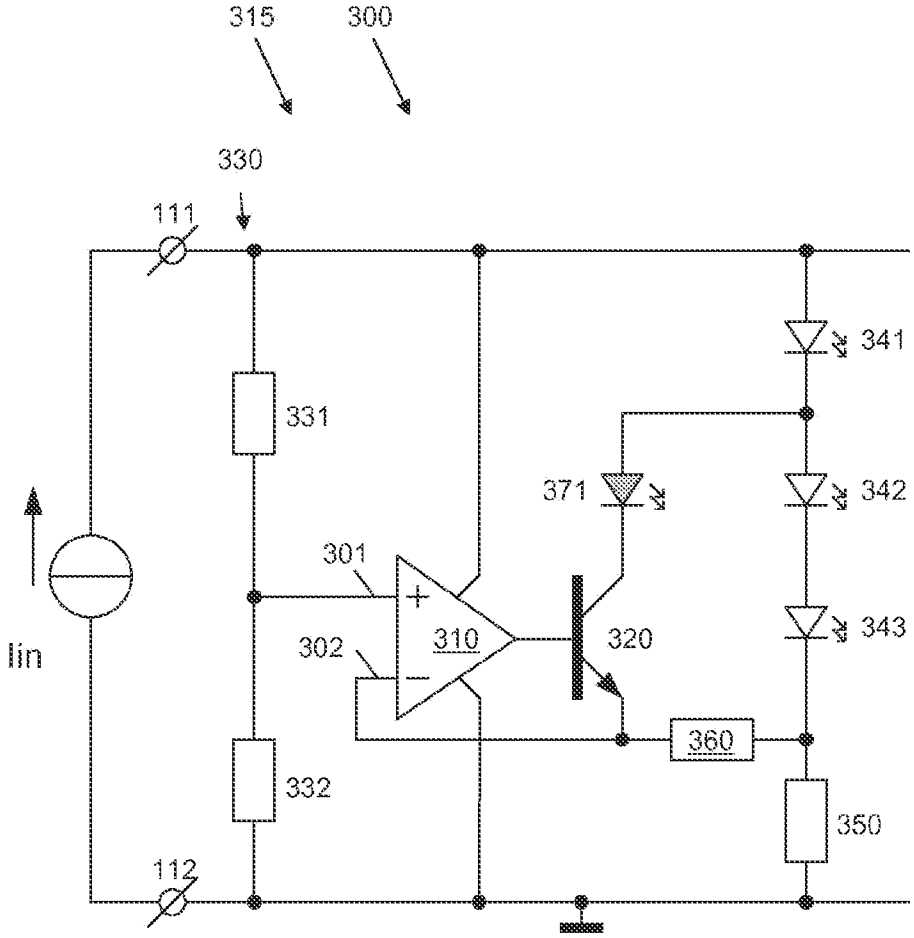

315
300
330
111
331
341
371
342
301
310
320
343
302
360
332
350
112
Iin

FIG. 3A

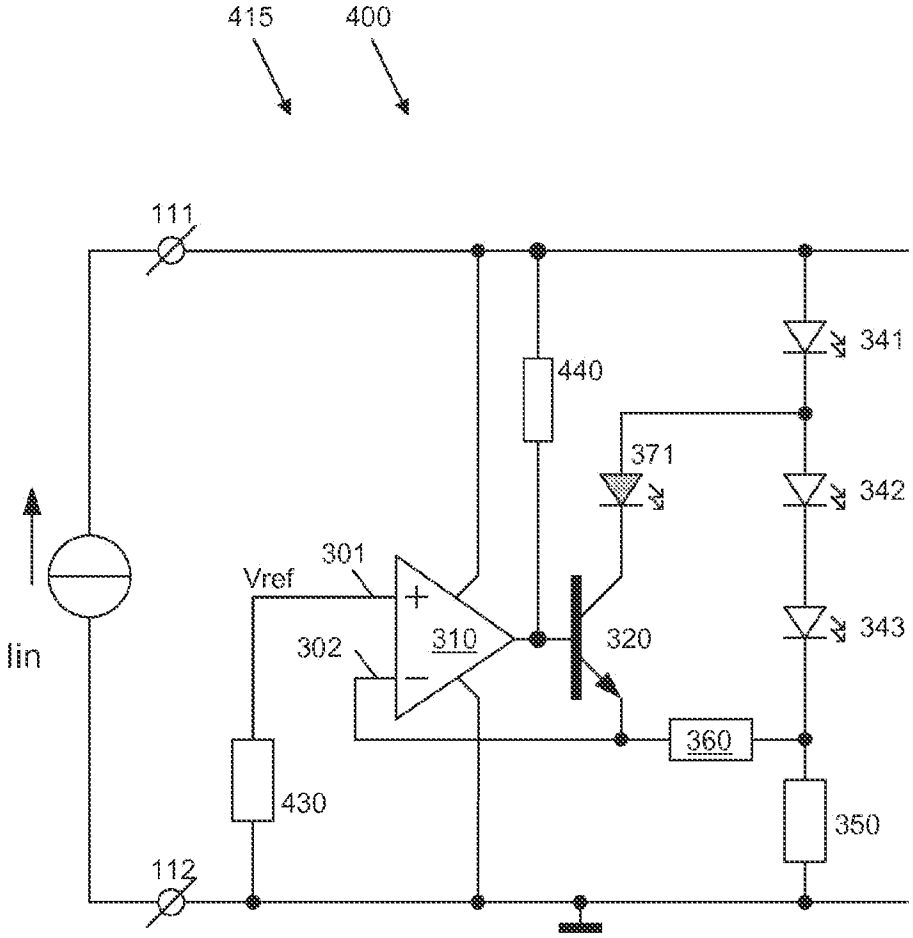

415
400
111
341
440
371
342
301
Vref
343
310
320
302
360
430
350
112
Iin

FIG. 3B

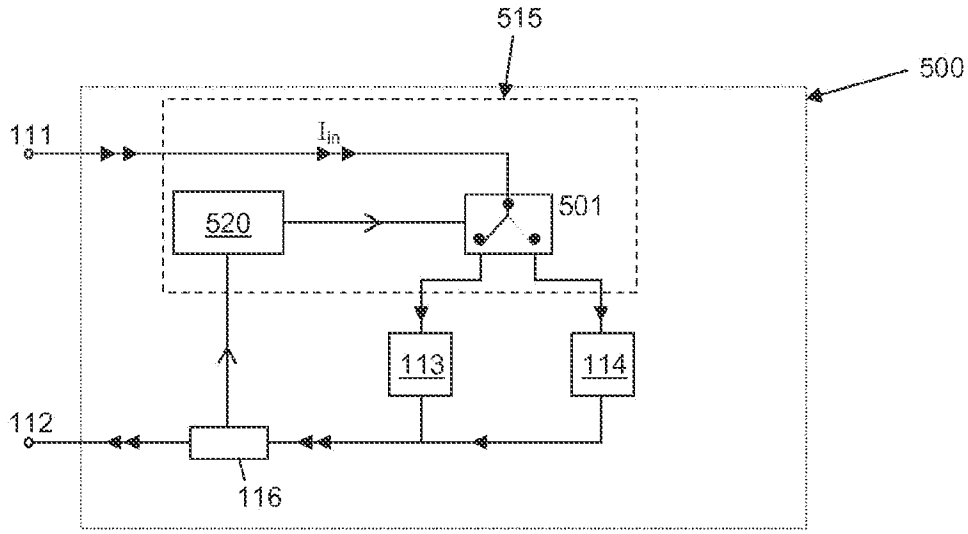

515
500
111
I_{in}
520
501
113
114
112
116

FIG. 4A

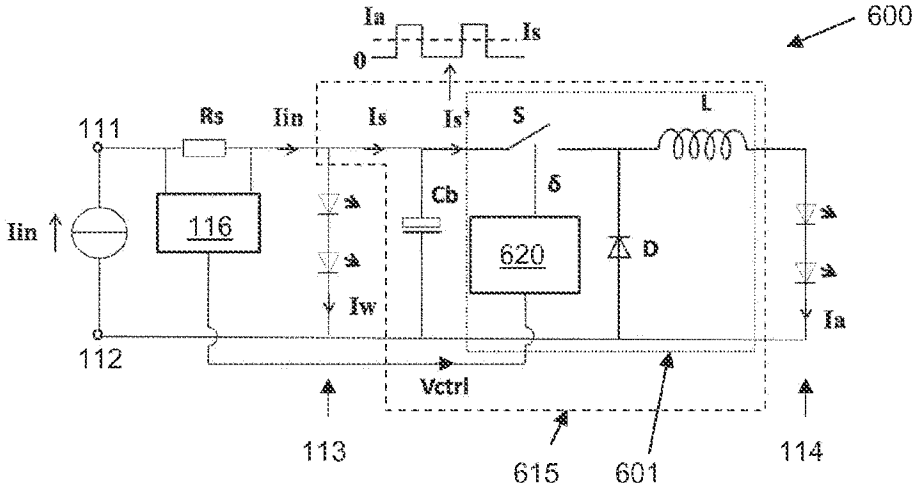

600
Ia
Is
0
111
Rs
Iin
Is
Is'
S
L
δ
Cb
116
620
D
Iw
Ia
112
Vctrl
113
615
601
114

FIG. 4B

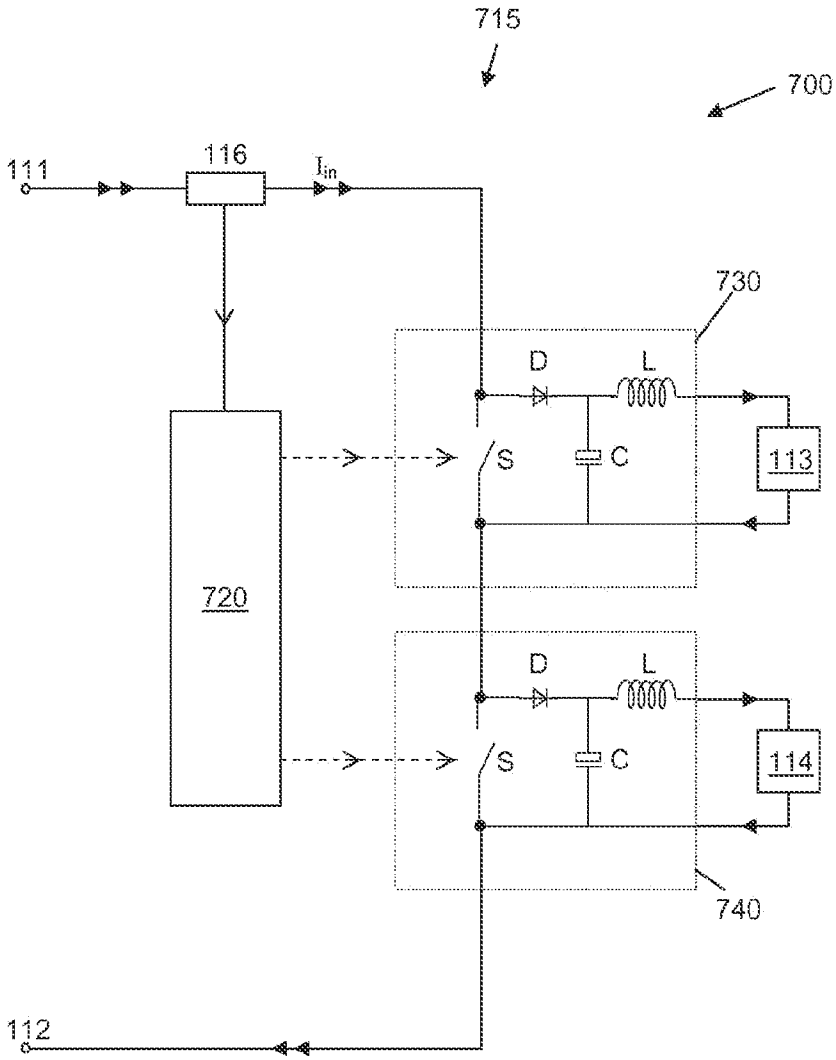


FIG. 5

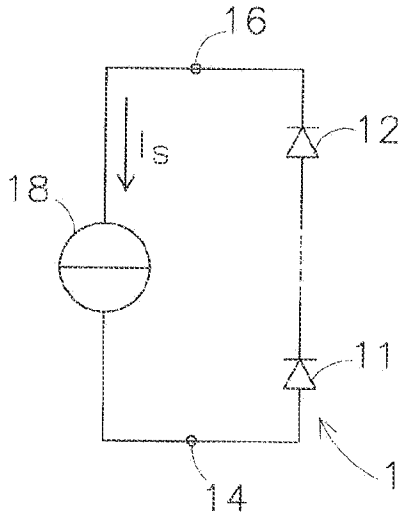

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FIG. 6

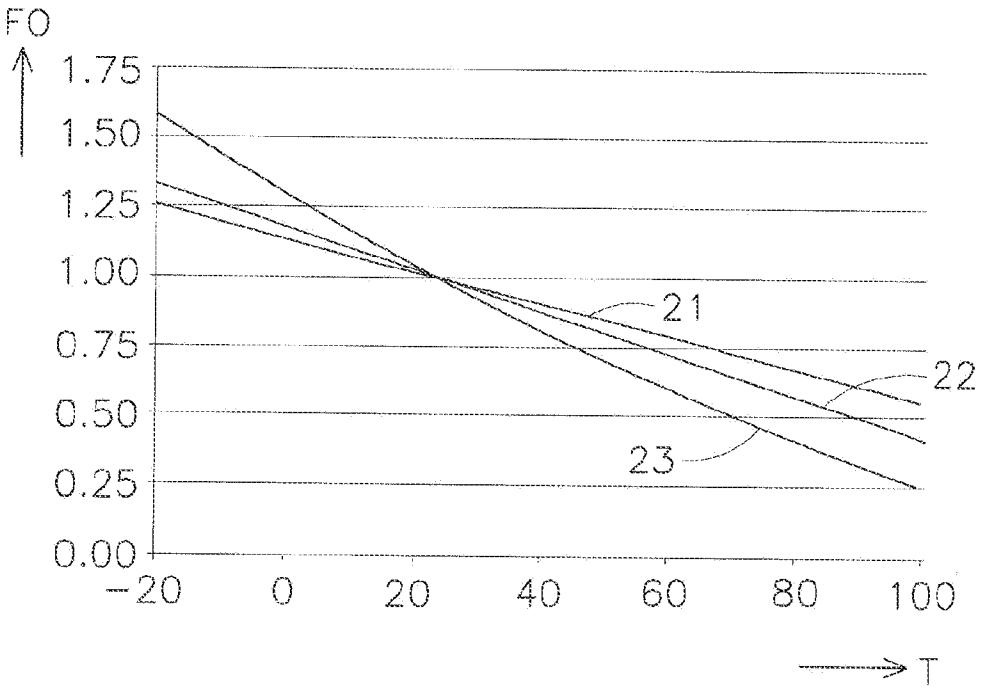

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1.00
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0.00
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60
80
100
T
21
22
23

FIG. 7

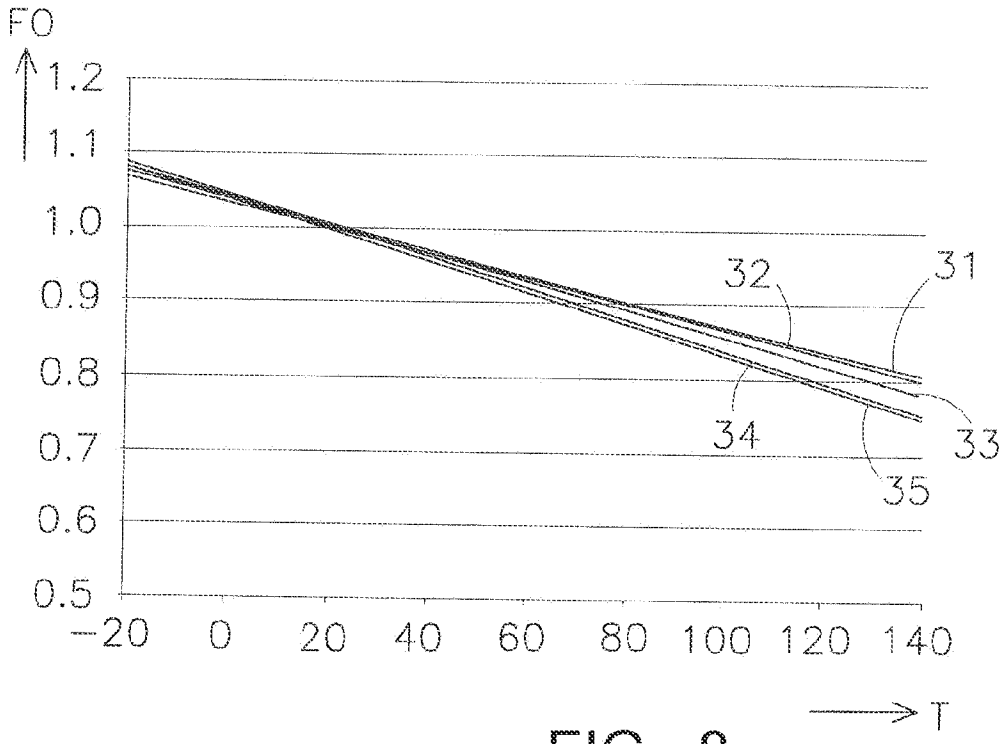

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0.9
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0.7
0.6
0.5
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60
80
100
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140
T
31
32
33
34
35

FIG. 8

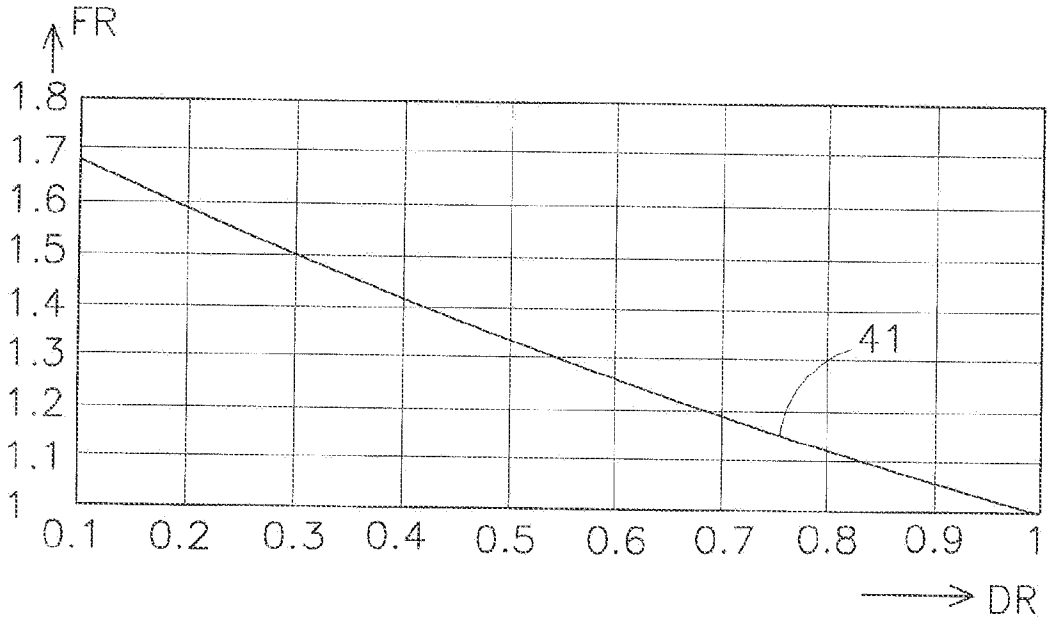

FR
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1.6
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1.4
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DR
41

FIG. 9

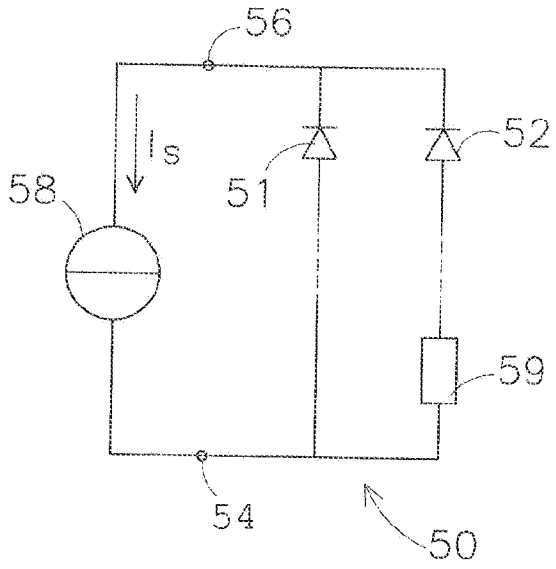

56
Is
58
51
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59
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50

FIG. 10

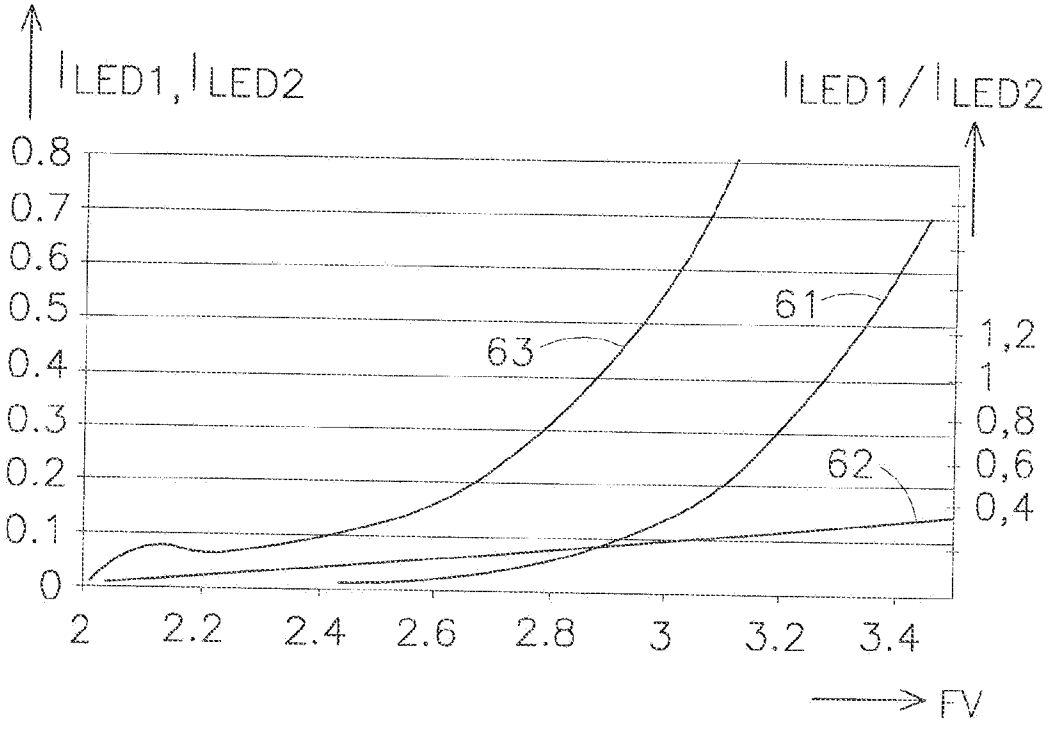

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ILED1/ILED2
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0.7
0.6
0.5
0.4
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0.2
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1
0,8
0,6
0,4
61
63
62
2
2.2
2.4
2.6
2.8
3
3.2
3.4
FV

FIG. 11

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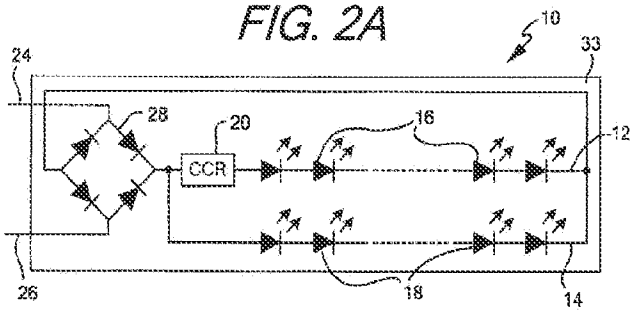
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(54) Title: COLOR TEMPERATURE CONTROLLED AND LOW THD LED LIGHTING DEVICES AND SYSTEMS AND METHODS OF DRIVING THE SAME

FIG. 2A



(57) Abstract: The purposes of the devices described herein are to provide an LED lighting device capable of efficiently and economically emitting light having a selectable color temperature or a warm-on-dim feature when driven with AC power and to provide LED lighting devices which have an improved power factor and a reduced total harmonic distortion when powered with AC power.

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COLOR TEMPERATURE CONTROLLED AND LOW THD LED LIGHTING DEVICES AND SYSTEMS AND METHODS OF DRIVING THE SAME

RELATED APPLICATIONS

[Para 1] The application claims priority to U.S. Provisional Application No. 61/630,025 entitled "Drive Method for Low THD and Color Temperature Changing LED Lighting Device Method and Apparatus" filed December 2, 2011; U.S. Provisional Application No. 61/570,200 entitled "Drive Method for Low THD and Color Temperature Changing LED Lighting Device Method and Apparatus" filed December 13, 2011; and, PCT Application No. PCT/US2012/051531 entitled "Devices and Systems Having LED Circuits and Methods of Driving the Same" filed August 20, 2012 - the contents of all of which are expressly incorporated herein by reference.

TECHNICAL FIELD

[Para 2] The present invention generally relates to light emitting diode ("LED") circuits for use with AC voltage sources. More specifically, the present invention relates to LED devices capable of having color temperature control, low total harmonic distortion, and methods of driving the same.

FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

[Para 3] None.

BACKGROUND OF THE INVENTION

[Para 4] LEDs are semiconductor devices that produce light when a current is supplied to them. LEDs are intrinsically DC devices that only pass current in one polarity, and historically have been driven by constant current or constant voltage DC power supplies. When driven by these DC power supplies, LEDs are typically provided in a series string, in parallel strings or in series parallel configurations based on the drive method and LED lighting system design.

[Para 5] Recent advancements in the field of lighting have led to the use of LED circuits which are capable of using AC power to drive LEDs configured in particular devices and/or circuit arrangements such that some of the LEDs may operate during the positive

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phase of the AC power cycle, some LEDs may operate during the negative phase of the AC power cycle, and, in some cases, some or all LEDs may operate during both the positive and negative phases of the AC power cycle. LEDs powered with AC power typically last substantially longer than traditional halogen and incandescent devices or lamps, and typically require much less power to produce a substantially similar amount of light. However, LEDs powered by AC power sources act as a non-linear load. As a result of the non-linearity, LEDs powered using AC power sources may have a lower power factor, and may have a greater total harmonic distortion, than existing halogen or incandescent lighting devices. Having a low power factor and increased distortion may result in higher energy costs, transmission losses, and/or damage to electrical equipment. While the amount of power needed to drive an LED lighting device may be less than to drive a halogen or incandescent lighting device producing a substantially similar amount of light, the overall cost of operating an LED lighting device using AC power may be equal to or more than the amount required to drive the halogen or incandescent lighting device using the same AC power source.

[Para 6] Another advantage that traditional halogen and incandescent lighting devices have over present LED lighting devices driven with AC power is that halogen and incandescent lighting devises have the ability to change color temperature when the voltage provided to them is changed. Light in halogen and incandescent lighting devices are typically generated by a hot wire filament. As the power provided to the bulb is decreased, the temperature of the filament typically decreases, causing the color temperature of the emitted light to move down the color spectrum and make the light appear warmer, *i.e.* closer to yellow or amber or red than white or blue. In order to achieve this effect in LED lighting devices driven with AC power, complicated and expensive drive schemes are currently required which drive up the cost of the lighting device and the cost to operate the same. One example would be color mixing with red, green and blue LEDs referred to as "RGB" which typically uses pulse width modulation to create any color of light desired. However, the power supplies for this are very complex and larger in size. Other complex versions of constant current or constant voltage DC with only two different LED colors can also be used, however these power supplies can also be large and complex. These drive schemes may also be inefficient and waste additional power or electricity, further increasing operating costs.

[Para 7] Therefore, it would be advantageous to design a circuit, device, or system utilizing LEDs that maximizes power factor while reducing the total harmonic distortion resulting from driving the circuit, device or system using AC power.

[Para 8] It would also be advantageous to design a circuit, device, or system where the

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color temperature of the LEDs driven with AC power may be dynamically adjusted using simple control methods without having to utilize any complicated or expensive drive mechanisms.

[Para 9] The present invention is provided to solve these and other issues.

SUMMARY OF THE INVENTION

[Para 10] Accordingly, the present invention is provided to increase the performance of LED lighting devices driven by AC power. The LED lighting devices of the present invention seek to provide one or more of a color temperature controllable AC LED lighting device and/or an AC LED lighting device having an increased power factor and reduced total harmonic distortion.

[Para 11] According to one aspect of the invention, an LED lighting device having at least two LED circuits connected in parallel, each of the at least two LED circuits having one or more LEDs is provided. Each of the at least two LED circuits that are connected in parallel have a different forward operating voltage than the other LED circuit(s) within the device, and, each of the at least two LED circuits are capable of emitting light having one or more of a different color or wavelength than the other LED circuit(s) within the device. The device further includes at least one active current limiting device connected in series with at least one LED in at least one of the at least two LED circuits. The device and/or circuits are configured such that each LED circuit is capable of emitting light during both a positive and a negative phase of a provided AC voltage when the LED lighting device is connected to an AC voltage source.

[Para 12] According to another aspect of the invention, the at least one current limiting device may be, for example, a current limiting diode or a constant current regulator.

[Para 13] According to another aspect of the invention, each of the LED circuits and the at least one active current limiting device are integrated onto a single substrate to form the device.

[Para 14] According to another aspect of the invention, the device may include additional active current limiting devices, which may also be integrated on the single substrate. Each LED circuit in the device may be connected in series to at least one active current limiting device. Where each LED circuit is connected in series to at least one active current limiting device, each circuit may be connected to its own current limiting device which may each allow a similar or different amount of current to flow through each circuit, or

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multiple circuits may be connected to at least one common current limiting device which acts to limit the current for each of the circuits.

[Para 15] According to another aspect of the invention, the LED lighting device may include a bridge rectifier having at least one of the at least two LED circuits connected across the output of the bridge rectifier.

[Para 16] According to another aspect of the invention, at least one of the at least two circuits may include two or more LEDs connected in an anti-parallel configuration.

[Para 17] According to another aspect of the invention, at least one of the at least two circuits may include at least five diodes, at least four of the diodes being LEDs. The at least four LEDs may be connected in a bridge rectifier configuration and the at least fifth diode may be connected across the output of the bridge rectifier. The at least fifth diode connected across the output of the bridge rectifier may be a standard diode, an LED or a constant current diode, or may alternatively a constant current regulator.

[Para 18] According to another aspect of the invention, at least one of the at least two circuits may include seven or more diodes, at least six of the diodes being LEDs. The at least six LEDs being connected in an imbalanced bridge rectifier configuration, with the at least seventh diode being connected across the output of the imbalanced bridge rectifier. The at least seventh diode connected across the output of the bridge rectifier may be a standard diode, an LED or a constant current diode, or may alternatively a constant current regulator.

[Para 19] According to another aspect of the invention, the light emitted by the one or more LEDs forming at least one of the at least two LED circuits may be one or more of a different color or wavelength than the light emitted by the one or more LEDs of the other connected LED circuit(s) in the device. Using different colored of LEDs in each circuit will allow each circuit to emit different colors of light to contribute to the overall color temperature of light emitted by the device.

[Para 20] According to another aspect of the invention, each of the at least two circuits may be coated in phosphor, each of the at least two circuits having a different phosphor coating than the other connected at least two LED circuits. The different phosphor coating on each of the at least two circuits may cause each circuit to emit one or more of a different color or wavelength of light than the other connected LED circuits.

[Para 21] According to another aspect of the invention, the LED lighting device may be integrated into a lighting system, the lighting system having a dimmer switch capable of providing AC voltage to the LED lighting device, *i.e.* the dimmer switch be a connected AC power source or supply. The dimmer switch may be used to control the AC voltage provided

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to the at least two LED circuits to control the light output of each circuit to control a color temperature of light emitted by the LED lighting device.

(Para 22] According to one aspect of the invention, a method of controlling color temperature of light emitted by an LED lighting device is provided. In order to control the color temperature of the light emitted by the device, at least two LED circuits are connected in parallel. Each connected LED circuit has a different forward operating voltage and is capable of emitting light of one or more of a different color or wavelength than the other LED circuits connected in parallel. The current provided to at least one of the at least two LED circuits is limited, and at least one of the provided voltage and current to control the light output of the LED circuits connected in parallel is adjusted. The voltage and current provided to each circuit may be a direct AC voltage and current or a rectified AC voltage or current, with the possibility that some circuits in the device are provided a direct AC voltage and current and some of the circuits in the device are provided with a rectified AC voltage and current.

[Para 23] According to one aspect of the invention, an LED lighting device is provided. The LED lighting device may include at least one LED circuit having two or more LEDs connected in series, and at least one active current limiting device, the active current limiting device being connected in parallel with the at least one LED in the at least one LED circuit.

[Para 24] According to another aspect of the invention, the LED lighting device may include at least a second active current limiting device, the second active current limiting device being connected in series with the at least one LED circuit.

[Para 25] According to another aspect of the invention, the LED lighting device may further include a bridge rectifier, wherein the at least one LED circuit is connected across the output of the bridge rectifier. The bridge rectifier may be constructed using either standard diodes, LEDs or some combination thereof.

[Para 26] According to another aspect of the invention, the LED lighting device may include at least one additional LED circuit having two or more LEDs connected in series and at least one active current limiting device connected in parallel with at least one of the two or more LEDs, the at least one additional LED circuit being connected to the at least one LED circuit in parallel. The at least one additional LED circuit may be capable of emitting light having one or more of a different color or wavelength than the at least one LED circuit in the device.

[Para 27] According to another aspect of the invention, the at least one LED circuit may include at least three LEDs connected in series.

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[Para 28] According to another aspect of the invention, the LED lighting device may include a resistor connected in series with the at least one LED circuit.

[Para 29] According to another aspect of the invention, each active current limiting device may be a constant current regulator or a current limiting diode.

[Para 30] According to one aspect of the invention, an LED lighting device is provided. The LED lighting device includes at least one LED circuit having at least two LEDs connected in series and two sets of connection leads. The first set of connection leads in the device are configured to provide a connection to the at least two - as well as any additional - LEDs in the at least one LED circuit in order to provide a connection to all of the LEDs. The first set of connection leads having a first connection lead and a second connection lead, where the first connection lead is connected to an input of the at least one LED circuit and the second connection lead is connected to an output of the at least one LED circuit. The second set of connection leads in the device include a third connection lead and a fourth connection lead where the third connection lead is connected to the anode of at least one of the at least two LEDs and the fourth connection lead being connected to the cathode of at least one of the at least two LEDs. The second set of connection leads are configured to provide a connection to less than all of the LEDs in the at least one circuit, *i.e.* only one of two LEDs or only two of four LEDs, etc.

[Para 31] According to another aspect of the invention, at least two LEDs may be configured into at least two sets of LEDs connected in series. Each set of LEDs includes at least one LED, and may have multiple LEDs. The first connection leads may be configured to provide a connection to both of the at least a first and a second set of LEDs, while the second connection leads are configured to provide a connection to only one of the first or second set of LEDs.

[Para 32] According to another aspect of the invention, the at least one circuit may include at least three LEDs, the at least three LEDs being connected in series between the first and second connection lead. Each the at least three LEDs may be configured into at least three sets of LEDs, each set having at least one, and sometimes multiple, LED(s). When the at least one circuit includes at least three LEDs, the third connection lead may connected the anode of the first LED in one of the first, second or third sets of LEDs, *i.e.* the anode of the first LED in a particular set. The fourth connection lead may be connected to the cathode of the last LED in the same set of LEDs, *i.e.* if the third connection lead is connected to the anode of the first LED in the first set, the fourth connection lead may be connected to the cathode of the last LED in the first set.

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[Para 33] According to another aspect of the invention, the lighting device may be integrated into a lighting system. The lighting system may include a driver having a bridge rectifier, at least two active current limiting devices, and at least three sets of driver connection leads. The first active current limiting device may be connected to the output of the bridge rectifier while the second active current limiting device may be electrically unconnected to the bridge rectifier and the first constant current diode. The first set of driver connection leads may provide a connection for the bridge rectifier to connect to an AC voltage source. The second set of driver connection leads may include a third driver connection lead providing an output from the first active current limiting device connected in series with the output of the bridge rectifier and a fourth driver connection lead providing a return from a load to the bridge rectifier. The third set of driver connections leads may include a fifth driver connection lead providing an input to the second active current limiting device, and a sixth driver connection lead providing an output from the second active current limiting device. When integrating the lighting device, the third driver connection lead may connect to the first connection lead of the lighting device and the fourth driver connection lead may connect to the second connection lead of the lighting device to drive the LED circuit. The fifth driver connection lead may connect to the third connection lead of the lighting device and the sixth driver connection lead may connect to the fourth connection lead of the lighting device to provide a bypass or shunt of the one or more LEDs located between the third and fourth connection leads of the lighting device.

[Para 34] According to one aspect of the invention, an LED lighting device is provided. The LED lighting device includes a bridge rectifier and at least one LED circuit having at least two LEDs connected in series across the output of the bridge rectifier. The lighting device includes two sets of connection leads. The first set of connection leads may be configured to provide a connection to the bridge rectifier with a first connection lead and a second connection lead. The first and second connection leads may be connected to provide an electrical input to and output from the bridge rectifier from an AC power source. The second set of connection leads may be configured to provide a connection to at least one of the least two LEDs connected in series across the output of the bridge rectifier. The second set of connection leads include a third connection lead and a fourth connection lead with the third connection lead being connected to the anode of one of the at least two LEDs and the fourth connection lead being connected to the cathode of one of the at least two LEDs. The second set of connection leads may be configured to provide a connection to all or less than all of the LEDs connected in series across the output of the bridge rectifier. The bridge

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rectifier may be constructed using diodes, LEDs, or some combination thereof.

[Para 35] According to one aspect of the invention a method of reducing total harmonic distortion in LED lighting circuits and devices is provided. The method requires that at least two LEDs be connected in series and that a bypass around or shunt at least one of the at least two LEDs connected in series is provided. A substantially constant current may be maintained flowing through at least one LED having while at least one LED is bypassed or shunted.

[Para 36] According to another aspect of the invention, an active current limiting device may be used as the bypass or shunt and connected in parallel with at least one of the at least two LEDs to provide the bypass or shunt. The active current limiting device may be a constant current regulator or a current limiting diode.

[Para 37] Other advantages and aspects of the present invention will become apparent upon reading the following description of the drawings and detailed description of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[Para 38] FIG. 1 shows a block diagram of a constant current regulator which may be used with the invention;

[Para 39] FIG. 2A shows a color temperature controllable LED lighting device as contemplated by the invention;

[Para 40] FIG. 2B shows a color temperature controllable LED lighting device as contemplated by the invention;

[Para 41] FIG. 3A shows a color temperature controllable LED lighting device as contemplated by the invention;

[Para 42] FIG. 3B shows a color temperature controllable LED lighting device as contemplated by the invention;

[Para 43] FIG. 4 shows a color temperature controllable LED lighting device as contemplated by the invention;

[Para 44] FIG. 5 shows a color temperature controllable LED lighting device as contemplated by the invention;

[Para 45] FIG. 6 shows a graphical representation of the forward voltage versus forward current for various colors of LEDs;

[Para 46] FIG. 7 shows a graphical representation of the forward current versus the relative luminous flux for various colors of LEDs;

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[Para 47] FIG. 8 shows a diagram of a lighting system in which the color temperature controllable LED lighting devices of FIGs. 1-4 may be used;

[Para 48] FIG. 9 shows a lighting device having an increased power factor and reduced total harmonic distortion as contemplated by the invention;

[Para 49] FIG. 10 shows a lighting device having an increased power factor and reduced total harmonic distortion as contemplated by the invention;

[Para 50] FIG. 11 shows a lighting device having an increased power factor and reduced total harmonic distortion as contemplated by the invention;

[Para 51] FIG. 12 shows a lighting device having an increased power factor and reduced total harmonic distortion as contemplated by the invention;

[Para 52] FIG. 13 shows a lighting device having an increased power factor and reduced total harmonic distortion as contemplated by the invention;

[Para 53] FIG. 14 shows a lighting device having multiple power connection leads for increasing power factor and reducing total harmonic distortion as contemplated by the invention;

[Para 54] FIG. 15 shows a driver for driving to the device of FIG. 13;

[Para 55] FIG. 16 shows a lighting device having multiple power connection leads for increasing power factor and reducing total harmonic distortion as contemplated by the invention;

[Para 56] FIG. 17 shows a lighting device having multiple power connection leads for increasing power factor and reducing total harmonic distortion as contemplated by the invention;

[Para 57] FIG. 18 shows a graphical representation of an applied voltage and forward current in a known LED lighting device; and,

[Para 58] FIG. 19 shows a graphical representation of an applied voltage and forward current in an LED lighting device having an increased power factor and reduced total harmonic distortion as contemplated by the invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

[Para 59] While this invention is susceptible to embodiments in many different forms, there is described in detail herein, various embodiments of the invention with the understanding that the present disclosures are to be considered as exemplifications of the principles of the invention and are not intended to limit the broad aspects of the invention to the embodiments illustrated.

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[Para 60] The present invention is directed to multiple lighting devices or systems, the light emitting circuits contained therein, and methods of driving and operating the same. As discussed herein, a lighting device may include any device capable of emitting light no matter the intention. Examples of lighting devices which are contemplated by this invention include, but are not limited to, LED chips, LED packages, LED chip on board assemblies, LED assemblies or LED modules. The devices may also include any required power connections or leads or contacts, or drivers, required to provide power to the circuits and allow the circuits within the device to emit light. A lighting system may include multiple such devices, and some or all of the required parts to drive such a device or multiple devices, including but not limited to, power supplies, transformers, inverters, rectifiers, sensors or light emitting circuitry discussed herein. While a lighting device may be incorporated into a lighting system or into a lamp or light bulb, it is contemplated that any required light emitting elements may be included within the system directly, whether in the form of a device as a chip or package, or as circuits within the system.

[Para 61] The purposes of the devices described herein are twofold, and may be accomplished independent of each other. One intention of the devices described herein is to provide an LED lighting device capable of efficiently and economically emitting light having a selectable color temperature or a warm-on-dim feature when driven with AC power. The second intention of the devices described herein is to provide LED lighting devices which have an improved power factor and a reduced total harmonic distortion when powered with AC power.

[Para 62] In order to achieve either of the goals of the devices described herein, it may be necessary to include one or more active current limiting devices within each LED lighting device, regardless of whether the device is designed to allow color temperature control, increase power factor while reducing THD, or both. While any known current limiting device which sets a substantially upper limit on the current which is allowed to flow through a circuit may be used with any of the circuits or devices described herein, the devices in the present application will primarily discuss using a constant current regulator (CCR), like for example those sold by ON Semiconductor or operating having the internal structures as shown in the block diagram of FIG. 1, and a current limiting or current controlled diode (CLD). Both CCRs and CLDs actively limit the current flowing through a particular circuit or device by substantially limiting the current to, and maintaining the current at, a threshold level once the current in a connected circuit or device has reached or exceeded a particular value. Using such devices is advantageous over using current limiting resistors insofar as

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CCRs and CLDs both cap the total current which is allowed to flow through a connected circuit or device, while the resistor only acts to reduce any every climbing current. With a current limiting resistor, as the input voltage to the circuit continues to increase, the current will likewise continue to increase without limit, albeit it at a lower value than without the resistor. With a CCR or a CLD, once the current reaches a threshold maximum, the current will remain substantially constant until the input voltage is reduced, even if the input voltage continues to climb. As will be described herein, in some cases the combination of a CCR or CLD and a current limiting resistor may be beneficial or required.

[Para 63] While both CCRs and CLDs may be used interchangeably to accomplish the goals of the devices described herein, there are differences between the devices. The primary difference between the devices is that CCRs, like those sold by ON Semiconductor, typically have internal transistor based control circuits and have little or no turn on voltage. CLDs are a form of a diode which are based in part on a JFET having a gate shorted to the power source and have a measurable turn on voltage. While the CLDs may be utilized with any of the devices described herein, it may be advantageous to use a CCR when possible in order to avoid the additional turn on voltage requirements of the CLD. However, CCRs and CLDs may be used interchangeably to accomplish the goals of the invention.

[Para 64] FIGs. 2-5 show exemplary LED lighting devices capable of emitting color temperature controlled light. As seen in FIG. 2A, lighting device 10 includes at least two LED circuits 12, 14 which are connected in parallel. Each LED circuit 12, 14 includes one or more LEDs 16, 18 respectively. Each LED circuit 12, 14 has a different forward operating voltage and is capable of emitting light having one or more of a different color or a different wavelength than the other circuit. For example, LED circuit 12 may emit amber or yellow light, while LED circuit 14 emits white or blue light. In order to limit the current within either LED circuit 12, 14, an active current limiting device such as a CCR or CLD, shown as CCR 20 connected in series with at least one LED 16 in first circuit 12, may be provided. As seen in FIG. 2B, additional active current limiting devices, like for example CCR 22, may be added to the device so that each LED circuit is connected in series with an active current limiting device. LED device 10 may further include connection leads 24, 26 for connecting the device to an AC power source, like for example mains power or a switch or dimmer connected to mains power. In order to fully utilize AC power and produce a substantially constant light output, device 10 and/or circuits 12, 14 should be configured such that each circuit 12, 14 is capable of emitting light during both a positive and negative phase of the provided AC voltage.

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[Para 65] In devices where one or both of LED circuits 12, 14 include only a single LED, or, as shown in FIGs. 2A and 2B a series string of LEDs 16, 18 respectively, in order to insure each circuit emits light during both the positive and negative phase of the provided AC power device 10 may include bridge rectifier 28. The electrical inputs of bridge rectifier 28 may connect directly to leads 24, 26, while the output and return of the bridge rectifier connects to parallel circuits 12, 14, providing rectified AC power to each circuit. Providing the rectified power insures that each circuit is capable of emitting light during both the positive and negative when device 10 is electrically connected to an AC power source. When utilized herein, unless otherwise noted, connecting an LED circuit across the output of a bridge rectifier refers to connecting the LED circuit to both the output and return of the bridge rectifier, such that the circuit receives power from the output of the bridge rectifier at one end and has a return path to the return of the bridge rectifier, effectively creating a closed loop between the LED circuit and the bridge rectifier.

[Para 66] While single LEDs or series strings like LED circuits 12, 14 may require device 10 to include a bridge rectifier to utilize both phases of connected AC power, one or more of circuits 12, 14 may be modified to use direct AC power without the requirement of rectification. For example, as seen in FIGs. 3A and 3B, device 10' may include LED circuits 12', 14' where each circuit includes at least one LED 16', 18' respectively, connected in an antiparallel configuration. With LEDs 16', 18' connected in an anti-parallel configuration, LED circuits 12', 14' are capable of emitting light during both phases of AC power without the need for rectification as each circuit has one or more LEDs configured to use both the positive and negative phase of a connected AC power source. As a result, circuits 12', 14' may be directly connected to leads 24', 26' as shown in FIGs. 3A and 3B without an intervening rectifier. When utilizing an anti-parallel configuration, however, in order to protect the LEDs during both phases of AC power in at least one of circuit 12', 14', more than one active current limiting device may be required. For example, as seen in FIG. 3A, each anti-parallel branch in circuit 12' (or 14') may include an active current limiting device, which may be either a CCR or CLDs 30'. Rather than connect one current limiting device in series with each branch of anti-parallel circuit 12', back-to-back CLDs or CCRs may be attached at one end of the circuit, between circuit 12' and either lead 24' or 26' as seen in FIG. 3B. Inasmuch as both CLDs and CCRs have very low reverse breakdown characteristics, it is possible to connect CLDs or CCRs in a back-to-back fashion and realize the current protecting features of the forward-biased CLD or CCR.

[Para 67] Other circuit configurations which may directly use AC power may be utilized

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in the LED lighting device as well. For example, rather than use a separate bridge rectifier connected to circuits having a single LED or series string of LEDs, one or more of the LED circuits may be configured in a bridge rectifier configuration with an additional diode, LED, CLD or CCR connected across the output of the rectifier. As seen in FIG. 4 LED lighting device 10" may include circuits 12", 14" which each include at least five diodes, at least four of the diodes being LEDs 16", 18" respectively. LEDs 16", 18" may be configured in a bridge rectifier configuration with a fifth diode, which may be a standard diode, LED 32" as shown in circuit 12", or CLD 30" as shown in circuit 14". Configuring circuit 10" in a bridge configuration with a diode, LED, or active current limiting device across the output of the rectifier allows for AC power to be used during both the positive and negative phase when provided to device 10". As a result, like the device shown in 10', circuits 12", 14" may be directly connected to connection leads 24", 26" without an intervening bridge rectifier. As seen in each circuit, unlike the circuits shown in FIG. 2, a single active current limiting device may be used to protect each of circuit 12", 14" if it is located across the output of each rectifier circuit. Inasmuch as current will flow through the at least fifth diode during both the positive and negative phases, placing the active current limiting device in series with the at least fifth diode (or making the at least fifth diode the active current limiting device) will insure that current during both phases of provided AC power flows through the current limiting device, effectively limiting the current for each LED within the circuit.

[Para 68] In order to further protect the LEDs in a circuit directly using AC power, each circuit in the LED lighting device may be configured in an imbalanced bridge configuration. As seen in FIG. 5, device 10"' may include circuits 12"', 14"' which each include at least diodes, at least six of which are LEDs connected in an imbalanced bridge configuration. The imbalanced bridge configuration will act substantially similar to, and have substantially the same characteristics as the circuits described in FIG. 4 with the added benefit of reverse breakdown protection for the LEDs forming the bridge. In order to imbalance the bridge, at least one additional LED is placed in series with one input LED (shown as the left branch of circuits 12"', 14"') than the other input LED, and at least one additional LED is placed in series with the opposing output LED (output LED during the opposite phase) than the aligned output LED. Configuring the LEDs forming the bridge in this manner helps reduce reverse breakdown of any of the LEDs in the circuit. Like a standard bridge, the cross-connecting branch across the output of the imbalanced bridge may be a standard diode, LED 32"', CLD 30"', or some combination thereof.

[Para 69] While FIGs. 2-5 show each of the aforementioned circuits in pairs, it is

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contemplated that the circuits disclosed in each FIG. may be mixed and matched within a single device as desired. For example, an LED lighting device may be made using circuits 12, 14" or 12', 14"'. Additional circuits may further be connected in parallel within a single device, the additional circuits having a different forward operating voltage than the other connected circuits, and each additional circuit being capable of emitting light of a different color than the other connected LED circuits within the device. The additional circuits may be configured in any manner shown in FIGs. 2-5 and connected to or include any rectifiers or connection leads as needed to receive power and emit light during both phases of any provided AC power.

[Para 70] Regardless of how many circuits are connected in parallel and the configuration of each circuit, any circuits forming an LED lighting device, along with the at least one active current limiting device, the connection leads and any required rectifiers or additional current limiting devices may be integrated on a single substrate 33 (FIGs. 2A, 2B), 33' (FIGs. 3A, 3B), 33" (FIG. 4), or 33"'(FIG. 5). The single substrate may then be directly incorporated into a lighting system or fixture, or a lamp or light bulb as desired.

[Para 71] While any known method for creating LED circuits capable of emitting light of a different color within a single device is contemplated by the invention, two examples will be discussed herein.

[Para 72] The first method by which the light emitted by each circuit may be made different is by using a different phosphor coating on each circuit. When using a phosphor coating, the color of the LEDs used in each circuit, for example LEDs 16, 18 in FIG. 2A, may emit a substantially similar color, like for example blue, or different colors, as the phosphor coating substantially creating the different colors of emission light for each circuit. Though the device and circuits of FIG. 2A will be used for examples herein, it should be appreciated that the devices and circuits of FIG. 2B-5, or any combination of circuits as discussed above, may be used in substantially the same manner to achieve substantially the same effect.

[Para 73] In order to create different forward operating voltages when using a phosphor coating, different colored LEDs having a different turn on voltage may be used, or the circuits may utilize a different number of similar colored LEDs. For example, a first circuit, like circuit 12 in FIG. 2A, may include five blue LEDs and be coated in yellow or amber phosphor, while circuit 14 may include 10 blue LEDs and be coated in white phosphor. Since the first circuit includes fewer LEDs, it will begin operating first as it will have a lower turn on voltage, causing the emission of light by device 10 substantially equal to the color of the phosphor coating on circuit 12, or yellow or amber. As the voltage provided to device 10

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increases, the current flowing through circuit 12 will increase, causing the yellow or amber light to more brightly emit. The current flowing through circuit 12 will continue to increase until the current threshold of the at least one active current limiting device (CCR 20) connected in series therewith is reached. It should be noted that when only a single active current limiting device is used, it is important that the current limiting device be connected to the circuit having the lower turn on voltage in order to protect and prevent the LEDs of the circuit from overdriving as the voltage is increased to turn on and intensify the LEDs of the LED circuit having the higher turn on voltage.

[Para 74] Using the example of a five blue LED circuit coated in yellow or amber phosphor and a ten blue LED circuit coated in white phosphor for circuits 12, 14 given above, as is known in the art, each blue LED has a turn on voltage of approximately 2.2V and will reach a nominal operating current at approximately 3.2V. The total turn on voltage for circuit 12 having five blue LEDs would therefore be approximately 11V (2.2V time five LEDs) while the nominal current would reached at approximately 16V. The turn on voltage for circuit 14 would be approximately 22V with the nominal current being reached at approximately 32V. Using this example, as voltage is applied to device 10 in FIG. 2A, once the applied voltage reaches 11V (assuming a CCR is connected as the active current limiting device, otherwise slightly higher than 11V if a CLD is used), LEDs 16 of circuit 12 will begin to emit light, which will be yellow or amber as a result of the phosphor coating applied to the circuit. The brightness of the light emitted by device 10 and circuit 12 will increase until the current flowing through circuit 12 reaches the maximum threshold of CCR 20. If the maximum threshold current of CCR 20 is matched to nominal current of LEDs 16, this means that the current will be capped once 16V input is reached, which is well below the turn on or voltage for nominal current in circuit 14. Having the CCR connected in series with circuit 12 will prevent the overdrive of LEDs 16, protecting them from early burnout resulting from overdrive or overheating as the voltage increases to turn on circuit 14.

[Para 75] Once the input voltage is increased to 22V, LEDs 18 of circuit 14 will begin emitting white light as a result of the white phosphor coating. As circuit 14 begins emitting white light, the combination of yellow or amber and white light will be emitted by device 10, causing the color temperature to begin moving towards the cooler end of the color spectrum. As the voltage continues to increase to device 10, the amount of white light mixed in with the already fully emitted yellow or amber light will continue to increase as the current in circuit 14 increases, causing the color temperature to become cooler and cooler. As is shown in FIG. 2B, an additional or second active current limiting device may be included in device 10,

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CCR 22, which may limit the current within circuit 14 to the nominal current which will be reached at approximately 32V. Using this example, if CCR 22 is used in device 10, the maximum light output of device 10 will be reached at 32V along with the coolest possible temperature color. If the provided voltage increases over 32V, substantially no additional current will flow through either circuit, setting the uppermost light output of each circuit. When the voltage begins to be reduced and device 10 is dimmed, once the voltage begins falling below 32V, circuit 14 will begin emitting less white colored light as the current will drop below nominal level. As the current in circuit 14 decreases and circuit 14 dims, the light emitted by device 10 will both dim and become warmer as the yellow or amber component will become a larger percentage of the light emitted. Eventually at approximately 22V, circuit 14 will turn off and the only light emitted by device 10 will come from circuit 12, providing less light and creating a warmer yellow or amber light than when both circuit 12 and 14 were emitting light.

[Para 76] By using a set amount of LEDs in each LED circuit and setting the current at a level for one or more of the circuits, the amount of each color of light emitted by the device may be controlled by controlling the input voltage, and the color temperature change and light intensity characteristics can be known and tailored to a desired output.

[Para 77] The second method by which the color of the light emitted by the circuits may be made different is by using different colored LEDs in each circuit. The different colored LEDs will emit light of different colors, thereby causing each circuit to emit light of different colors. However, rather than using different numbers of LEDs to different forward operating voltages, the turn on voltage characteristics of the different colored LEDs may utilized to create the difference depending on the colors of the LEDs in the circuits. As is known in the art, there are two common turn on voltages for LEDs emitting colored light. The first turn on voltage is approximately 1.5V for InP diodes which are typically red, amber and yellow LEDs which each reach their nominal operating current at about 2.2V. The second turn on voltage is approximately 2.2V for GaN diodes which are typically green or blue which reach their nominal operating current at about 3.2V.

[Para 78] When using different colored LEDs, in order to create the amber-white device like that described above, circuit 12 may include five LEDs 16 which emit amber light while circuit 14 may include five LEDs 18 which emit blue light and are coated in white phosphor. Using this example, circuit 12 will begin emitting light at approximately 7.5V (again, if a CCR is connected in series, and at a higher voltage if a CLD is used) and reach nominal current at approximately 11V. Circuit 14 will begin emitting light at 11V but will not reach

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nominal current until approximately 16V. As circuit 12 begins to emit, a low level of amber light will be emitted by device 10 until the current value of the series active current limiting device is reached. The active current limiting device connected in series with the LEDs of circuit 12 may be set to prevent the current from rising higher than the nominal current value for the circuit, effectively fixing the intensity of light emitted by circuit 12 while protecting the one or more LEDs therein from overdrive as the voltage increases. As the voltage increases to 11V, circuit 14 will begin emitting white light, cooling the color temperature of the light emitted by device 10. The cooling will continue until either the voltage stops rising, or an active current limiting device connected in series with circuit 14 prevents the current flowing through circuit 14 from rising higher. As the voltage is decreased, the current and intensity of light emitted by circuit 14 will fall, causing the light to both dim and become warmer as the amount of light emitted from the amber LEDs will provide a greater percentage of the light emitted, creating a warmer color temperature colored light. At approximately 11V circuit 14 will turn off, and only circuit 12 and the amber LEDs will continue to emit light, creating a warmer and dimmer light as only the amber colored LEDs will be emitting light at this voltage. As the voltage continues to drop towards 7.5V, the amber LEDs will become dimmer and eventually turn off.

[Para 79] FIGs. 6 and 7 show the forward operating voltage and current characteristics for red (lines indicated by 34), blue (lines indicated by 36), and green (lines indicated by 38) LEDs. These graphical representations of the forward voltage for each LED vs. the forward operating current for each LED and the forward operating current for each LED vs. the luminous flux of each LED show the operating characteristics of different colored LEDs and the importance of connecting an active current limiting device in series with at least the lowest turn on voltage in the device. As seen in FIG. 7, each LED color reaches approximately 100% relative luminous flux, *i.e.* nominal flux, at around 350 mA. Less current than this will cause the LEDs to emit less than 100% flux while more current will overdrive the LEDs, causing more than 100% flux and unwanted heat and eventual breakdown or premature failure. FIG. 5 shows that red LEDs typically reach 350 mA around 2.2V (which is substantially similar for yellow or amber LEDs), blue LEDs around 3.1V, and green LEDs around 3.3V. Using the example above with circuit 12 having five amber LEDs and circuit 14 having five blue LEDs and being coated in white phosphor, by the time the blue LEDs reach nominal current and luminosity, approximately 15.5V-16V will be applied to each of circuit 12, 14 as they are connected in parallel. Assuming each amber LED will have an approximately equal amount of voltage across it, this means that each amber LED

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will have approximately 3.1V-3.2V like the blue LEDs. As seen in FIG. 6, this will cause a current of greater than 1000 mA to flow through each amber LED, and as seen in FIG. 7 cause of luminous flux of greater than 200%. This places the amber LEDs at significant risk for overheating and overdriving, causing potential premature failure of the LEDs. By placing the active current limiting device in series with circuit 12, the current is effectively limited at the selected value, *i.e.* the nominal value, and as the voltage applied to circuit 12 increases, the circuits are current limited and the one or more LEDs therein are protected. However, as seen in FIG. 6, slight variations in voltage across each LED can cause significant increases in the current through each LED. Therefore, it may be advantageous to place an active current limiting device in series with each LED circuit in the device, in order to protect each circuit against increases or spikes in voltage.

[Para 80] In order to control the power provided to device 10, and therefore the voltage and current provided to each circuit and the overall color temperature of the light emitted by device 10 (or 10', 10", 10"'), the power provided to device 10 may be adjusted and controlled using any means known in the art. For example, device 10 may be integrated into a lighting system or fixture 40 having a dimmer switch providing the AC power to device 10. As seen in FIG. 8, dimmer switch 42 may be connected to AC power source 44, which may be, for example, mains power or a dimmer switch connected to mains power, and may be used to control the voltage provided to device 10. The dimmer switch may be any known in the art, like for example, a phase dimmer switch. The dimmer switch may be used to control the voltage to the circuit, causing more or less voltage to be applied to device 10. As the dimmer switch is turned to provide more voltage to the circuit, circuit 12 which may have amber colored LEDs or be coated in amber phosphor may be turned on and increased in intensity. As the switch continues to be turned and provide more power and voltage to the device, circuit 14, which may have blue LEDs or be coated in white phosphor, will turn on and add to the intensity of light emitted by device 10. As the dimmer switch is continually turned up and the light emitted by circuit 14 increases, the intensity of the light emitted by device 10 will increase while the color temperature decreases. When dimmer switch 42 is finally turned down and less voltage is provided to device 10, eventually circuit 14 will begin decreasing in intensity, causing the circuit 12 to produce a greater percentage of the light emitted by device 10, causing the light to have a warmer color temperature.

[Para 81] While the circuits, devices and systems described above will provide an AC LED lighting device option having the ability warm on dim, AC LED devices may be further or alternatively enhanced by increasing the power factor and reducing the total harmonic

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distortion (THD) of the devices and light emitting circuits therein.

[Para 82] FIGs. 9-13 show LED lighting devices which have both an increased power factor and a reduced THD regardless of the color of the LEDs contained therein. As seen in FIG. 9, device 100 includes at least one LED circuit, LED circuit 102, having at least two or more LEDs, LEDs 104, 106, 108, connected in series. Connected in parallel with at least one of the LEDs, shown as LEDs 106, is an active current limiting device, shown as CCR 110. As discussed throughout, though a CCR may be advantageous due to its low or non-existent turn on voltage, using a CLD may replace CCR and accomplish similar results. When using a CLD, however, the turn on voltage of the CLD will at least somewhat lower the power factor gains and reduction of THD realized by using a CCR. When connected in parallel with LEDs 106 (and any additional LEDs), the active current limiting device will provide a current bypass around the LEDs until the turn on voltage for the bypassed or shunted LEDs is reached. This will allow LEDs 104, 108 in circuit 102 to turn on earlier than if all LEDs had to be turned on before any LEDs emit light when a voltage is applied to connection leads 112, 114, increasing the power factor of the circuit. For as long as the active current limiting device is utilized to bypass or shunt LEDs 106, the current flowing through LEDs 104, 108 will be effectively limited and controlled. The controlled current will protect LEDs 104, 108 as the voltage is increased to turn on LEDs 106 and substantially reduce the effect of any harmonic currents created by the non-linear reacting LEDs. The harmonic currents and current gains and non-linearity can be effectively reduced by controlling a threshold amount current flowing through the circuit until the additional LEDs are ready to turn on. As with color temperature controlled LED lighting devices, all elements of any low THD LED lighting devices may be integrated on a single substrate 115, not matter the configuration and elements included within the device.

[Para 83] While CCR 110 will help keep the current limited to a threshold value while LEDs 106 are bypassed, once the input voltage to device 100 reaches a level where LEDs 106 will turn on with LEDs 104, 108, the current will be allowed to increase unimpeded through circuit 102 as current will substantially flow through LEDs 104, 106, 108 without a limiter in place to maintain the current. In order to protect all the LEDs in circuit 102 once LEDs 106 reach their turn on voltage, a second active current limiting device, shown in FIG. 9 as CLD 116 though it may advantageously be a CCR substantially eliminating any turn on voltage, and/or a current limiting resistor 118 (as shown in FIG. 10 for example) may be connected in series with LEDs 104, 106, 108 and formed as part of circuit 102. The additional current limiting device or current limiting resistor will help keep the current in the

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circuit down once LEDs 106 turn on, with the active current limiting device having the added benefit of creating an upper threshold of current flowing through the circuit.

[Para 84] While circuit 102 in FIGs. 9 and 10 are capable of being driven off of DC power, in order to connect and drive device 100 with AC power where THD and power factor present a greater problem, like for example mains power, device 100 may be integrated into a system or connected to a driver having a bridge rectifier, wherein rectified power is provided to circuit 102 through connection leads 112, 114. Alternatively, an additional circuit substantially identical to circuit 102 may be connected to circuit 102 in an anti-parallel configuration (like for example circuits 12' in FIG. 3A) to utilize both the positive and negative phases of a supplied AC power. Each circuit may then have a connection to leads 112, 114 to receive a provided AC power and operate during its respective phase.

[Para 85] Alternatively, as seen in FIGs. 12 and 13, device 100' may include a bridge rectifier 120 or 122 with circuit 102 connected across the output, either internally or externally. When a bridge rectifier is incorporated into the device, leads 112, 114 may connect to the inputs of the rectifier, allowing the rectifier to receive AC power from an AC power source. Circuit 102 may then connect across the output of the rectifier, receiving and utilizing the rectified AC power. The bridge rectifier may be made using standard diodes, LEDs or some combination thereof.

[Para 86] As seen in FIG. 11, a THD lowering active current device may be utilized in devices having color changing LEDs as well. As seen in FIG. 11, circuits 124, 126 may be substantially identical and placed in parallel with each other. Like circuits 12, 14 in FIG. 2A, for example, circuit 124, 126 may each have a different forward operating voltage and be capable of emitting light of a different color. Circuits 124, 126 may be incorporated into a system or driven by a driver having a bridge rectifier, or may be used to replace any of circuits 12, 14 or 12', 14' in FIGs. 2-3. The parallel current limiting device in each circuit will have substantially the same effect as described above, allowing some of the LEDs in the lower voltage circuit to turn on at a lower voltage than all of the LEDs, and reduce the harmonic distortion current resulting from the non-linearity of the LEDs. A portion of the LEDs in the higher voltage circuit may likewise turn on earlier, creating further temperature control as more intermediate levels of color may be realized as only some LEDs in the higher voltage circuit may turn on at first before all LEDs in the higher voltage circuit turn on. This configuration may allow for some or all LEDS in the lower voltage circuit to turn on, followed by some LEDs in the higher voltage circuit to turn on, beginning a cooling or warming of the light emitted by the device before all the LEDs are turned on. Eventually,

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shunted LEDs will turn on, further cooling or warming the light emitted by the device as it provided power and voltage increase.

[Para 87] An example of a driver and alternative lighting device which may be used to create a lower THD LED lighting device when driven with AC power may be seen in FIGs. 14 and 15. As seen in FIG. 14, LED lighting device 200 may include LED circuit 202 having at least two LEDs, shown as LEDs 204 connected in series. Device 200 may include a first set of connection leads 206, 208 which are connected to the input and output of circuit 202, effectively providing a connection to all of the LEDs within the circuit. A second set of connection leads 210, 212 may be provided as well. Connection leads 210, 212 may provide a connection to the anode of one LED and a connection to the cathode of one LED respectively. Connection leads 210, 212 may be configured, as seen in FIG. 14, to provide a connection to less than all of the LEDs in circuit 202. The first set of connection leads may be used to receive and return power for circuit 202, while the second set of connection leads may be used to connect a bypass or shunt, like for example an active current limiting device, to a subset or a portion of the LEDs forming circuit 202. Though shown as extending outside device 200, it should be understood that where power connections are used herein, whether with device 200, driver 220, or alternative devices 200', that any power connections may extend outside the device or include contacts formed as a portion of the device on or inside the substrate.

[Para 88] Each group of LEDs located either inside or outside the second set of connection leads may get categorized as a group, and may include additional connection leads as needed. For example, group 214 may comprise a first set of LEDs, group 216 may comprise a second group of LEDs and group 218 may comprise a third group of LEDs. Though shown in FIG. 14 as providing a connection to group 216, it should be appreciated that connection leads 210, 212 may be moved to provide a connection to group 214 or group 218. A third set of connection leads may also be provided to provide a connection to a second group, to create a further bypass or shunt if needed.

[Para 89] Providing device 200 with second connection leads 210, 212 instead of a fixed active current limiting device allows for an end user to better control the current that will flow through circuit 202 when the LEDs between connection leads 210, 212 are bypassed or shunted. The connection leads will allow an end user to select a driver or active current limiting bypass which will allow a particular amount of current to flow through the non-bypassed LEDs to create a desired level of luminance from device 200. Creating devices 200 with connection leads instead of bypasses also allows for different LED circuits to be

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connected to the same bypass or driver if the light needs of device 200 change. For example, device 200 may initially include a circuit which includes 20 LEDs, 10 of which are bypassed, but now requires a circuit of 40 LEDs, 10 of which are bypassed, to provide more light. Rather than have to buy a new LED lighting device having the active current limiting device already incorporated into the device, which may be more costly, the end user would be able to purchase a new LED lighting device having connection leads capable of connecting some of the LEDs to an active current limiting device the end user already has. Such is particularly advantageous if the LEDs in the lighting device fail before the active current limiting device, as a cheaper LED lighting device may be purchased to replace the failed device and the still operational current limiting device may be utilized with the new LED lighting device. Likewise, if the driver or bypass or shunt active current limiting device fails, the LED lighting device may be disconnected from the failed driver or bypass and be re-used with a new driver or bypass.

[Para 90] In order to drive device 200 in FIG. 14, device 200 should be integrated into a lighting system or fixture having a driver having a bridge rectifier and one or more active current limiting devices. An exemplary driver can be seen in FIG. 15. As seen in FIG. 15, driver 220 may include bridge rectifier 222 and at least two active current limiting devices, shown as CCRs 224, 226. CCR 224 may be connected to an output of the bridge rectifier to control any current flowing from the bridge rectifier, while CCR 226 may be electrically unconnected to both the bridge rectifier and CCR 224 to effectively be able to provide a bypass or shunt for LEDs in circuit 202. In order to receive and provide power, and provide an effective bypass, driver 220 may include three sets of driver connection leads. A first set of driver connection leads 228, 230 may be utilized to provide a connection between the bridge rectifier and an AC power source. A second set of driver connection leads 232, 234 may be used to connect the rectifier and associated CCR to the circuit. Connection lead 232 may, for example, extend from the output of CCR 224 and connect to connection lead 206 of device 200 to provide rectified AC power from rectifier 222 to circuit 202. Connection lead 234 may, for example, extend from the return of rectifier 222, and connect to connection lead 208 of circuit 202 to receive a return form circuit 202 to complete the circuit. Connecting leads 232, 234 and 206, 208 in this manner will provide power to each LED and active current limiting device in circuit 202 and enable the circuit to be driven.

[Para 91] In order to provide a bypass or shunt for one or more of the LEDs in circuit 202, the third set of connection leads 236, 238 in driver 220 should connect to the input and output of CCR 226 respectively. Connection lead 236 may then connect to connection lead

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210 while connection lead 238 connects to connection 212 to effectively provide a bypass around the LEDs connected between leads 210, 212 in circuit 202. Since CCR 226 is electrically unconnected to rectifier 222 and CCR 224, it will effectively act as a bypass when connected across one or more of the LEDs in circuit 202 in a substantially identical manner as bypass CCR 110 does in FIG. 9.

[Para 92] As seen in FIGs. 16 and 17, the bypass connections may likewise be utilized in circuit 100' with a first set of connection leads 210', 212' being connected to the inputs of the bridge rectifier and one or more of the LEDs 250' connected across the output of the bridge rectifier being connected to a second set of connection leads 214', 216' in device 200'. Such a configuration would allow an end user to select a bypass of choice, with particular current limiting characteristics for driving any LEDs formed as part of the bridge rectifier 248', and/or any LEDs 250' connected across the output of the rectifier which are not bypassed by the parallel current limiting device. As described above, connection leads may also help keep the costs of the device down as end users will be able to purchase a separate active current limiting device and use it with multiple rectifier devices.

[Para 93] Regardless of whether an active current limiting bypass is incorporated into a device, like in FIGs. 9-13, or is externally connected to connection leads like in FIGs. 14, 16, and 17, it has been found by the inventors that the ratio of circuit efficiency is inversely proportional to the THD realized by the circuit as more or less LEDs are bypassed. For example, in a circuit having 20 LEDs, if five are bypassed the circuit may be highly efficient but realize a smaller reduction in THD. If 15 LEDs are bypassed, the circuit may be less efficient, but have a greater reduction in THD. It is therefore contemplated that the number of the two or more LEDs which are bypassed in any given circuit may be adjusted to match the desired characteristics of the end user of the lighting device. If a more efficient light is desired, then a device having fewer bypassed LEDs may be provided, while if lower THD is required a device having more LEDs bypassed may be provided. This inverse reaction to more or less LEDs being bypassed provides a further advantage to using devices having connection leads which attach to external active current limiting device bypasses, as it allows an end user to use a single active current limiting device to bypass different LED devices which may operate with greater efficiency or lower THD as is currently needed by the end user.

[Para 94] The improvement of any circuit using an active current limiting device bypass, again regardless of whether it is integrated within the device or externally connected, can be seen in FIGs. 18 and 19. FIG. 18 shows curve 240 which represents an AC input voltage to a

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known LED lighting device not using an active current limiting bypass and instead using a current limiting resistor, for example, and the current response curve 242 of the same device. FIG. 19 shows the same two curves, curve 244 showing an AC input voltage and curve 246 showing current, when a device having an identical number of LEDs to the circuit producing the curve in FIG. 18 is used with an active current limiting bypass as described herein. As seen in FIGs. 18 and 19, utilizing the bypass in the present invention increases power factor, as current begins flowing through the device much closer to the voltage turn on point when a bypass is used than when it is not. This better power factor is the result of the device having the bypass circuit beginning to emit light much earlier as only enough voltage to turn on the non-bypasssed (and CLD if used instead of a CCR) is required for the device to begin emitting light. If each circuit includes 20 LEDs which each turn on at 2.2V, for example, and 10 LEDs are bypassed in a circuit and device as described herein, it will turn on once the provided AC voltage reaches 22V whereas the device not having the bypass will not turn on until provided AC voltage reaches 44V. The bypass allows the device to turn on much earlier, allowing light to be emitted much earlier in the provided voltage waveform, *i.e.* increasing the power factor. As a result of the bypass, the current response using a bypass also has a substantially reduced THD, as the current waveform better approximates the provided AC voltage.

[Para 95] While the foregoing there has set forth embodiments of the invention, it is to be understood that the present invention may be embodied in other forms without departing from the spirit or central characteristics thereof. The present embodiments, therefore, are to be considered in all respects as illustrative and not restrictive, and the invention is not to be limited to the details given herein. While specific embodiments have been illustrated and described, numerous modifications come to mind without significantly departing from the characteristics of the invention and the scope of protection is only limited by the scope of the accompanying claims.

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CLAIMS

What is claimed is:

1. An LED lighting device comprising:

at least two LED circuits connected in parallel, each of the at least two LED circuits having one or more LEDs, each LED circuit

having a different forward operating voltage than the other LED circuits, and,

being capable of emitting light having one or more of a different color or wavelength than the other LED circuits;

at least one active current limiting device being connected in series with at least one LED in at least one of the at least two LED circuits,

wherein each LED circuit is capable of emitting light during both a positive and a negative phase of a provided AC voltage when the LED lighting device is connected to an AC voltage source.

2. The LED lighting device of claim 1 wherein the at least one current limiting device is a current limiting diode.

3. The LED lighting device of claim 1 wherein the at least one current limiting device is a constant current regulator.

4. The LED lighting device of any one of claims 1-3 wherein the at least two LED circuits and the at least one active current limiting device are integrated onto a single substrate.

5. The LED lighting device of any one of claims 1-4 wherein each of the at least two circuits are connected in series to at least one active current limiting device.

6. The LED lighting device of any one of claims 1-5 further comprising a bridge rectifier, wherein at least one of the at least two LED circuits is connected across the output of the bridge rectifier.

7. The LED lighting device of any one of claims 1-6 wherein at least one of the at least two circuits includes two or more LEDs connected in an anti-parallel configuration.

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8. The LED lighting device of any one of claims 1-7 wherein at least one of the at least two circuits includes at least five diodes, at least four of the diodes being LEDs, the at least four LEDs being connected in a bridge rectifier configuration and the at least fifth diode being connected across the output of the bridge rectifier.

9. The LED lighting device of claim 8 wherein the at least fifth diode connected across the output of the bridge rectifier is an LED.

10. The LED lighting device of claim 8 wherein the at least fifth diode connected across the output of the bridge rectifier is a constant current diode.

11. The LED lighting device of any one of claims 1-10 wherein at least one of the at least two circuits includes seven or more diodes, at least six of the diodes being LEDs, the at least six LEDs being connected in an unbalanced bridge rectifier configuration, with the at least seventh diode being connected across the output of the unbalanced bridge rectifier.

12. The LED lighting device of claim 11 wherein the at least seventh diode connected across the output of the bridge rectifier is an LED.

13. The LED lighting device of claim 11 wherein the at least seventh diode connected across the output of the bridge rectifier is a constant current diode.

14. The LED lighting device of any one of claims 1-13 wherein light emitted by the one or more LEDs forming at least one of the at least two LED circuits is one or more of a different color or wavelength than the light emitted by the one or more LEDs of the other connected LED circuits in the device.

15. The LED lighting device of any one of claims 1-14 wherein each of the at least two circuits are coated in phosphor, each circuit having a different phosphor coating than the other connected at least two LED circuits, the different phosphor coating on each of the at least two circuits causing each circuit to emit one or more of a different color or wavelength of light than the other connected LED circuits.

16. The LED lighting device of any one of claims 1-15 being integrated into a lighting system, the lighting system having a dimmer switch capable of providing AC voltage to the

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LED lighting device, wherein the dimmer switch may be used to control the AC voltage provided to the at least two LED circuits to control the light output of each circuit to control a color temperature of light emitted by the LED lighting device.

17. A method of controlling color temperature of light emitted by an LED lighting device, the method comprising the steps of:

connecting at least two LED circuits in parallel, with each LED circuit having a different forward operating voltage and being capable of emitting light of one or more of a different color or wavelength than the other LED circuits;

providing a voltage and a current to the at least two LED circuits;

limiting the current provided to at least one of the at least two LED circuits;

adjusting at least one of the provided voltage and current to control the light output of the LEDs connected in parallel.

18. The method of claim 17 further comprising the step of providing an AC voltage and current to at least one of the at least two LED circuits.

19. The method of claims 17 or 18 further comprising the step of rectifying an AC voltage and current before providing the voltage and current to at least one of the at least two LED circuits.

20. An LED lighting device comprising:

at least one LED circuit having at least two or more LEDs connected in series;

at least one active current limiting device, the active current limiting device being connected in parallel with the at least one LED in the at least one LED circuit.

21. The LED lighting device of claim 20 further comprising at least a second active current limiting device, the second active current limiting device being connected in series with the at least one LED circuit.

22. The LED lighting device of claims 20 or 21 further comprising a bridge rectifier, wherein the at least one LED circuit is connected across the output of the bridge rectifier.

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23. The LED lighting device of claim 23 wherein the bridge rectifier is constructed using LEDs.

24. The LED lighting device of any one of claims 20-23 further comprising at least one additional LED circuit having two or more LEDs connected in series and at least one active current limiting device connected in parallel with at least one of the two or more LEDs, the at least one additional LED circuit being connected to the at least one LED circuit in parallel.

25. The LED lighting device of claim 24 wherein the at least one LED circuit is capable of emitting light having one or more of a different color or wavelength than the at least one additional LED circuit.

26. The LED lighting device of any one of claims 20-25 wherein the at least one LED circuit includes at least three LEDs connected in series.

27. The LED lighting device of any one of claims 20-26 further comprising a resistor, the resistor being connected in series with the at least one LED circuit.

28. The LED lighting device of any one of claims 20-27 wherein the at least one active current limiting device is a constant current regulator.

29. The LED lighting device of any one of claims 20-27 wherein the at least one active current limiting device is a current limiting diode.

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30. An LED lighting device comprising:

at least one LED circuit having at least two LEDs connected in series;

a first set of connection leads configured to provide a connection to the at least two LEDs in the at least one LED circuit, the first set of connection leads having a first connection lead and a second connection lead,

the first connection lead being connected to an input of the at least one LED circuit and,

the second connection lead being connected to an output of the at least one LED circuit; and,

a second set of connection leads, the second set of connection leads having a third connection lead and a fourth connection lead,

the third connection lead being to the anode of at least one of the at least two LEDs

the fourth connection lead being connected to the cathode of at least one of the at least two LEDs,

wherein the second set of connection leads are configured to provide a connection to less than all of the LEDs in the at least one circuit.

31. The LED lighting device of claim 30 wherein the at least two LEDs are configured into at least two sets of LEDs connected in series, each set of LEDs having at least one LED, wherein the first connection leads are configured to provide a connection to both of the at least a first and a second set of LEDs and the second connection leads are configured to provide a connection to only one of the first or second set of LEDs.

32. The LED lighting device of claims 30 or 31 wherein the at least one circuit includes at least three LEDs, the at least three LEDs being connected in series between the first and second connection lead.

33. The LED lighting device of claim 32 wherein each the at least three LEDs of the at least one LED circuit are configured into at least three sets of LEDs, each set having at least one LED.

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34. The LED lighting device of claims 33 wherein the third connection lead is connected the anode of the first LED in one of the first, second or third sets of LEDs, and the fourth connection lead is connected to the cathode of the last LED in the same set of LEDs.

35. A lighting system comprising the lighting device of any one of claims 30-34, the lighting system further comprising:

a driver, the driver having

a bridge rectifier;

a first active current limiting device connected to the output of the bridge rectifier:

a second active current limiting device electrically unconnected to the bridge rectifier and the first constant current diode;

a first set of driver connection leads, the first set of driver connection leads providing a connection for the bridge rectifier to connect to an AC voltage source;

a second set of driver connection leads, the second set of driver connection leads having a third driver connection lead providing an output from the first active current limiting device and a fourth driver connection lead providing a return from a load to the bridge rectifier;

a third set of driver connections leads, the third set of driver connection leads having a fifth driver connection lead providing an input the second active current limiting device and a sixth driver connection lead providing an output the second active current limiting device;

wherein the third driver connection lead connects to the first connection lead of the lighting device and the fourth driver connection lead connects to the second connection lead of the lighting device to drive the LED circuit, and the fifth driver connection lead connects to the third connection lead of the lighting device and the sixth driver connection lead connects to the fourth connection lead of the lighting device to provide a bypass of one or more LEDs.

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36. An LED lighting device comprising:

a bridge rectifier;

at least one LED circuit having at least two LEDs connected in series across the output of the bridge rectifier;

a first set of connection leads configured to provide a connection to the bridge rectifier, the first set of connection leads having a first connection lead and a second connection lead, the first and second connection leads being connected to provide an electrical input and output from the bridge rectifier;

a second set of connection leads configured to provide a connection to at least one of the least two LEDs connected in series across the output of the bridge rectifier, the second set of connection leads having a third connection lead and a fourth connection lead;

the third connection lead being connected to the anode of one of the at least two LEDs

the fourth connection lead being connected to the cathode of one of the at least two LEDs.

37. The LED lighting device of claim 36 wherein the second set of connection leads are configured to provide a connection to less than all of the LEDs connected in series across the output of the bridge rectifier.

38. The LED lighting device of claims 36 or 37 wherein the bridge rectifier is constructed using LEDs.

39. A method of reducing harmonic distortion in LED lighting circuits and devices, the method comprising the steps of:

connecting at least two LEDs in series;

providing a bypass around at least one of the at least two LEDs connected in series; and,

maintaining a substantially constant current flowing through at least one LED having while at least one LED is bypassed.

40. The method of claim 39 further comprising the step of connecting an active current limiting device in parallel with at least one of the at least two LEDs to provide the bypass.

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41. An LED circuit as described herein.

42. An LED lighting device as claimed and described herein.

43. An LED lighting system as claimed and described herein.

44. A method of driving an LED lighting device or system as claimed and described herein.

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FIG. 1

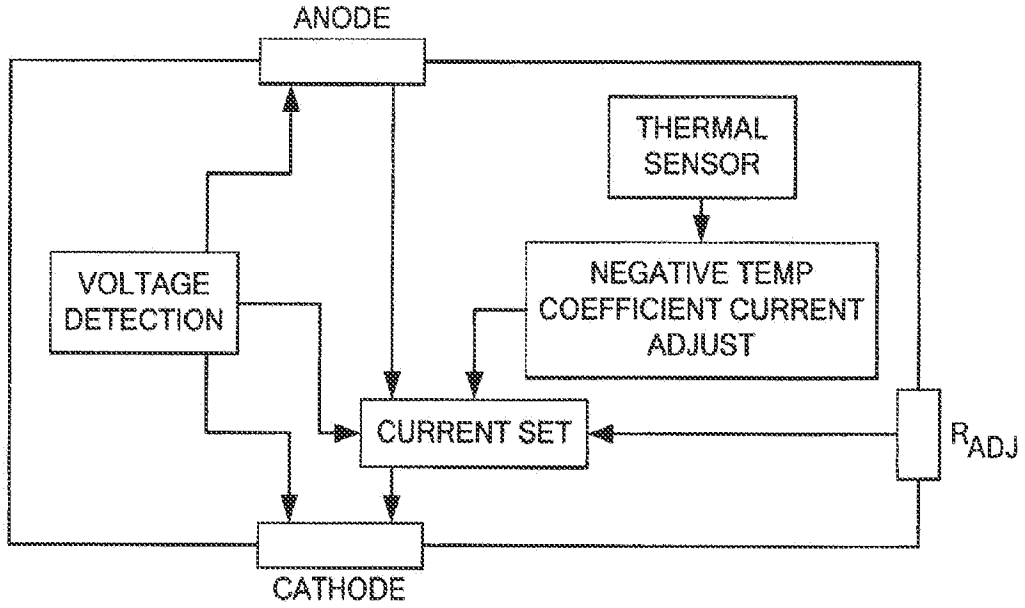


FIG. 2A

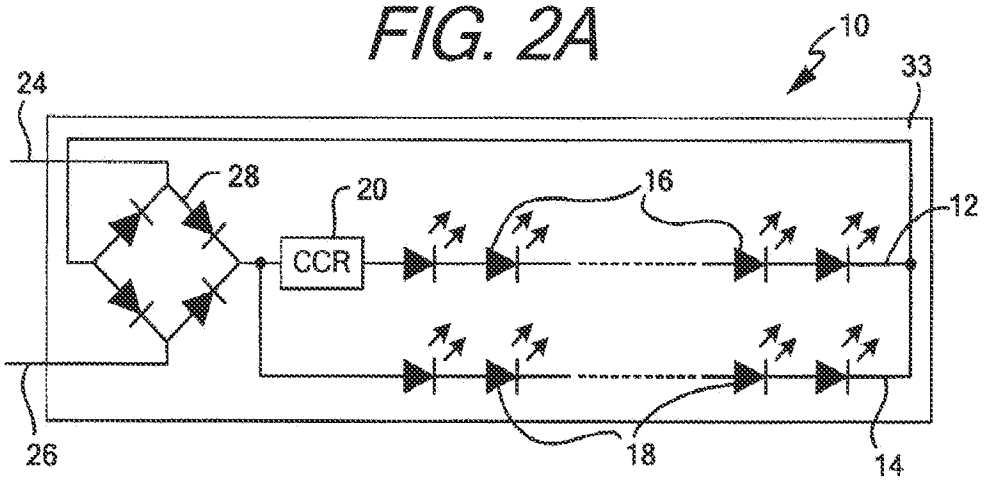


FIG. 2B

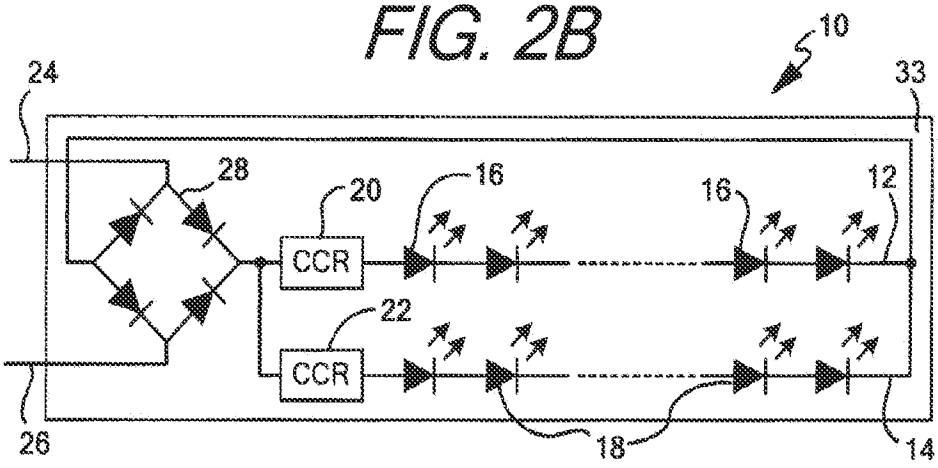


FIG. 3A

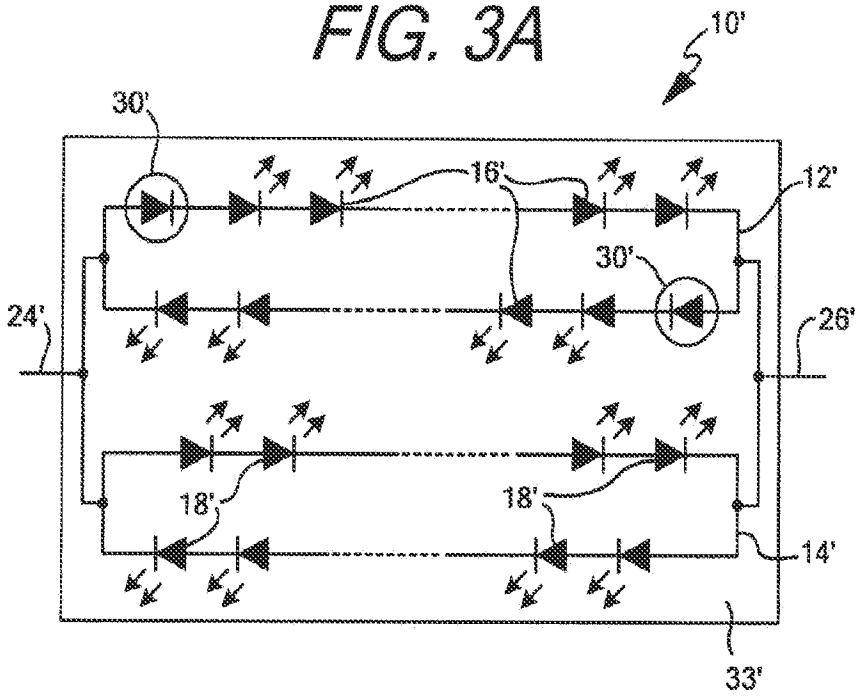


FIG. 3B

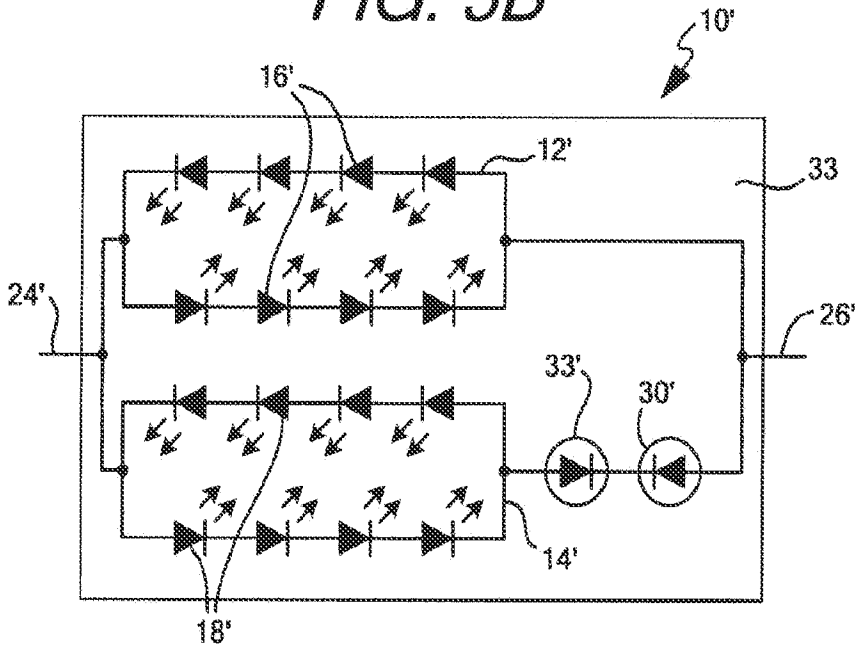


FIG. 4

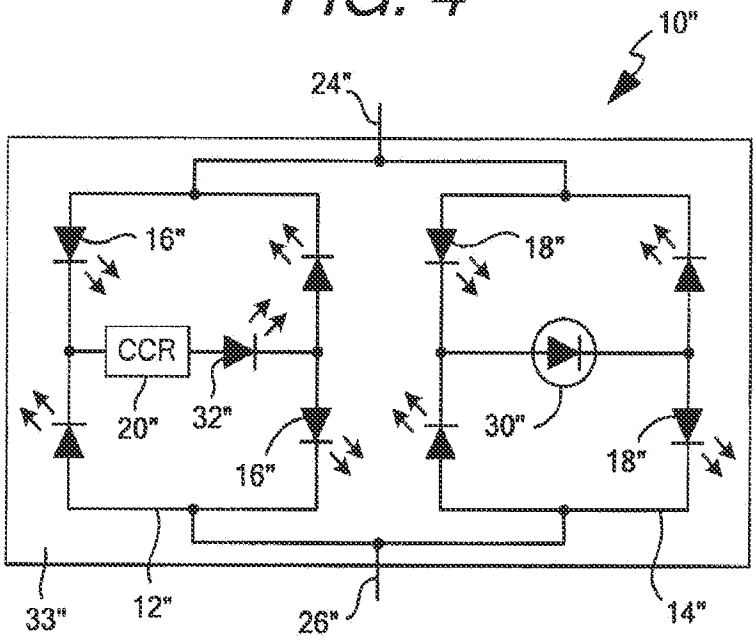

10"
24"
16"
18"
CCR
20"
32"
16"
30"
18"
33"
12"
26"
14"

FIG. 5

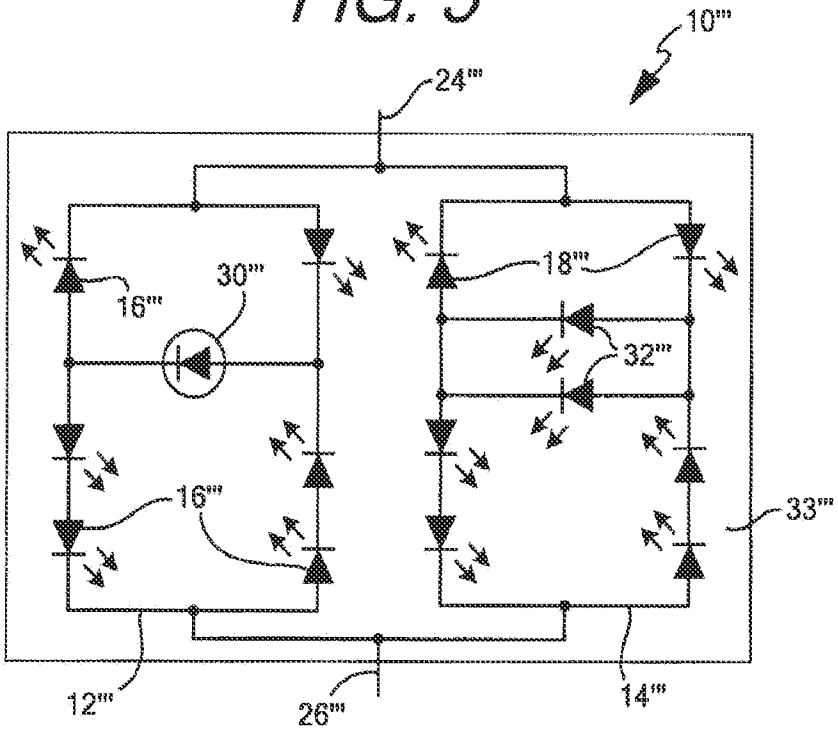

10'''
24'''
16'''
30'''
18'''
32'''
16'''
33'''
12'''
26'''
14'''

FIG. 6

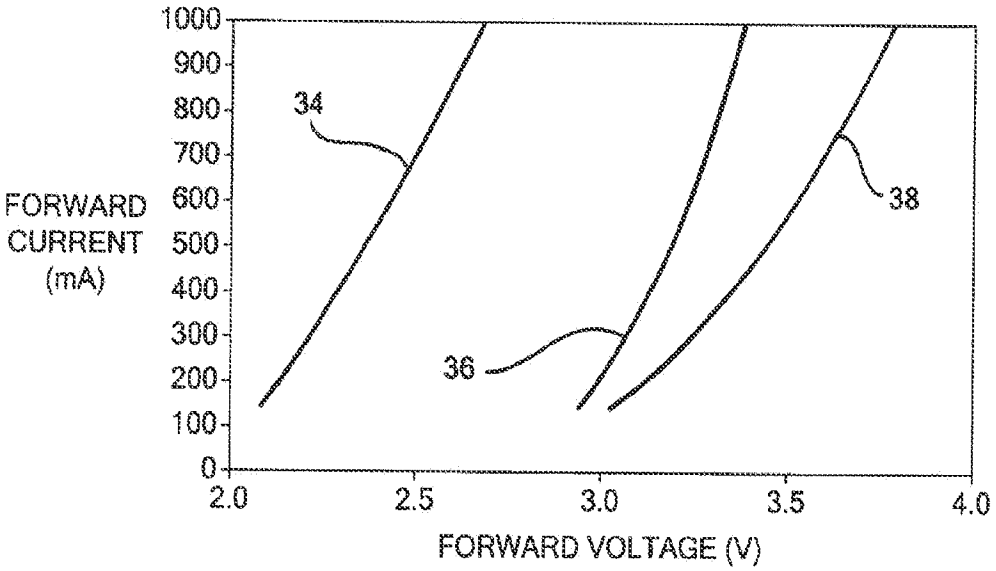

1000
900
800
700
600
500
400
300
200
100
0
FORWARD CURRENT (mA)
34
36
38
2.0
2.5
3.0
3.5
4.0
FORWARD VOLTAGE (V)

FIG. 7

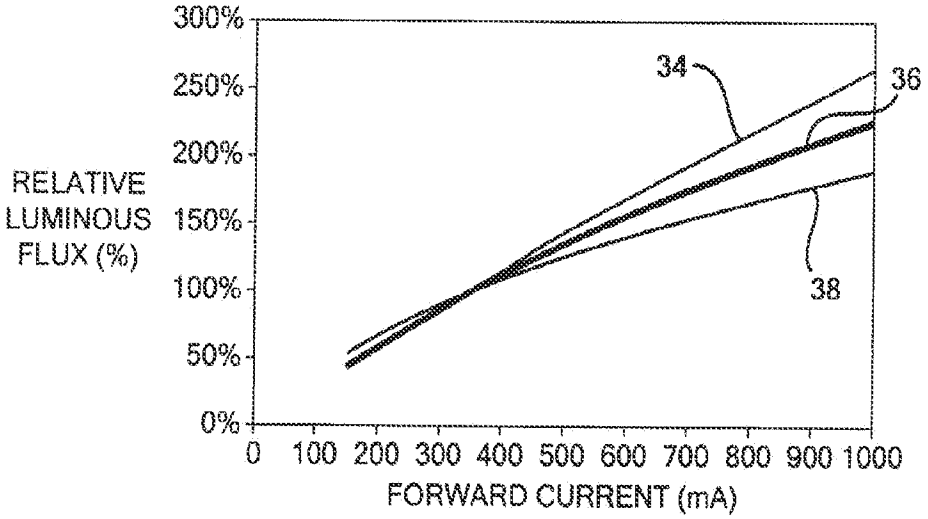

300%
250%
200%
150%
100%
50%
0%
RELATIVE LUMINOUS FLUX (%)
34
36
38
0 100 200 300 400 500 600 700 800 900 1000
FORWARD CURRENT (mA)

FIG. 8

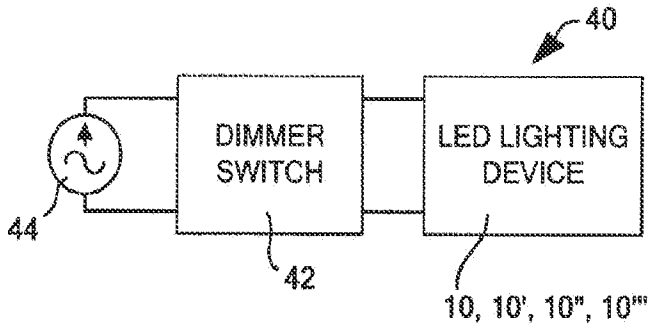


FIG. 9

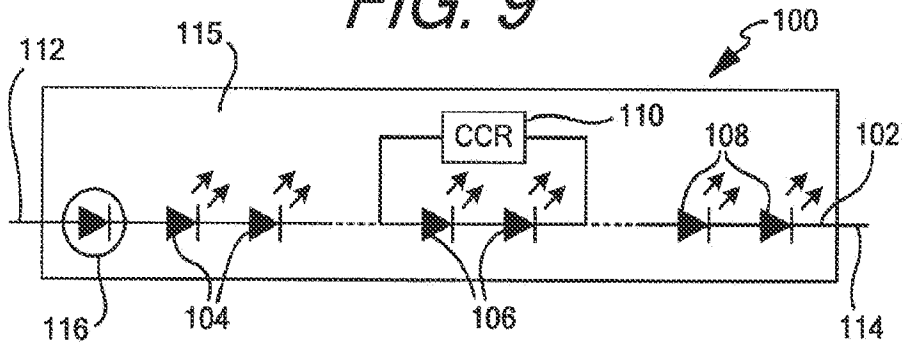


FIG. 10

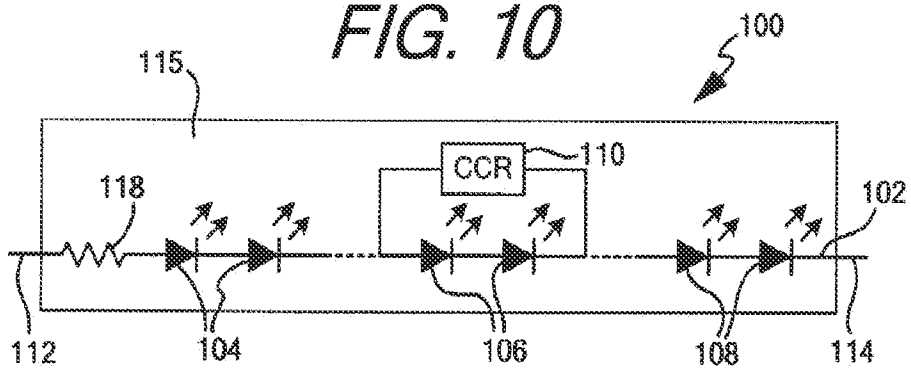
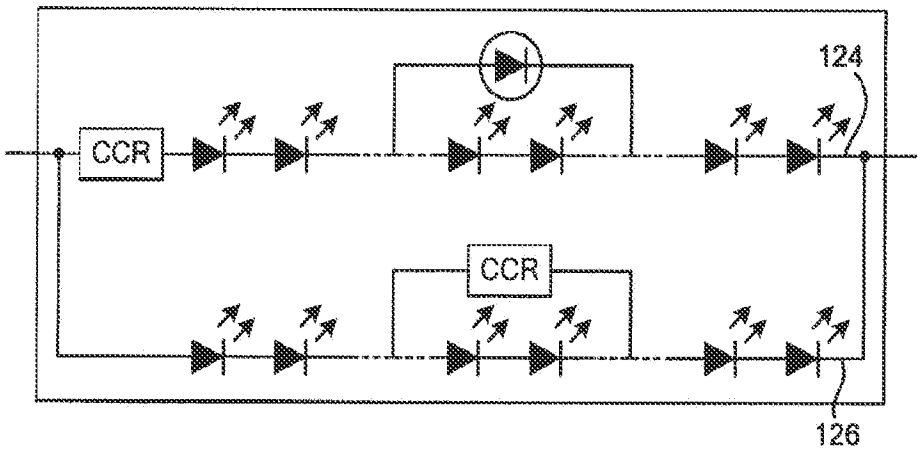


FIG. 11



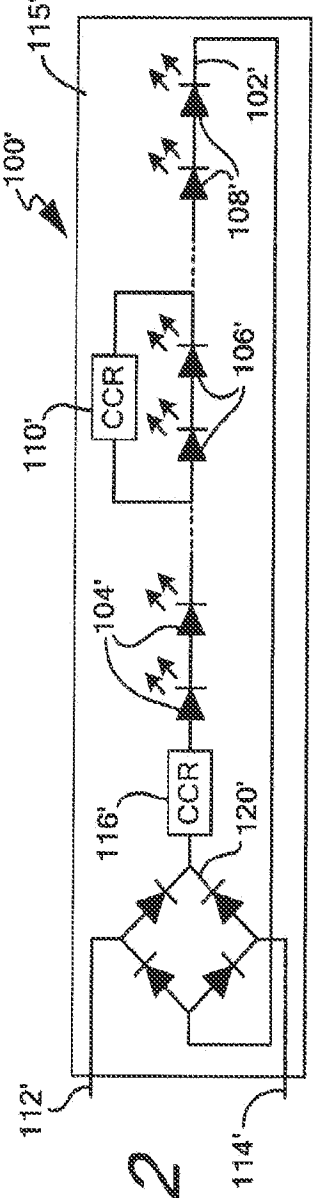


FIG. 12

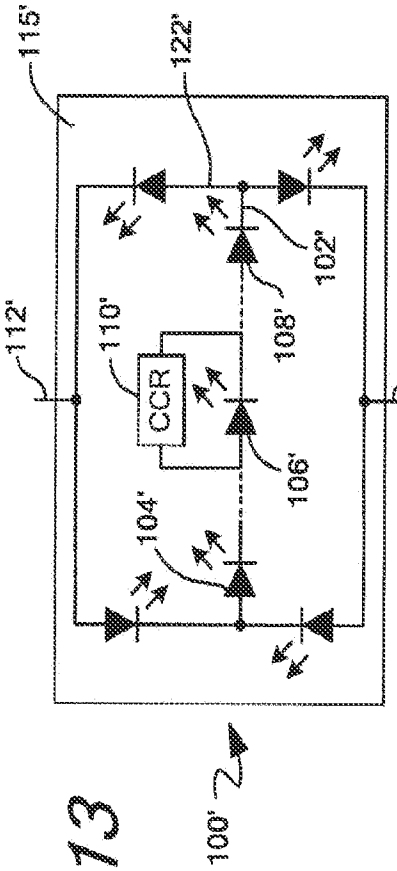


FIG. 13

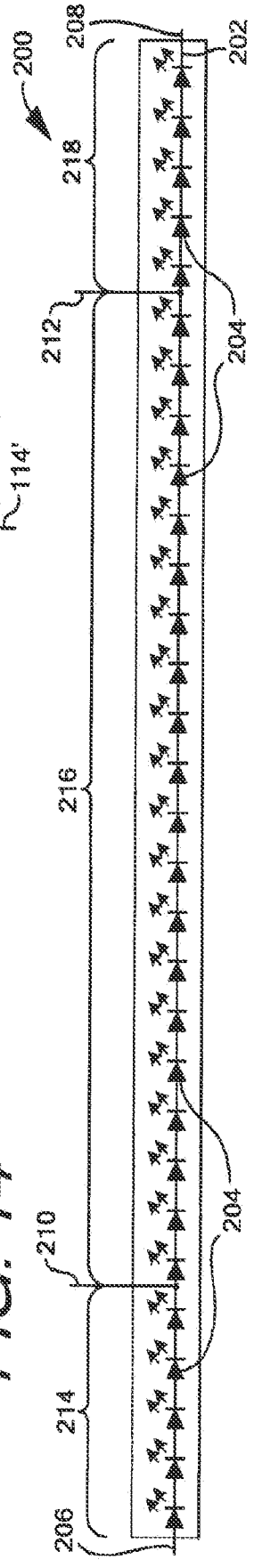


FIG. 14

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FIG. 15

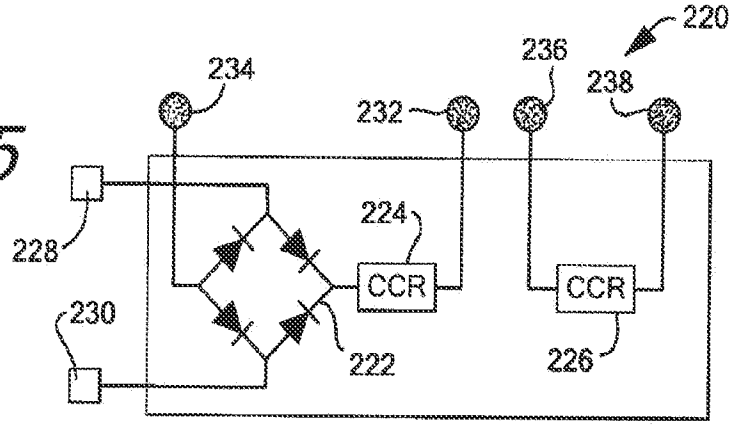


FIG. 16

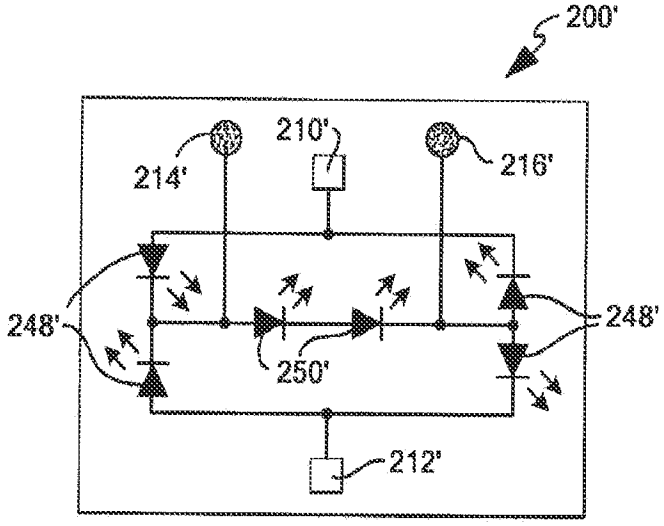


FIG. 17

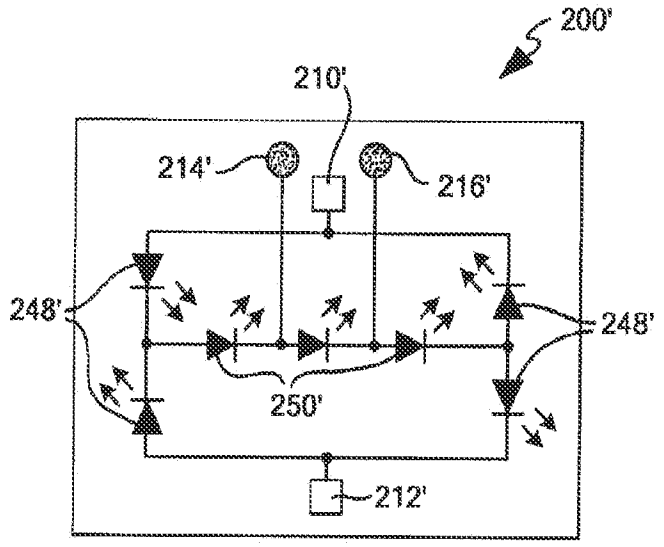


FIG. 18
PRIOR ART

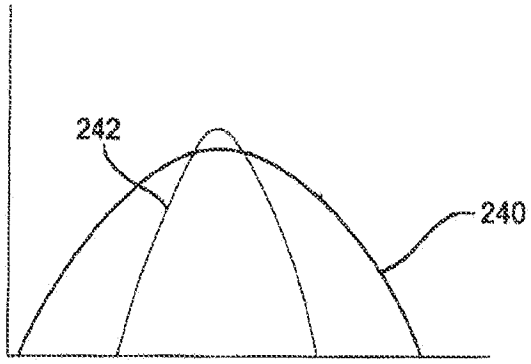
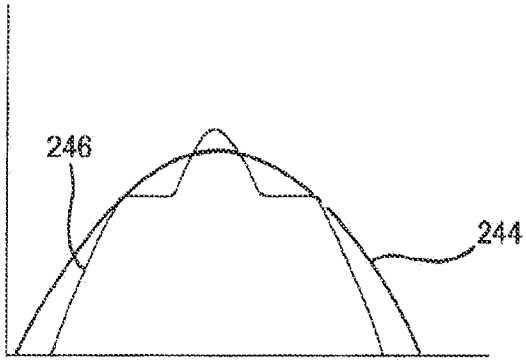


FIG. 19



INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 12/67623

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - H05B 37/00, H05B 39/00 (2012.01)
USPC - 315/192
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC(8): H05B 37/00, H05B 39/00 (2012.01)
USPC: 315/192

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
IPC(8): H05B 37/00, H05B 39/00 (2012.01) (keyword limited, see terms below)
USPC: 315/64, 69, 185, 192 (keyword limited, see terms below)

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
PatBase, Google Scholar, PubWest (PGPB,USPT,EPAB,JPAB) Search terms used: LED, light, emitting, diode, lighting, color, wavelength, AC, alternating, current, limit, regulate, series, parallel, lead, harmonic, vary, modify, adjust, increase, decrease, anode, cathode, substrate, temperature, controlled, low, thd, distortion, bypass, Lynk Labs, Michae

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X --- Y	WO 2010/13821 1 A1 (Miskin et al.) 02 December 2010 (02.12.2010) entire document, especially: Fig 3, 8, para [0015], [0023]-[0028], [0053], [0054], [0058]	30-34, 36-38 --- 1-4, 17-23, 39, 40
Y	US 2010/0109558 A1 (CHEW) 06 May 2010 (06.05.2010) para [0092]-[0094], [0140], [0149]	1-4, 17-23, 39, 40
A	US 2007/0273299 A1 (MISKIN et al.) 29 November 2007 (29.11.2007) entire document	1-4, 17-23, 30-34, 36-40

☐ Further documents are listed in the continuation of Box C. ☐

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
21 January 2013 (21.01.2013)	19 FEB 2013
Name and mailing address of the ISA/US Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-3201	Authorized officer: Lee W. Young PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774

Form PCT/ISA/210 (second sheet) (July 2009)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 12/67623

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☒ Claims Nos.: 41-44
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

because they are improper omnibus claims, not drafted in accordance with Rule 6.2(a).

3. ☒ Claims Nos.: 5-16, 24-29, 35
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.

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Espacenet

Bibliographic data: JP2011159495 (A) — 2011-08-18

LIGHTING SYSTEM

Inventor(s): UCHIO SEIICHIRO ± (UCHIO SEIICHIRO)

Applicant(s): KAGA ELECTRONICS CO LTD ± (KAGA ELECTRONICS CO LTD)

Classification: **- international:** ***F21S2/00; H05B37/02;*** *F21Y101/02*
- cooperative:

Application number: JP20100020309 20100201 Global Dossier

Priority number(s): JP20100020309 20100201

Abstract of JP2011159495 (A)

PROBLEM TO BE SOLVED: To provide an LED lighting system stably operating LEDs (light emitting diodes) regardless of the fluctuation of AC voltage. ;SOLUTION: The LED lighting system has: a first LED group 10 constituted by connecting LEDs 10-1, 10-2, ..., 10-m, 10-n in series; a second LED group 20 constituted by connecting LEDs 20-1, 20-2, ..., 20-m, 20-n in series; a first constant current diode 12 connected to the LED 10-n of the first LED group 10; and a second constant current diode 22 connected to the LED 20-n of the second LED group 20. ;COPYRIGHT: (C)2011,JPO&INPIT

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(54) **Power surface mount light emitting die package**

Oberflächenmontiertes Gehäuse für lichtemittierenden Leistungschip

Ensemble de puces photoémettrices de puissance à montage en surface

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US-A- 4 152 618
US-A1- 2002 084 462
US-B1- 6 318 886

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Description

[0001] The present invention relates to a light-emitting die package.

[0002] From U.S. 2002/0084462 A1 a light-emitting die package is known which includes a light emitter, a light reflection member, and a resin sealing the light emitter by covering the light reflection member and the light emitter. Light deviated from a predetermined front region in the light emitted from the light emitter is totally reflected by a boundary surface of the resin to be forwardly emitted by the light reflection member, and the emitter is thermally contacted with the reflection member to dissipate the heat generated from the light emitter. Particularly, the lens is integrally formed with the encapsulating mold resin.

[0003] Light emitting diodes (LEDS) are often packaged within leadframe packages. A leadframe package typically includes a molded or cast plastic body that encapsulates an LED, a lens portion, and thin metal leads connected to the LED and extending outside the body. The metal leads of the leadframe package serve as the conduit to supply the LED with electrical power and, at the same time, may act to draw heat away from the LED. Heat is generated by the LED when power is applied to the LED to produce light. A portion of the leads extends out from the package body for connection to circuits external to the leadframe package.

[0004] Some of the heat generated by the LED is dissipated by the plastic package body; however, most of the heat is drawn away from the LED via the metal components of the package. The metal leads are typically very thin and has a small cross section. For this reason, capacity of the metal leads to remove heat from the LED is limited. This limits the amount of power that can be sent to the LED thereby limiting the amount of light that can be generated by the LED.

[0005] To increase the capacity of an LED package to dissipate heat, in one LED package design, a heat sink slug is introduced into the package. The heat sink slug draws heat from the LED chip. Hence, it increases the capacity of the LED package to dissipate heat. However, this design introduces empty spaces within the package that is be filled with an encapsulant to protect the LED chip. Furthermore, due to significant differences in CTE (coefficient of thermal expansion) between various components inside the LED package, bubbles tend to form inside the encapsulant or the encapsulant tends to delaminate from various portions within the package. This adversely affects the light output and reliability of the product. In addition, this design includes a pair of flimsy leads which are typically soldered by a hot-iron. This manufacturing process is incompatible with convenient surface mounting technology (SMT) that is popular in the art of electronic board assembly.

[0006] In another LED package design, the leads of the leadframe package have differing thicknesses extended (in various shapes and configurations) beyond the immediate edge of the LED package body. A thicker lead is utilized as a heat-spreader and the LED chip is mounted on it. This arrangement allows heat generated by the LED chip to dissipate through the thicker lead which is often connected to an external heat sink. This design is inherently unreliable due to significant difference in coefficient of thermal expansion (CTE) between the plastic body and the leadframe material. When subjected to temperature cycles, its rigid plastic body that adheres to the metal leads experiences high degree of thermal stresses in many directions. This potentially leads to various undesirable results such as cracking of the plastic body, separation of the plastic body from the LED chip, breaking of the bond wires, delaminating of the plastic body at the interfaces where it bonds to various parts, or resulting in a combination of these outcomes. In addition, the extended leads increase the package size and its footprint. For this reason, it is difficult to populate these LED packages in a dense cluster on a printed circuit board (PCB) to generate brighter light.

[0007] Another disadvantage of the current leadframe design is that the thick lead cannot be made or stamped into a fine circuit for flip-chip mounting of a LED - which is commonly used by some manufacturers for cost-effective manufacturing and device performance.

[0008] Consequently, there remains a need for an improved LED package that overcomes or alleviates one or more of the shortcomings of the prior art packages.

SUMMARY

[0009] The need is met by the present invention as defined in independent claim 1. Embodiments of the present invention provide a package for a semiconductor die such as a light emitting diode, the package including a substrate having traces for connecting to a light emitting diode at a mounting pad, a reflector plate coupled to the substrate and substantially surrounding the mounting pad, and lens substantially covering the mounting pad.

[0010] Other embodiments of the present invention provide a semiconductor die package includes a bottom heat sink and a top heat sink. The bottom heat sink has traces on its top surface. A semiconductor chip is mounted on the top surface of the bottom heat sink and electrically connected to the traces. The top heat sink is coupled to the bottom heat sink.

[0011] Other aspects and advantages of the present invention will become apparent from the following detailed description, taken in conjunction with the accompanying drawings, illustrating by way of example the principles of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] Figure 1A is a perspective view of a semiconductor die package according to one embodiment of the present invention;

[0013] Figure 1B is an exploded perspective view of

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the semiconductor package of Figure 1A;

[0014] Figure 2A is a top view of a portion of the semiconductor package of Figure 1A;

[0015] Figure 2B is a side view of a portion of the semiconductor package of Figure 1A;

[0016] Figure 2C is a front view of a portion of the semiconductor package of Figure 1A;

[0017] Figure 2D is a bottom view of a portion of the semiconductor package of Figure 1A;

[0018] Figure 3 is a cut-away side view of portions of the semiconductor package of Figure 1A;

[0019] Figure 4 is a side view of the semiconductor package of Figure 1A with additional elements;

[0020] Figure 5 an exploded perspective view of a semiconductor die package according to another embodiment of the present invention;

[0021] Figure 6A is a top view of a portion of the semiconductor package of Figure 5;

[0022] Figure 6B is a side view of a portion of the semiconductor package of Figure 5;

[0023] Figure 6C is a front view of a portion of the semiconductor package of Figure 5; and

[0024] Figure 6D is a bottom view of a portion of the semiconductor package of Figure 5.

DETAILED DESCRIPTION

[0025] The present invention will now be described with reference to the Figures 1 through 6D, which illustrate various embodiments of the present invention. As illustrated in the Figures, the sizes of layers or regions are exaggerated for illustrative purposes and, thus, are provided to illustrate the general structures of the present invention. Furthermore, various aspects of the present invention are described with reference to a layer or structure being formed on a substrate or other layer or structure. As will be appreciated by those of skill in the art, references to a layer being formed "on" another layer or substrate contemplates that additional layers may intervene. References to a layer being formed on another layer or substrate without an intervening layer are described herein as being formed "directly on" the layer or substrate. Furthermore, relative terms such as beneath may be used herein to describe one layer or regions relationship to another layer or region as illustrated in the Figures. It will be understood that these terms are intended to encompass different orientations of the device in addition to the orientation depicted in the Figures. For example, if the device in the Figures is turned over, layers or regions described as "beneath" other layers or regions would now be oriented "above" these other layers or regions. The term "beneath" is intended to encompass both above and beneath in this situation. Like numbers refer to like elements throughout.

[0026] As shown in the figures for the purposes of illustration, embodiments of the present invention are exemplified by a light emitting die package including a bottom heat sink (substrate) having traces for connecting to a light emitting diode at a mounting pad and a top heat sink (reflector plate) substantially surrounding the mounting pad. A lens covers the mounting pad. In effect, the die package according to some embodiments of the present invention comprises a two part heat sink with the bottom heat sink utilized (in additional to its utility for drawing and dissipating heat) as the substrate on which the LED is mounted and connected, and the top heat sink utilized (in additional to its utility for drawing and dissipating heat) as a reflector plate to direct light produced by the LED. Because both the bottom and the top heat sinks draw heat away from the LED, more power can be delivered to the LED, and the LED can thereby produce more light.

[0027] Further, in the present invention, the body of the die package itself may act as the heat' sink removing heat from the LED and dissipating it. For this reason, the LED die package of the present invention may not require a separate heat sink slugs or leads that extend away from the package. Accordingly, the LED die package of the present invention may be more compact, more reliable, and less costly to manufacture than the die packages of the prior art.

[0028] Figure 1A is a perspective view of a semiconductor die package 10 according to one embodiment of the present invention and Figure 1B is an exploded perspective view of the semiconductor package of Figure 1A. Referring to Figures 1A and 1B, the light emitting die package 10 of the present invention includes a bottom heat sink 20, a top heat sink 40, and a lens 50.

[0029] The bottom heat sink 20 is illustrated in more detail in Figures 2A through 2D. Figures 2A, 2B, 2C, and 2D provide, respectively, a top view, a side view, a front view, and a bottom view of the bottom heat sink 20 of Figure 1A. Further, Figure 2C also shows an LED assembly 60 in addition to the front view of the bottom heat sink 20. The LED assembly 60 is also illustrated in Figure 1B. Referring to Figures 1A through 2D, the bottom heat sink 20 provides support for electrical traces 22 and 24; for solder pads 26, 32, and 34; and for the LED assembly 60. For this reason, the bottom heat sink 20 is also referred to as a substrate 20. In the Figures, to avoid clutter, only representative solder pads 26, 32, and 34 are indicated with reference numbers. The traces 22 and 24 and the solder pads 32, 34, and 36 can be fabricated using conductive material. Further, additional traces and connections can be fabricated on the top, side, or bottom of the substrate 20, or layered within the substrate 20. The traces 22 and 24, the solder pads 32, 34, and 36, and any other connections can be interconnected to each other in any combinations using known methods, for example via holes.

[0030] The substrate 20 is made of material having high thermal conductivity but is electrically insulating, for example, aluminum nitride (AlN) or alumina (Al_2O_3). Dimensions of the substrate 20 can vary widely depending on application and processes used to manufacture the die package 10. For example, in the illustrated embodi-

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ment, the substrate 20 may have dimensions ranging from fractions of millimeters (mm) to tens of millimeters. Although the present invention is not limited to particular dimensions, one specific embodiment of the die package 10 of the present invention is illustrated in Figures having the dimensions denoted therein. All dimensions shown in the Figures are in millimeters (for lengths, widths, heights, and radii) and degrees (for angles) except as otherwise designated in the Figures, in the Specification herein, or both.

[0031] The substrate 20, in the illustrated embodiment, has a top surface 21, the top surface 21 including the electrical traces 22 and 24. The traces 22 and 24 provide electrical connections from the solder pads (for example top solder pads 26) to a mounting pad 28. The top solder pads 26 are portions of the traces 22 and 24 generally proximal to sides of the substrate 20. The top solder pads 26 are electrically connected to side solder pads 32. The mounting pad 28 is a portion of the top surface (including portions of the trace 22, the trace 24, or both) where the LED assembly 60 is mounted. Typically the mounting pad 28 is generally located proximal to center of the top surface 21. In alternative embodiments of the present invention, the LED assembly 60 can be replaced by other semiconductor circuits or chips.

[0032] The traces 22 and 24 provide electrical routes to allow the LED assembly 60 to electrically connect to the solder pads 26, 32, or 34. Accordingly, some of the traces are referred to as first traces 22 while other traces are referred to as second traces 24. In the illustrated embodiment, the mounting pad 28 includes portions of both the first traces 22 and the second traces 24. In the illustrated example, the LED assembly 60 is placed on the first trace 22 portion of the mounting pad 28 thereby making contact with the first trace 22. In the illustrated embodiment, top of the LED assembly 60 and the second traces 24 are connected to each other via a bond wire 62. Depending on the construction and orientation of LED assembly 60, first traces 22 may provide anode (positive) connections and second traces 24 may comprise, cathode (negative) connections for the LED assembly 60 (or vice versa).

[0033] The LED assembly 60 can include additional elements. For example, in Figures 1B and 2C, the LED assembly 60 is illustrated including the LED bond wire 62, an LED subassembly 64, and a light emitting diode (LED) 66. Such LED subassembly 64 is known in the art and is illustrated for the purposes of discussing the invention and is not meant to be a limitation of the present invention. In the Figures, the LED assembly 60 is shown die-attached to the substrate 20. In alternative embodiments, the mounting pad 28 can be configured to allow flip-chip attachment of the LED assembly 60. Additionally, multiple LED assemblies can be mounted on the mounting pad 28. In alternative embodiments, the LED assembly 60 can be mounted over multiple traces. This is especially true if flip-chip technology is used.

[0034] The topology of the traces 22 and 24 can vary widely from the topology illustrated in the Figures while still remaining within the scope of the present invention. In the Figures, three separate cathode (negative) traces 24 are shown to illustrate that three LED assemblies can be placed on the mounting pad 28, each connected to a different cathode (negative) trace; thus, the three LED assemblies may be separately electrically controllable. The traces 22 and 24 are made of conductive material such as gold, silver, tin, or other metals. The traces 22 and 24 can have dimensions as illustrated in the Figures and having thickness in the order of microns or tens of microns depending on application. For example, the traces 22 and 24 can be 15 microns thick. Figures 1A and 2A illustrate an orientation marking 27. Such markings can be used to identify the proper orientation of the die package 10 even after assembling the die package 10. The orientation marking 27 is not a via or a through hole. The traces 22 and 24, as illustrated, can extend from the mounting pad 28 to sides of the substrate 20.

[0035] Continuing to refer to Figures 1A through 2D, the substrate 20 defines semi-cylindrical spaces 23 and quarter-cylindrical spaces 25 proximal to its sides. In the Figures, to avoid clutter, only representative spaces 23 and 25 are indicated with reference numbers. The semi-cylindrical spaces 23 and the quarter-cylindrical spaces 25 provide spaces for solder to flow-through and solidify-in when the die package 10 is attached to a printed circuit board (PCB) or another apparatus (not shown) to which the die package 10 is a component thereof. Moreover, the semi-cylindrical spaces 23 and the quarter-cylindrical spaces 25 provide convenient delineation and break points during the manufacturing process.

[0036] The substrate 20 can be manufactured as one individual section of a strip or a plate having a plurality of adjacent sections, each section being a substrate 20. Alternatively, the substrate 20 can be manufactured as one individual section of an array of sections, the array having multiple rows and columns of adjacent sections. In such configuration, the semi-cylindrical spaces 23 and quarter-cylindrical spaces 25 can be utilized as tooling holes for the strip, the plate, or the array during the manufacturing process.

[0037] Furthermore, the semi-cylindrical spaces 23 and the quarter-cylindrical spaces 25, combined with scribed grooves or other etchings between the sections, assist in separating each individual substrate from the strip, the plate, or the wafer. The separation can be accomplished by introducing physical stress to the perforation (semi through holes at a close pitch) or scribe lines made by laser, or premolded, or etched lines (crossing the semi-cylindrical spaces 23 and the quarter-cylindrical spaces 25) by bending the strip, the plate, or the wafer. These features simplify the manufacturing process thus reducing costs by eliminating the need for special carrier fixtures to handle individual unit of the substrate 20 during the manufacturing process. Furthermore, the semi-cylindrical spaces 23 and the quarter-cylindrical spaces 25 serve as via holes connecting the top solder pads 26, the

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side solder pads 32, and the bottom solder pads 34.

[0038] The substrate 20 has a bottom surface 29 including a thermal contact pad 36. The thermal contact pad 36 can be fabricated using material having high thermally and electrically conductive material such as gold, silver, tin, or other material including but not limited to precious metals.

[0039] Figure 3 illustrates a cut-away side view of portions of the semiconductor package of Figures 1A and 1B. In particular, the Figure 3 illustrates a cut-away side view of the top heat sink 40 and the lens 50. Referring to Figures 1A, 1B, and 3, the top heat sink 40 is made from material having high thermal conductivity such as aluminum, copper, ceramics, plastics, composites, or a combination of these materials. A high temperature, mechanically tough, dielectric material can be used to overcoat the traces 22 and 24 (with the exception of the central die-attach area) to seal the traces 22 and 24 and provide protection from physical and environmental harm such as scratches and oxidation. The overcoating process can be a part of the substrate manufacturing process. The overcoat, when used, may insulate the substrate 20 from the top heat sink 40. The overcoat may then be covered with a high temperature adhesive such as thermal interface material manufactured by THERMOSET that bonds the substrate 20 to the top heat sink 40.

[0040] The top heat sink 40 may include a reflective surface 42 substantially surrounding the LED assembly 60 mounted on the mounting pad 28 (of Figures 2A and 2C). When the top heat sink 40 is used to dissipate heat generated by the LED in the die package 10, it can be "top-mounted" directly on to an external heat sink by an adhesive or solder joint to dissipate heat efficiently. In another embodiment, if heat has to be dissipated by either a compressible or non-compressible medium such as air or cooling fluid, the top heat sink 40 may be made to equip with cooling fins or any feature that will enhance heat transfer between the top heat sink 40 and the cooling medium. In both of these embodiments, the electrical terminals and the bottom heat sink 20 of the die package 10, can still be connected to its application printed circuit board (PCB) using, for example, the normal surface-mount-technology (SMT) method.

[0041] The reflective surface 42 reflects portions of light from the LED assembly 60 as illustrated by sample light rays 63. Other portions of the light are not reflected by the reflective surface 42 as illustrated by sample light ray 61. Illustrative light rays 61 and 63 are not meant to represent light traces often use in the optical arts. For efficient reflection of the light, the top heat sink 40 is preferably made from material that can be polished, coined, molded, or any combination of these. Alternatively, to achieve high reflectivity, the optical reflective surface 42 or the entire heat sink 40 can be plated or deposited with high reflective material such as silver, aluminum, or any substance that serves the purpose. For this reason, the top heat sink 40 is also referred to as a reflector plate 40. The reflector plate 40 is made of material having high thermal conductivity if and when required by the thermal performance of the package 10. In the illustrated embodiment, the reflective surface 42 is illustrated as a flat surface at an angle, for example 45 degrees, relative to the reflective plate's horizontal plane. The present invention is not limited to the illustrated embodiment. For example, the reflective surface 42 can be at a different angle relative to the reflective plate's horizontal plane. Alternatively, the reflective plate can have a parabolic, toroid or any other shape that helps to meet the desired spectral luminous performance of the package.

[0042] The reflective plate 40 includes a ledge 44 for supporting and coupling with the lens 50. The LED assembly 60 is encapsulated within the die package 10 (of Figures 1A and 1B) using encapsulation material 46 such as, for example only, soft and elastic silicones or polymers. The encapsulation material 46 is preferably high temperature polymer with high light transmissivity and refractive index that matches or closely matches refractive index of the lens 50. The encapsulant 46 is preferably not affected by most wavelengths that alter its light transmissivity or clarity.

[0043] The lens 50 is made from material having high light transmissivity such as, for example only, glass, quartz, high temperature and transparent plastic, or a combination of these materials. The lens 50 is placed on top of and adheres to the encapsulation material 46. The lens 50 is not rigidly bonded to the reflector 40. This "floating lens" design will ensure that the encapsulant 46 can expand and contract under high and low temperature conditions without problem. For instance, when the die package 10 is operating or being subjected to high temperature environment, encapsulant 46 experiences greater volumetric expansion than the cavity space that contains it. By allowing the lens 50 to float up somewhat freely on top of the encapsulant 46, no encapsulant will be squeezed out of its cavity space. Likewise, when the die package 10 is subjected to cold temperature, the encapsulant 46 will contract more than the other components that make up the cavity space for the encapsulant 46; the lens will float freely on top of the encapsulant 46 as the latter shrinks and its level drops. Hence, the reliability of the die package 10 is maintained over a relatively large temperature ranges as the thermal stresses induced on its encapsulant 46 is reduced by the floating lens design.

[0044] In some embodiments, the lens 50 defines a recess 52 having a curved, hemispherical, or other geometry, which can be filled with optical materials intended to influence or change the nature of the light emitted by the LED chip(s) before it leaves the die package 10. Examples of one type of optical materials are luminescence converting phosphors, dyes, fluorescent polymers or other materials which absorb some of the light emitted by the chip(s) and re-emit light of different wavelengths. Examples of another type of optical materials are light diffusants such as calcium carbonate, scattering particles (such as Titanium oxides) or voids which disperse or scat-

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ter light. Any single or combination of the above materials can be applied on the lens to obtain certain spectral luminous performance.

[0045] Figure 4 illustrates the die package 10 coupled to an external heat sink 70. Referring to Figure 4, the thermal contact pad 36 can be attached to the external heat sink 70 using epoxy, solder, or any other thermally conductive adhesive, electrically conductive adhesive, or thermally and electrically conductive adhesive 74. The external heat sink 70 can be a printed circuit board (PCB) or other structure that draws heat from the die package 10. The external heat sink can include circuit elements (not shown) or heat dissipation fins 72 in various configurations.

[0046] An embodiment of the invention having certain alternate configuration is shown in Figures 5 through 6D. Portions of this second embodiment are similar to corresponding portions of the first embodiment illustrated in Figures 1A through 4. For convenience, portions of the second embodiment as illustrated in Figures 5 through 6D that are similar to portions of the first embodiment are assigned the same reference numerals, analogous but changed portions are assigned the same reference numerals accompanied by letter "a," and different portions are assigned different reference numerals.

[0047] Figure 5 is an exploded perspective view of an LED die package 10a in accordance with other embodiments of the present invention. Referring to Figure 5, the light emitting die package 10a of the present invention includes a bottom heat sink (substrate) 20a, a top heat sink (reflector plate) 40a, and a lens 50.

[0048] Figures 6A, 6B, 6C, and 6D, provide, respectively, a top view, a side view a front view, and a bottom view of the substrate 20a of Figure 5. Referring to Figures 5 through 6D, in the illustrated embodiment, the substrate 20a includes one first trace 22a and four second traces 24a. These traces 22a and 24a have are configured differently than the traces 22 and 24 of Figure 2A. The substrate 20a includes flanges 31 that define latch spaces 33 for reception of legs 35 of the reflector plate 40a thereby mechanically engaging the reflector plate 40a with the substrate 20a.

Claims

1. A light emitting die package (10; 10a), comprising:

   a substrate (20; 20a) supporting an LED chip (66) thereon that is encapsulated within a encapsulant (46);
   a reflector plate (40; 40a) on the substrate, said reflector plate (40; 40a) substantially surrounding the LED chip (66) and having a circular-opening which forms a circular sidewall within the reflector plate; and
   a lens (50) which sits within the opening on top of the encapsulant and which adheres to the encapsulant, the lens being free to move relative to the circular sidewall of the reflector plate as the encapsulant expands and contracts.

2. A light emitting die package (10, 10a) according to claim 1, wherein each of the substrate (20, 20a) and reflector plate (40, 40a) have a heat sink capability to draw away heat generated by the LED chip (66) during package operation.

3. A light emitting die package (10; 10a) according to Claim 1, wherein the reflector plate (40; 40a) is mechanically coupled to the substrate (20; 20a).

4. A light emitting die package (10a) according to Claim 3, wherein the substrate (20a) includes flanges (31) along at least one side thereof for mechanically engaging the reflector plate (40a).

5. The light emitting die package (10a) of claim 4, wherein the reflector plate (40a) includes legs (35) for mechanically engaging the substrate (20a) between the flanges (31) for increased thermal contact area.

6. The light emitting die package (10; 10a) of claim 1, wherein the substrate (20; 20a) comprises an electrically insulating material having high thermal conductivity.

7. The light emitting die package (10; 10a) of claim 6, wherein the substrate (20; 20a) has a bottom side with a thermal contact pad (36) for coupling with an external heat sink (70).

8. The light emitting die package (10; 10a) of claim 7, further comprising an external heat sink (70) coupled to the substrate (20; 20a).

9. The light emitting die package (10; 10a) of claim 1, wherein the lens (50) is composed of a material selected from a group consisting of glass, quartz, and a high temperature plastic material.

10. The light emitting die package (10; 10a) of claim 1, wherein the lens (50) includes luminescence converting phosphors.

11. The light emitting die package (10; 10a) of claim 1, wherein the lens (50) includes an optical diffusant.

12. The light emitting die package of claim 1, wherein the lens (50) includes a phosphor.

Patentansprüche

1. Leuchtchip-Gehäuse (10; 10a), aufweisend:

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- ein Substrat (20; 20a), das einen LED-Chip (66) trägt, der in einer Kapsel (46) eingekapselt ist;
- eine Reflektorplatte (40; 40a) auf dem Substrat, wobei die Reflektorplatte (40; 40a) den LED-Chip (66) im Wesentlichen umgibt und eine kreisförmige Öffnung aufweist, die eine kreisförmige Seitenwand innerhalb der Reflektorplatte bildet; und
- eine Linse (50), die sich innerhalb der Öffnung oben auf der Kapsel befindet und an der Kapsel haftet, wobei die Linse relativ zu der kreisförmigen Seitenwand der Reflektorplatte frei beweglich ist, wenn sich die Kapsel ausdehnt und zusammenzieht.

2. Leuchtchip-Gehäuse (10; 10a) nach Anspruch 1, wobei jedes Element von Substrat (20, 20a) und Reflektorplatte (40, 40a) eine Wärmesenkkapazität aufweist, um während des Gehäusebetriebs erzeugte Wärme von dem LED-Chip (66) abzuführen.

3. Leuchtchip-Gehäuse (10; 10a) nach Anspruch 1, wobei die Reflektorplatte (40; 40a) mechanisch an das Substrat (20; 20a) gekoppelt ist.

4. Leuchtchip-Gehäuse (10a) nach Anspruch 3, wobei das Substrat (20a) entlang mindestens einer seiner Seiten Flansche (31) zum mechanischen Eingriff in die Reflektorplatte (40a) aufweist.

5. Leuchtchip-Gehäuse (10a) nach Anspruch 4, wobei die Reflektorplatte (40a) Schenkel (35) zum mechanischen Eingriff des Substrats (20a) zwischen den Flanschen (31) für eine vergrößerte Wärmekontaktfläche aufweist.

6. Leuchtchip-Gehäuse (10; 10a) nach Anspruch 1, wobei das Substrat (20; 20a) ein elektrisch isolierendes Material mit einer hohen Wärmeleitfähigkeit aufweist.

7. Leuchtchip-Gehäuse (10; 10a) nach Anspruch 6, wobei das Substrat (20; 20a) eine Unterseite mit einer Wärmekontaktfläche (36) zum Koppeln mit einer externen Wärmesenke (70) aufweist.

8. Leuchtchip-Gehäuse (10; 10a) nach Anspruch 7, ferner aufweisend eine externe Wärmesenke (70), die an das Substrat (20; 20a) gekoppelt ist.

9. Leuchtchip-Gehäuse (10; 10a) nach Anspruch 1, wobei die Linse (50) aus einem Material besteht, das ausgewählt ist aus einer Gruppe bestehend aus Glas, Quarz und einem Hochtemperatur-Kunststoffmaterial.

10. Leuchtchip-Gehäuse (10; 10a) nach Anspruch 1, wobei die Linse (50) Lumineszenz umwandelnde Phosphore aufweist.

11. Leuchtchip-Gehäuse (10; 10a) nach Anspruch 1, wobei die Linse (50) einen optischen Streukörper aufweist.

12. Leuchtchip-Gehäuse nach Anspruch 1, wobei die Linse (50) ein Phosphor aufweist.

Revendications

1. Boîtier de puce électroluminescent (10 ; 10a), comprenant :

   - un substrat (20 ; 20a) supportant une puce de LED (66) sur celui-ci qui est encapsulée dans un matériau d'encapsulation (46) ;
   - une plaque réflectrice (40 ; 40a) sur le substrat, ladite plaque réflectrice (40 ; 40a) entourant sensiblement la puce de LED (66) et comportant une ouverture circulaire qui forme une paroi latérale circulaire à l'intérieur de la plaque réflectrice ; et
   - une lentille (50) qui est logée dans l'ouverture au-dessus du matériau d'encapsulation et qui adhère au matériau d'encapsulation, la lentille étant libre de bouger par rapport à la paroi latérale circulaire de la plaque réflectrice lorsque le matériau d'encapsulation se dilate et se contracte.

2. Boîtier de puce électroluminescent (10 ; 10a) selon la revendication 1, dans lequel chacun du substrat (20 ; 20a) et de la plaque réflectrice (40 ; 40a) possède une capacité de dissipation de chaleur pour éloigner la chaleur générée par la puce de LED (66) pendant le fonctionnement du boîtier.

3. Boîtier de puce électroluminescent (10 ; 10a) selon la revendication 1, dans lequel la plaque réflectrice (40 ; 40a) est couplée mécaniquement au substrat (20 ; 20a).

4. Boîtier de puce électroluminescent (10a) selon la revendication 3, dans lequel le substrat (20a) comprend des brides (31) le long d'au moins un côté de celui-ci pour venir en prise mécaniquement avec la plaque réflectrice (40a).

5. Boîtier de puce électroluminescent (10a) selon la revendication 4, dans lequel la plaque réflectrice (40a) comprend des pattes (35) pour venir en prise mécaniquement avec le substrat (20a) entre les brides (31) afin d'augmenter la surface de contact thermique.

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6. Boîtier de puce électroluminescent (10 ; 10a) selon la revendication 1, dans lequel le substrat (20 ; 208) comprend un matériau électro-isolant présentant une conductivité thermique élevée.

7. Boîtier de puce électroluminescent (10 ; 10a) selon la revendication 6, dans lequel le substrat (20 ; 20a) a un côté inférieur muni d'une plage de contact thermique (36) pour le couplage avec un dissipateur de chaleur externe (70).

8. Boîtier de puce électroluminescent (10 ; 10a) selon la revendication 7, comprenant en outre un dissipateur de chaleur externe (70) couplé au substrat (20 ; 20a).

9. Boîtier de puce électroluminescent (10 ; 10a) selon la revendication 1, dans lequel la lentille (50) est composée d'un matériau choisi dans un groupe constitué par le verre, le quartz et une matière plastique haute température.

10. Boîtier de puce électroluminescent (10 ; 10a) selon la revendication 1, dans lequel la lentille (50) comprend des substances luminescentes de conversion de luminescence.

11. Boîtier de puce électroluminescent (10 ; 10a) selon la revendication 1, dans lequel la lentille (50) comprend un diffusant optique.

12. Boîtier de puce électroluminescent selon la revendication 1, dans lequel la lentille (50) comprend une substance luminescente.

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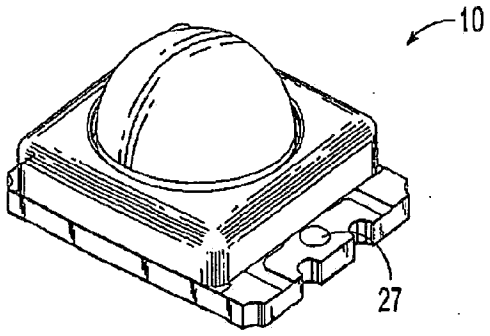


FIG. 1A

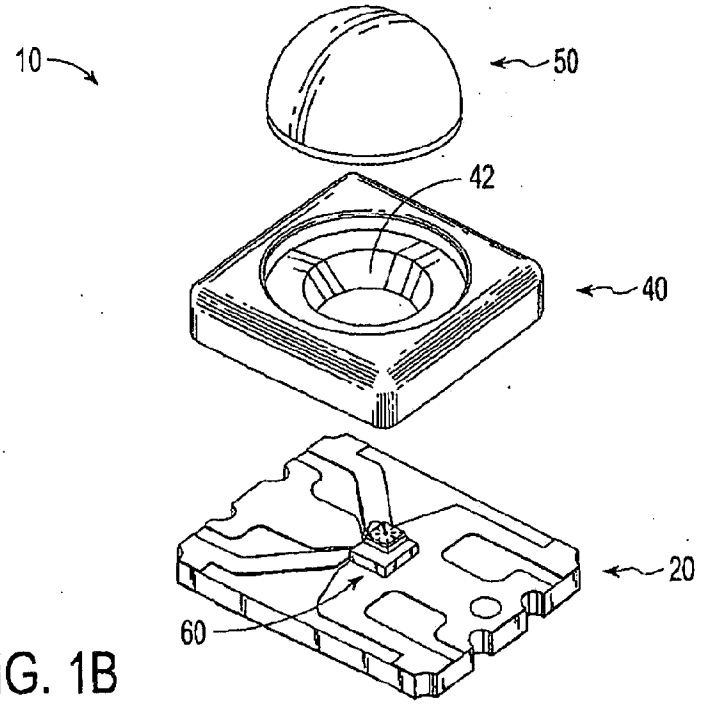


FIG. 1B

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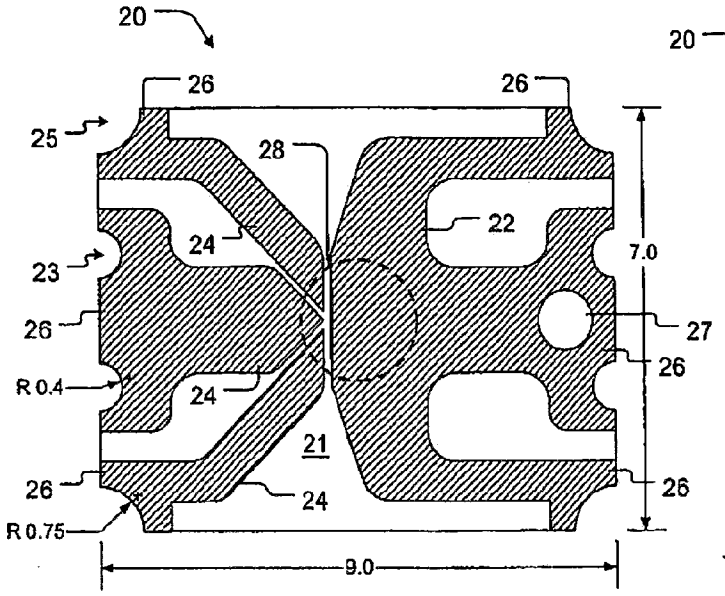


FIG. 2A

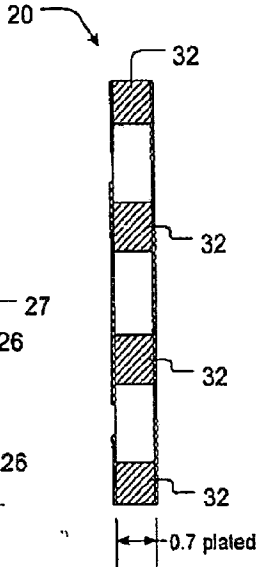


FIG. 2B

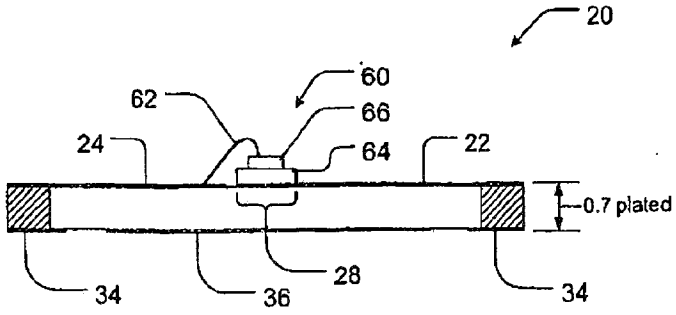


FIG. 2C

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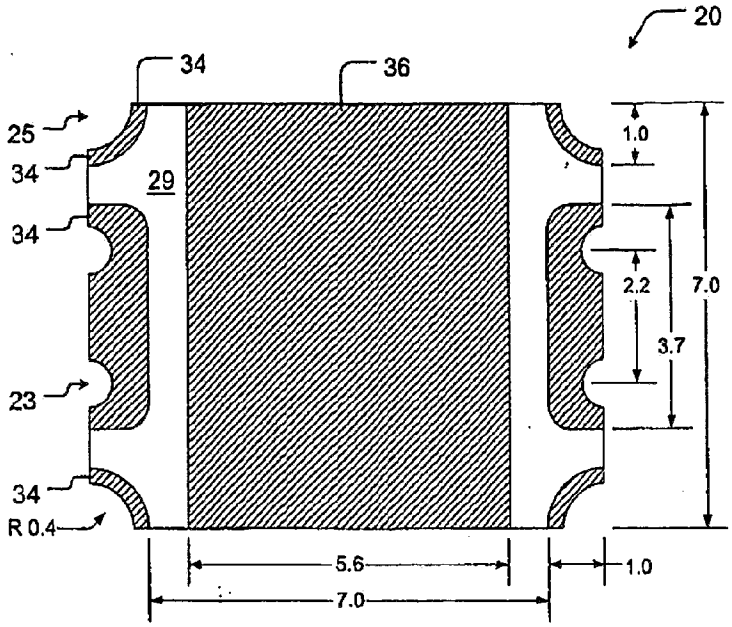


FIG. 2D

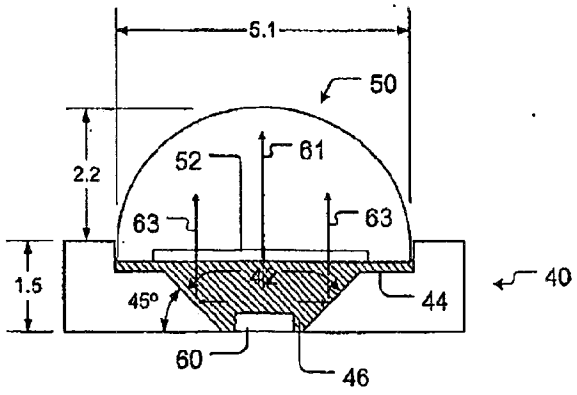


FIG. 3

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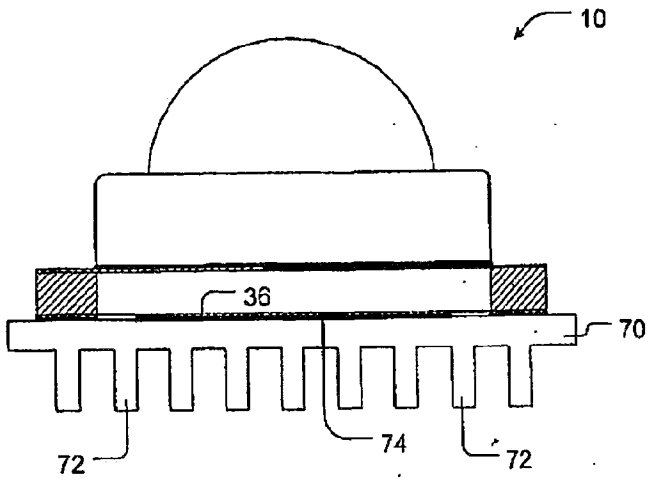


FIG. 4

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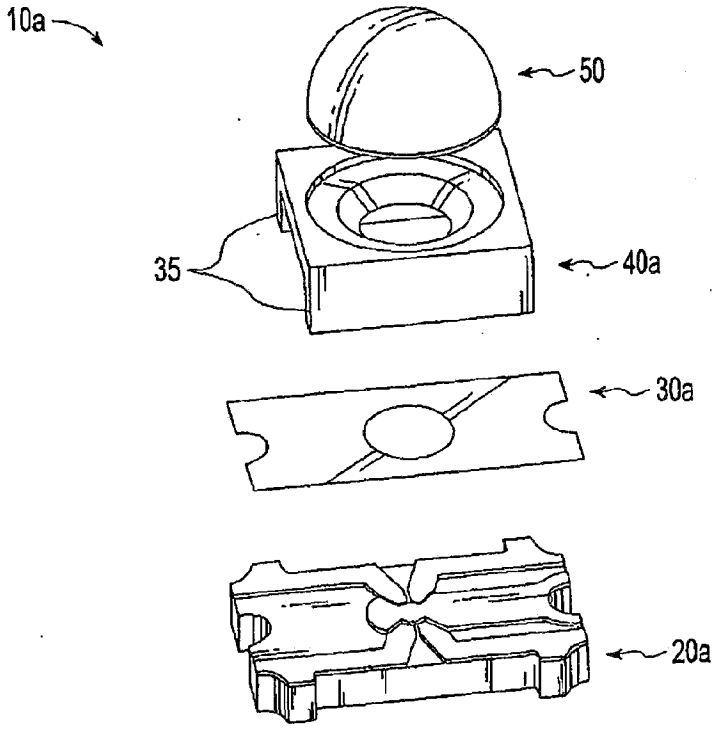


FIG. 5

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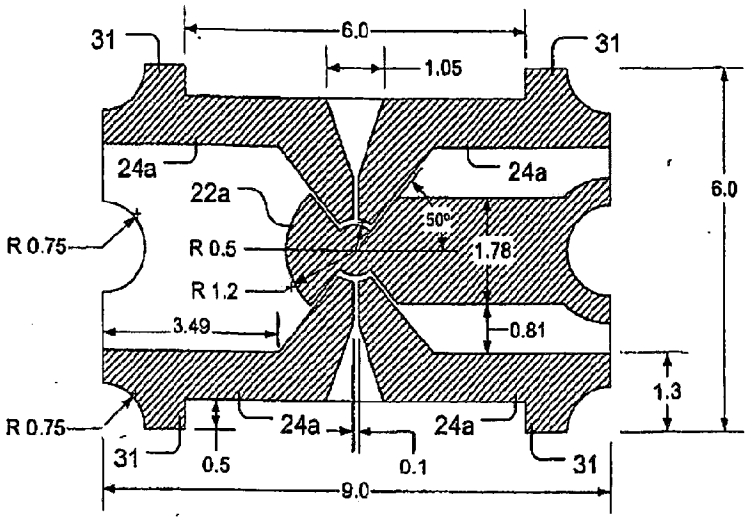


FIG. 6A

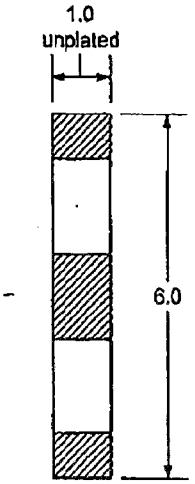


FIG. 6B



FIG. 6C

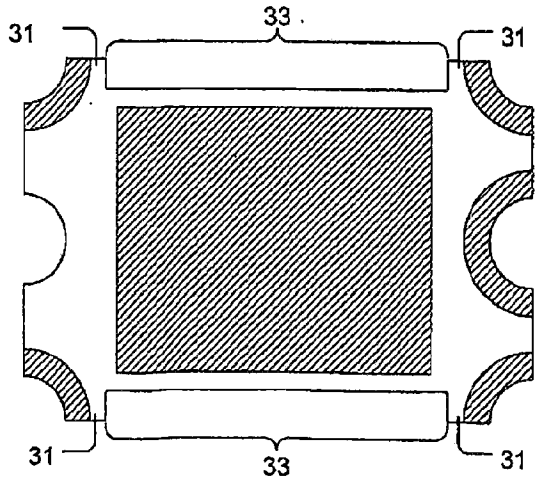


FIG. 6D

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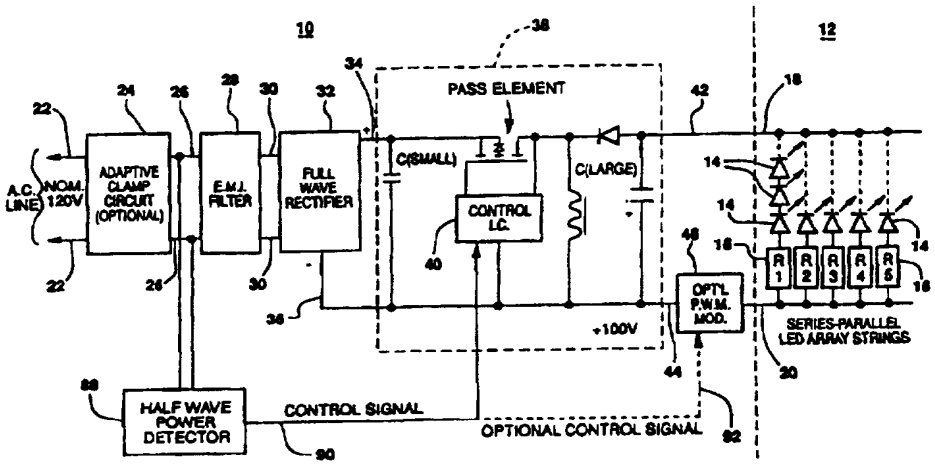
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(54) Title: POWER SUPPLY FOR LIGHT EMITTING DIODE ARRAY



(57) Abstract

An apparatus (10) for supplying regulated voltage d.c. electrical power to an LED array (12) includes a rectifier (32) responsive to a.c power for generating rectified d.c. power and a power factor correcting and voltage regulating buck/boost switchmode converter (38) responsive to the rectified d.c. power for generating regulated voltage d.c. power to illuminate the LED array (12). A battery backup system (62) receives the a.c. power applied to the rectifier (32) for charging a rechargeable battery (66) and sensing an a.c. power failure. A switch-over relay (82) is connected between the battery backup system (62) and the rectifier. Upon sensing a failure of the a.c. power, the battery backup system (62) controls the switch-over relay (82) to connect the battery backup system (62) to the rectifier (32) to provide d.c. power to the switchmode converter (38) to illuminate the LED array (12). A half wave power detector (88) causes the apparatus (10) to reduce regulated d.c. power to dim the LED array (12).

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TITLE

POWER SUPPLY FOR LIGHT EMITTING DIODE ARRAY

BACKGROUND OF THE INVENTION

The present invention relates generally to an apparatus for generating power to a light emitting diode array and, in particular, to a power supply for operating light emitting diode array traffic signals.

Light emitting diode (LED) arrays are becoming more common in many applications as they are used to replace less efficient incandescent lamps. Status annunciators, message boards, liquid crystal display back lights and traffic signals are common applications for LED arrays. In most of these uses, electrical power is obtained from a.c. mains (120 v.a.c., 60 Hz) and some form of power supply converts the alternating line voltage to d.c., or pulsing d.c., for powering the plurality of LEDs.

LEDs typically exhibit forward voltage drops on the order of 1.2 to 2.0 volts when driven at average currents of 20 to 25 ma. For purposes of efficiency, the LEDs are usually connected in series so that a higher power supply voltage can be used to light an array of LEDs.

In many applications where a relatively large number of LEDs are necessary to deliver substantial light output, several series strings of LEDs with a ballasting resistor in each string are normally connected in parallel. As shown in the Fig. 1., this traditional circuit arrangement provides some redundancy from single point LED failure, as any "open" LED will only extinguish its own series string leaving the other strings active. Since this relatively simple circuit does not provide any regulation, i.e. the light output varies with varying input voltage, it has been generally superseded by the regulated circuit shown in the Fig. 2. The regulated circuit employs a linear current regulator instead of individual ballasting resistors to maintain a given current through the LED strings. The highly dissipative nature of such linear regulators makes such use questionable in heat sensitive apparatus such as

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LED signals however. Heat generated by the regulator could exacerbate the deterioration of the thermally sensitive LEDs.

A non dissipative, unregulated power supply for LED signals is shown in Fig. 3, and uses a series capacitor as the current limiting element. Such highly reactive power supplies exhibit very poor power factors however, and may be disallowed by power utilities.

Several problems are associated with these prior art simple circuit topologies. The input current wave forms are generally badly distorted and the power factor is poor. Reasons for the poor power factor and high distortion relate to the discontinuous conduction of the diodes in the circuit feeding large capacitors. This phenomenon is well understood, and plagues many small off line power supplies. Until recently these concerns were essentially disregarded by the electrical power industry because the impact to the power grid was relatively small. Of course, as larger numbers of these low power appliances are connected to the power grid, the effect is no longer inconsequential. In fact, many utilities are placing limits on permissible power factor and distortion behavior of electrical devices connected to their lines.

LED traffic signals are being retrofitted in place of incandescent lamps primarily because of the energy savings common to LED signals. For example, an 8 inch diameter incandescent signal might consume 67 watts and its LED equivalent 14 watts, or a 12 inch diameter incandescent signal would consume 150 watts while its LED replacement would consume only 28 watts. The dramatic energy savings translate into greatly reduced operating cost, which is an important criterion, as electrical power is becoming more expensive. Also, in many parts of the country, electrical generating capacity is at its limits, and new capacity cannot be added because of environmental concerns. This strong interest in LED signals as an important energy conservation resource is clouded however by the poor power factor performance of commercially available signals.

Power factor (p.f.) is well understood in the electrical engineering community as the ratio of real power to real power plus reactive power, or more conveniently, p.f. = cos θ where θ is the angle in electrical degrees of the current - voltage phase offset. That is, in many reactive loads powered by sinusoidal (alternating) current, the voltage and current may be out of phase.

The apparent power that has to be delivered to a given load in volt-amperes (VA) is, therefore equal to the true power consumption of the device in Watts divided by the power factor. For example, an appliance with a internal power consumption of 100 Watts that exhibited a power factor of 0.4, would require 100/.4 or 250 VA of energy from the power line and utility generator. Taken separately, the many small electrical appliances that are widely used have only a moderate effect on generating capacity. However in aggregate, a large number of small devices can have a significant impact on the power grid.

By means of example, a medium size city (San Francisco) may have some 2000 signalized intersections with a total of 16,000 mixed 8 inch and 12 inch traffic signals. If the existing incandescent signals with an average power consumption of 100 watts are replaced with LED variants of 20 watt rating, a significant power saving should result. The 1600 kilowatt (kW) load imposed by the incandescent signals should be reduced to 320 kw by the LED retrofit devices. However, if the LED signals exhibit an actual power factor of 0.3, the resulting load to the power grid is 320 kW divided by 0.3 p.f. or 1067 kW. The energy savings is then only 533 kW, which is the net amount of power that the utility can convert to other uses. Clearly then, the need for power factors close to unity is apparent. Another factor that directly influences the amount of power (apparent VA) that needs to be delivered to a given load is the total harmonic distortion of the current waveform supplying the device. True power factor is adversely affected by current or voltage distortion, and the significance of this influence is only now being

widely accepted. There is shown in the Fig. 4, a traditional power factor vector diagram (which is normally two dimensional) which has been expanded to a three dimensional form to indicate the influence of distortion on the apparent power vector. The total power required vector VA (apparent power) is determined by the combination of the working power vector WATTS, the volt-amperes reactive vector VAR (non-working power) and the distortion volt-amperes vector DVA (non-working power).

Harmonic distortion or deviation from true sinusoidal wave forms not only gives rise to further wasted energy, but increases the electromagnetic interference potential of the load. Radiated and conducted interference is a concern because of the interference potential with other services (radio communications for example).

Harmonic distortion is becoming more prevalent in power supplies as these devices are converted from inefficient linear operation to far more efficient switchmode operation. A wide variety of circuit topologies are used in modern switching power supplies such as thyristor and triac phase control, or bipolar or field effect transistor switches. A consequence of these solid state approaches is increased harmonic distortion and poor power factor behavior. In order to mitigate these problems, several approaches to power factor and distortion control have been developed that operate with and use the efficiency of the switchmode power supply itself. That is, instead of correcting for power factor in a separate functional device (that is connected between the power supply and line), the power factor and distortion correcting function is part of the switchmode power supply. A number of manufacturers of integrated circuits (Linear Technology, Silicon General, Motorola and Unitrode for example) offer monolithic devices that perform the power factor and distortion control function. A review of this art is presented in *Power Supply Cookbook* by Marty Brown, 1994, Butterworth-Heinemann.

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SUMMARY OF THE INVENTION

The present invention concerns an apparatus for supplying regulated voltage d.c. electrical power to an LED array. The apparatus includes a rectifier having an input and an output, the rectifier being responsive to a.c. power at the input for generating rectified d.c. power at the output, a power factor correction converter having an input connected to the rectifier output and an output, the power factor correction converter being responsive to the rectified d.c. power at the power factor correction converter input for generating regulated voltage, d.c. power at the power factor correction converter output, and an LED array having an input connected to the power factor correction converter output for receiving the d.c. power to illuminate the LED array. The power factor correction converter can be a power factor correcting and voltage regulating buck/boost switchmode converter.

A primary object of the present invention is to provide a power factor correcting, (boost, buck/boost or buck) switchmode converter to power a line operated LED signal.

Another object of the present invention is to use the inherent pulse modulating nature of a switchmode power supply to provide voltage regulation to an LED array.

The apparatus according to the present invention also includes an adaptive clamp circuit connected to the rectifier input for eliminating leakage current problems. The adaptive clamp circuit has an input adapted to be connected to a pair of a.c. power lines, a pair of clamp circuit output lines connected to the adaptive clamp circuit input, a voltage sensing means connected across the adaptive clamp circuit input, and a controlled load means connected across the clamp circuit output lines and to the voltage sensing means. The voltage sensing means is responsive to a magnitude of a.c. voltage at the adaptive clamp circuit input lower than a predetermined magnitude for turning on the controlled load means to connect a low impedance load in the controlled load means across the clamp circuit output

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lines and the voltage sensing means is responsive to a magnitude of the a.c. voltage at the adaptive clamp circuit input equal to or greater than the predetermined magnitude for turning off the controlled load means to disconnect the low impedance load from the clamp circuit output lines.

It is also an objective of the present invention to eliminate leakage current problems by providing an adaptive clamp circuit.

Another feature of the present invention is to provide an adaptive line loading means or clamp that switches itself in or out of the circuit as needed.

The apparatus according to the present invention further includes a battery backup system having an input for receiving a.c. power applied to the rectifier input and having an output at which d.c. power is generated, and a switch-over relay connected to the battery backup system output and to the rectifier input, the battery backup system being responsive to a failure of a.c. power at the battery backup system input for controlling the switch-over relay to connect the battery backup system output to the rectifier input to provide d.c. power to illuminate the LED array and being responsive to a.c. power at the battery backup system input for controlling the switch-over relay to disconnect the battery backup system output from the rectifier input.

Another object of the present invention is the use of a d.c. power supply (instead of the a.c. power line) as a power backup that is activated upon a.c. power line loss.

BRIEF DESCRIPTION OF THE DRAWINGS

The above, as well as other advantages of the present invention, will become readily apparent to those skilled in the art from the following detailed description of a preferred embodiment when considered in the light of the accompanying drawings in which:

Fig. 1 is a schematic diagram of a prior art unregulated power supply for LED signals;

Fig. 2 is a schematic diagram of a prior art linear current regulated power supply for LED signals;

Fig. 3 is a schematic diagram of a prior art reactively ballasted power supply for LED signals;

Fig. 4 is a three dimensional vector diagram of the total power required to operate an LED array;

Fig. 5 is a schematic diagram of a regulated voltage, switchmode power supply for LED signals in accordance with the present invention;

Fig. 6a is a schematic block diagram of the adaptive clamp circuit shown in the Fig. 5;

Fig. 6b is a schematic diagram of the adaptive clamp circuit shown in the Fig. 6a; and

Fig. 7 is a schematic block diagram of a battery backup system for LED signals according to the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

As noted above, the elementary power supplies that are currently used for powering LED array signals do not meet current standards for efficiency, reliability and performance. The unregulated, resistively ballasted power supply shown in the Fig. 1 does not isolate the LEDs from line voltage variations, and exhibits a poor power factor because of the rectifier and large capacitor. The commercially produced current regulated LED power supply, which is shown in the Fig. 2, does provide much better LED light intensity regulation with input voltage variation. However, the use of a linear, dissipative (heat producing) regulator presents problems. LEDs are thermally sensitive devices which degrade quickly at elevated temperatures. Since most power supplies for LED signals are part of, or are attached to the LED array, heat rise from the linear regulator can be deleterious. Furthermore, the traditional rectifier-capacitor circuit does not produce a satisfactory power factor.

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The use of capacitors as non-dissipative current limiters in a.c. circuits is well established, and is shown in the Fig. 3 as another example of a commercially available LED array signal power supply. Current and voltage wave forms are essentially out of phase in this type of circuit, so that heat is not generated in the current limiting capacitor (15 μF). However, the power factor and distortion performance of this type of circuit is very poor (P.F. $\approx$ 0.3).

There is shown in the Fig. 5, a regulated voltage, switchmode power supply **10** according to the present invention connected to an LED array **12**. The LED array **12** includes a plurality of strings of series connected LEDs **14** with a ballasting resistor **16** (R1, R2, R3, R4, R5, ...) connected in each string. The strings are connected in parallel between a first input line **18** and a second input line **20** of the LED array **12**.

The power supply **10** has a pair of power input lines **22** for connection to a source (not shown) of a.c. power such as main power lines at a nominal 120 volts a.c. An input of an adaptive clamp circuit **24** can be connected to the lines **22** as an option. A problem peculiar to signals that are switched by means of solid state relays is the leakage current that can flow through the load when the solid state switch or relay is "OFF". This phenomenon is common to triac and thyristor switches that are commonly employed in traffic signal controllers. While not apparent when incandescent signals are employed (because they are low impedance loads), the problems surface when relatively low power loads (such as LEDs) are connected to these same controllers. Typically, other safety devices used in traffic signal controllers such as conflict monitors must be "tricked" to reduce this leakage current. Commonly, a large capacitor is placed across the a.c. input leads to the LED load, in order to absorb the leakage current reactively. Of course, such provisions only aggravate the power factor problems.

An output of the adaptive clamp circuit **24** is connected by a pair of clamp circuit output lines **26** to an input of an electromagnetic interference

(E.M.I.) filter **28**. The E.M.I. filter **28** keeps conducted interference from feeding back into the power lines where it might cause problems to other circuitry on the line. An output of the filter **28** is connected by a pair of filter output lines **30** to an input of a rectifier means **32** which converts the incoming a.c. power to a pulsing d.c. power generated on a positive polarity rectifier output line **34** and a negative polarity rectifier output line **36**. Although the rectifier means is shown as a full wave diode bridge rectifier, any type of rectifier can be used. The lines **34** and **36** are connected to an input of a power factor correction, buck/boost converter **38**. The converter **38** includes a power factor correction (P.F.C.) integrated circuit (I.C.) controller **40**, which is a commercial device available from many sources and functions by allowing current to charge a storage capacitor **C (LARGE)** only in phase with the rectified a.c. voltage thereby assuring a power factor close to unity. The control I.C. **40** also provides voltage regulation in the switchmode buck/boost converter by monitoring the output voltage and adjusting the high frequency on-off switching period of the pass element commensurately. Although a buck/boost converter is diagrammed, buck or boost topologies are also possible. Voltage output and current-mode control techniques are the primary differences in the various geometries, but these details are incidental to the functionality of the circuit.

A positive polarity output of the converter **38** is connected by a positive polarity converter output line **42** to the first input line **18** of the LED array **12**. A negative polarity output of the converter **38** is connected by a negative polarity converter output line **44** to the second input line **20** of the LED array **12** through an optional pulse width modulated (P.W.M.) modulator **46**.

The output voltage from the P.F.C. switch mode converter **38** is either fed directly to the LED array **12**, or alternatively through the P.W.M. modulator **46**. Such pulse modulation has been shown to be advantageous in certain LED signal applications. The functions of the switchmode P.F.C.

converter **38** as the off line power supply are the same irrespective of the load. The obvious advantage of using a switching, voltage regulated power supply is efficiency. Line isolation, which is generally not provided by this transformerless design, is generally unnecessary for insulated LED signals, but a high frequency transformer could be incorporated. The intrinsic power factor correction provided by using the switchmode converter **38** in conjunction with the P.F.C. integrated circuit controller **40** is not only cost effective, but allows d.c. backup power to be used in case of line failure.

A primary aspect of the present invention is the use of a power factor correcting, (boost, buck/boost or buck) switchmode converter to power a line operated LED array signal **12**. Another function of the present invention is to use the inherent pulse modulating nature of the switchmode power supply to provide voltage regulation to the LED array signal **12**. Instead of using dissipative (heat producing) linear regulators for either voltage or current (to accommodate line voltage variations), the power factor and distortion controlling switchmode power supply **10** is used as an efficient voltage regulator. That is, the LED array **12**, consisting of a large number of series-parallel connected LED devices **14**, can be kept at essentially constant luminosity over a substantial range of input voltages. In actual practice, the output of such LED array signals has been kept within $\pm 10\%$ of nominal value over a power line variation of 85 volts to 140 volts (for a nominal 120 v.a.c. line).

It is also an objective of the present invention to eliminate leakage current problems by providing the adaptive clamp circuit **24** which is shown in more detail in the Figs. 6a and 6b. The power input lines **22** are connected directly through the adaptive clamp circuit **24** to the clamp circuit output lines **26**. The adaptive clamp circuit **24** monitors the input voltage feeding the LED array **12** on the input lines **22** with a voltage sensing means **48** connected across the lines **22** and loads the input lines resistively with a low impedance controlled load means **50**, connected across the output lines **26**,

whenever the line voltage is below some critical amount (typically 40 volts a.c. r.m.s.). The adaptive clamp circuit **24** assumes that voltages lower than a certain value (typically 40 volts) are due to leakage currents through the solid state control relay or switch. The adaptive clamp circuit **24** loads the lines with a resistor to draw current, forcing the leakage voltage to a lower voltage (typically on the order of 10 volts a.c.) that will not cause problems for the conflict monitor or power factor correction (p.f.c.) circuit. Most traffic signals must be capable of being flashed (at least the red and yellow signals) from the traffic controller electronics. It has been found experimentally that residual leakage currents interfere with the ability to flash signals that are equipped with power factor correction circuits. The adaptive clamp circuit **24** prevents this problem by allowing the p.f.c. circuit to completely discharge between power line pulses which flash the signal at a nominal sixty flashes per minute. In summary, the adaptive clamp circuit **24** performs two functions by reducing the leakage voltage: 1) it provides a reactance free means to eliminate problems with conflict monitors (while preventing poor power factors); and 2) it allows the p.f.c. circuit to properly flash the LED array signal **12**.

The adaptive clamp circuit **24** is shown in more detail in the Fig. 6b wherein a first pair of diodes **D3** and **D4** has anodes connected to the lines **22** and cathodes connected together. A second pair of diodes **D1** and **D2** has cathodes connected to the lines **26** and anodes connected together. A first resistor (R1) **52** is connected between the junction of the second pair of diodes **D1** and **D2** and an anode of a Zener diode **D5**. The Zener diode **D5** has a cathode connected to the junction of the first pair of diodes **D3** and **D4**. A second resistor (R2) **54** is connected between the anode of the Zener diode **D5** and a base of a first NPN transistor **Q1**. The transistor **Q1** has an emitter connected to the junction of the second pair of diodes **D1** and **D2** and a collector connected through a third resistor (R3) **56** to the junction of the first pair of diodes **D3** and **D4**. A fourth resistor (R4) **58** is connected between the

collector of the transistor **Q1** and a base of a second NPN transistor **Q2**. The transistor **Q2** has an emitter connected to the junction of the second pair of diodes **D1** and **D2** and a collector connected through a fifth resistor (R5) **60** to the junction of the first pair of diodes **D3** and **D4**.

The optional adaptive clamping circuit **24** is advantageously placed across the input terminals of the p.f.c., switchmode power supply **10** as shown in the Fig. 5. As noted above, as a consequence of using solid state relays or switches in signal controllers, the power to the signals is not fully disconnected (even when the signal should be off). This leakage current often causes problems with safety devices such as electronic conflict monitors. Additionally, these leakage currents may present problems during flashing operation of LED signals, as the power supply circuits may not be fully discharged between flashes. Switchmode, p.f.c. power suppliers of the type proposed for the present invention are particularly sensitive to such leakage currents and will be inhibited from flashing LEDs at an acceptable rate (55 to 60 flashes per minute).

In current practice, these leakage currents are minimized by "short circuiting" them by means of a reactive, non dissipative element. The input capacitor (typically 1-2 μF), as shown in the Fig. 3 for example, performs this function. However this same capacitor is across the line when the LED array signal is energized, drawing reactive power and contributing to a poor power factor.

Another feature of the present invention is to provide for an adaptive line loading means or clamp that switches itself in or out of circuit as needed. As shown in the Fig. 6b, the adaptive clamp circuit **24** monitors the line voltage, and when only leakage currents are present that drop the line voltage to about 40 v.a.c., the circuit applies a resistive load **60** across the lines **22** by turning on the solid-state switch **Q2**. When the lines **22** are loaded by the fifth resistor **60**, having a suitable value (typically 1 kOhm), the leakage voltage will drop to under 10 volts. At this depressed voltage, the p.f.c.

switchmode converter is fully off, and can properly flash the LEDs **14** at the requisite rate.

This adaptive clamp **24** can of course be used with other types of power supplies where the addition of reactive elements could degrade the power factor. The clamping circuit **24** works by using the sensing transistor **Q1** and the Zener diode **D5** (the voltage sensing means **48** of the Fig. 6a) to determine if the line voltage is below a certain magnitude (typically 40 volts). The sensing transistor **Q1** and the Zener diode **D5** are the voltage sensing means **48** of the Fig. 6a. If the Zener diode **D5** does not conduct, the transistor **Q2** is turned on to place the load resistor **60** the power lines **22** causing the leakage voltage to drop below 10 volts. The transistor **Q2** and the resistor **60** are the controlled load means **50** of the Fig. 6a. Whenever the traffic signal controller relay "closes", the line voltage appearing at the input to the adaptive clamping circuit **24** rises to nominally 120 volts and the sensing circuit (**Q1** and **D5**) turn off the controlling transistor **Q2**, removing the resistor **60** from the circuit thereby preventing unnecessary dissipation of power. Since there are no reactances involved, this circuit does not influence the power factor reflected at the a.c. input lines **22**.

Another aspect of the present invention is the use of a d.c. input (instead of the a.c. power line) as a power backup feature that is activated upon power line loss. Conventional practice employs battery driven a.c. inverters to generate the backup power upon line failure. Such inverters are expensive, inefficient and are failure prone. The use of battery power (d.c.) to directly energize the regulated switchmode power supply that powers the LED array signal is very cost effective and energy efficient. The wide input voltage range of most switchmode power supplies allows the batteries to be used optimally as they can be virtually fully discharged in the power backup cycle yielding very good use of battery capacity. Lower cost, smaller batteries are therefore useable.

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As noted previously, the use of a direct line operated, non-transformer isolated converter to power the LED array signal allows d.c. power to be used (instead of a.c.) in case of line failure. Using batteries without having to rely on an inverter to perform the d.c. to a.c. conversion is novel, extremely reliable, and cost effective. The importance of battery backup for critical traffic signals is obvious, and the need for reliability is also apparent. As shown in the Fig. 7, a battery backup system **62** includes a temperature compensated, line powered automatic battery charger **64** having an input connected to the lines **22** and an output connected to an input of a rechargeable battery **66** to keep the battery fully charged at all times that a.c. power is available. Temperature compensation can be used to stop the charging process to extend the life of the battery, as it is well known that the optimal end point charging voltage for most secondary cells is a function of temperature.

Because of the critical safety nature of these devices, an automatic battery testing circuit and load **68** is built into the battery backup system **62**. Deterioration of the battery **66**, which is inevitable over time, is thereby monitored and degradation past a certain point is flagged or announced. The testing circuit **68** has an input connected to an output of the battery **66** for sensing battery voltage. An alarm signal line **70** is connected to an output of the circuit **68** for generating the alarm signal and a set flag signal line **72** is connected to another output of the circuit **68** for generating the set flag signal. A control line **74** is connected between an output of the circuit **68** and an input of the battery **66**. Secondary batteries that are kept in float service for any length of time tend to degrade and loose capacity. This deterioration is far more apparent in high temperature environments, and can adversely affect the safety margins of the backup power supply. That is, instead of providing 8 to 10 hours of flashing red LED array signal backup service, a degraded battery might only last a few hours. Determining the actual condition or serviceability of a storage battery is difficult, because a

measurement of terminal voltage does not necessarily indicate loss of capacity. It has been experimentally determined that a good measure of battery capacity can be made by loading the battery with a substantial current (typically 5-10 amperes) for several minutes and measuring the terminal voltage under load. Naturally the battery charger is inhibited during this test. This method is well recognized as a good diagnostic test as it depletes any "surface charge" on the electrodes and more accurately indicates remaining battery ampere-hours.

A voltage comparator circuit in the battery testing circuit and load **68** establishes an "accept" or "reject" level for the battery **66** as it is tested every 24 hours or so. In order to accommodate partly discharged cells, two sequential, battery tests that result in a "reject" are registered in a latch which may trigger a visual or audible alarm signal on the line **70**. Alternatively, a relay or contact closure (flag) may be set to generate a signal on the line **72** so that a data modem can relay the degraded battery information to a central service facility. Of course, such calls or alarm signals are triggered well before the battery is no longer serviceable so that safety is not comprised.

A line failure detection circuit **76** has an input connected to the power lines **22** and another input connected to an output of the battery **66** to receive operating power from the battery. The circuit **76** initiates the power switch-over process whenever a.c. input power is disconnected. An output of the line failure detection circuit **76** is connected to an input of a time delay and restoration circuit **78** which has another input connected to an output of the battery **66** to receive operating power from the battery. The time delay function ensures that short, transient line dropouts are disregarded. An output of the time delay and restoration circuit **78** is connected to an input of a d.c. power switch-over and flasher circuit **80** which has another input connected to an output of the battery **66** to receive operating power from the battery. Outputs of the circuit **80** are connected to a first set of input terminals of a switch-over relay **82**. The relay has a second set of terminals connected to red signal outputs of a traffic controller **84** having an input connected to the

power lines **22**. Output terminals of the switch-over relay **82** are connected to the input of the switchmode converter power supply **10** which is connected to the red LED array signal **12**. Normally, the switch-over relay **82** is in the position shown to connect a.c. power on the lines **22** through the traffic controller **84** to the power supply **10**.

Generally, line loss in excess of 250 msec will cause the d.c. power switch-over relay **82** to switch the output terminals to disconnect the power supply **10** and the red LED array signal **10** from the traffic controller **84** (and the a.c. feed) and connect them to the d.c. battery **66** through the d.c. power switch-over and flasher circuit **80**. Note that the d.c. supply is flashed or pulsed by the circuit **80** at a nominal rate of 60 pulses per minute (1 Hz) to place all the red LED array signals at an intersection in a flashing mode, effecting a four way stop. While an electromechanical switch-over relay **82** is shown for complete isolation of the existing traffic controller **84** and the battery backup system **62**, solid state devices could be used.

Whenever the line power is restored, the time delay and restoration circuit **78** will wait some period (typically 10-15 seconds) before the LED array signal 12 is switched back to the a.c. power mode. This delay avoids the many transients that usually accompany a.c. line restoration after a power outage. Note that no inverter is employed in this system, as is common practice in existing commercial hardware. The inefficiency and poor reliability of d.c. to a.c. converters is thereby avoided. Because the switchmode power supply **10** can accommodate wide variations in input voltage (both a.c. and d.c.) the storage battery **66** can be discharged virtually completely while maintaining essentially constant luminosity of the LED array signal **12**.

Additionally, as shown in the Fig. 7, there are provisions for the introduction of narrow "marker pulses" superimposed on the d.c. supply for use as synchronizing pulses. An optional synchronizing pulse generator **86** has an output connected to an input of the d.c. power switch-over and flasher

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circuit **80** for generating such pulses. This optional feature permits a number of LED array signals that are pulse modulated to operate in sync in the absence of the 60 Hz a.c. line signal. These "marker pulses" are essentially short (200 μsec) power dropouts that do not affect the operation of the LED array signal **12**, but are easily extracted at the signal to effect pulse synchronization of several pulsed LED array signals.

As noted above, the lack of input transformers or series capacitors before the full wave bridge, allows d.c. power to be applied at the input terminals of the power supply **10** in lieu of a.c. power. Since there are no reactive (a.c.) components in the input circuitry, proper operation of the switchmode converter is maintained, and output voltage regulation is still available. Obviously, the p.f.c. portion of the circuit **10** will be nonfunctional during operation on d.c. input power. As shown, the switchmode converter will provide an essentially constant output voltage (nom. 100 volts d.c.) to the LED array **12** over a range of a.c. input voltages from 85 volts r.m.s. to 140 volts r.m.s. and over a d.c. input voltage range of 38 volts d.c. to 65 volts d.c. The wide (input voltage) operating range allows rechargeable batteries to be used very efficiently, since their capacity can be fully utilized in the discharge cycle, as their terminal voltage drops.

As discussed above, LED signals are being used to replace incandescent lamps in many applications. Traffic signals are among the more common devices that are being upgraded for with LEDs because of the tremendous power savings and the dramatic improvement in service life. In most cases the incandescent lamps are merely replaced with an integral LED retrofit assembly that does not require any modification of the existing traffic signal housing or the drive and control circuitry associated with the signal. That is, users expect the LED retrofit lamps to operate normally without added modifications to the housing or traffic controller.

One aspect of this conversion to LED signals from incandescent lamps poses significant problems however. Many existing incandescent lamp traffic

signals are dimmed at night to reduce glare and, of course, power consumption. LED signals can be dimmed by reducing the average current through the LED array. A problem arises however because existing traffic signal controllers dim incandescent signals by providing half-wave rectified a.c. to the devices. Normally the traffic lamps are powered by switched a.c. line power which has, in virtually all cases, a sinusoidal wave form. Simply rectifying this power allows the traffic signal controller to reduce the average voltage and current to the load in a loss free manner. This technique has been in common use for many years and has become the "defacto" standard dimming technique.

Most LED traffic signals do not work satisfactorily with half wave rectified a.c.; in fact, many simply do not light. Some LED lamp arrays which are equipped with regulated power supplies will illuminate satisfactorily when powered by half wave rectified a.c. current, but they do not dim. The regulated power supplies accept the half wave rectified a.c. line power and treat it merely as a low line voltage and correct for this phenomenon. The voltage impressed across the LED array is kept relatively constant in spite of such input voltage variations thereby keeping the LED luminous output essentially unchanged, i.e. undimmed.

Certain switchmode, regulating power supplies are able to power LED signals satisfactorily from even half wave rectified a.c. power supplies. A half wave detector circuit in the LED signal power supply can determine whether the traffic signal controller is sending a "dimming" command. Upon detection of this half wave signal, the switchmode power supply can be programmed or adjusted to reduce its output voltage to the LED array. By adjusting either the pulse width or the frequency (at constant pulse width) of the switchmode power supply, the output voltage (and/or current) can be reduced in an efficient, nondissipative manner.

Alternatively, the half wave detector can be used to change the average current through the LED array by reducing the effective pulse width of a

pulse width modulation controller that drives the LEDs. In either method, the average LED current and intensity are reduced in response to the detection of a half wave rectified input current. In this way, the LED signal is "transparent" to the user who may now utilize the LED device in the same manner as conventional incandescent signals.

As shown in the Fig. 5, a half wave power detector circuit **88** has inputs connected to the inputs of the full wave rectifier **32** at the clamp circuit output lines **26** to monitor the input a.c. power on the power input lines **22** to the power supply **10**. The detector **88** has an output connected to a control signal line **90** which is connected to an input of the control I.C. **40**. The detector **88** generates a control signal on the line **90** in response to the detection of a half wave dimming signal on the a.c. power lines **22**. The control signal is directed to the power supply regulator circuit **38**, where it causes the output voltage of the switchmode power supply **10** to be reduced in response to the dimming command. For current regulated power supplies, the average output current to the LED arrays can be reduced to effect dimming. In cases where the LED array is powered by a pulse width modulator, such as the modulator **46**, the connection of the line **90** to the control I.C. **40** is eliminated and the output of the detector **88** is connected by a control signal line **92** to an input of the modulator **46** such that the average current delivered to the LED array may be reduced by decreasing the pulse width of the modulator.

All such dimming methods have one key feature in common; the average current through the LED signal **12** is decreased in response to the detection of a half wave dimming signal impressed on the power supply input lines **22**. The detection of half wave power by the detector **88** causes the LED power supply **10** to either adjust the output pulse width at constant frequency or adjust the frequency at constant pulse width. The power supply **10** can be any type of power supply which converts a.c. power to d.c. power suitable for illuminating the LED array **12**.

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The present invention is an apparatus **10** for supplying regulated voltage d.c. electrical power to an LED array including a rectifier means **32** having an input and an output, the rectifier means **32** being responsive to a.c. power at the input for generating rectified d.c. power at the output, a power factor correction converter means **38** having an input connected to the rectifier means **32** output and an output, the power factor correction converter means **38** being responsive to the rectified d.c. power at the power factor correction converter means input for generating regulated voltage, power factor corrected d.c. power at the power factor correction converter means output, and an LED array **12** having an input connected to the power factor correction converter means **38** output for receiving the power factor corrected d.c. power to illuminate the LED array **12**. The power factor correction converter means **38** can be a power factor correcting and voltage regulating buck/boost switchmode converter.

The apparatus **10** includes a pulse width modulated modulator means **46** connected to the power factor correction converter means **38** output and the LED array **12** input for modulating the power factor corrected d.c. power and an electromagnetic interference filter means **28** connected to the full wave rectifier means **32** input for preventing conducted interference from feeding back onto a.c. power lines **22** connected to the rectifier means **32** input. The apparatus **10** also includes an adaptive clamp circuit means **24** connected to the rectifier means **32** input for eliminating leakage current problems. The adaptive clamp circuit means **24** has an input adapted to be connected to a pair of a.c. power lines **22**, a pair of clamp circuit output lines **26** connected to the adaptive clamp circuit means **24** input, a voltage sensing means **48** connected across the adaptive clamp circuit means **24** input, and a controlled load means **50** connected across the clamp circuit output lines **26** and to the voltage sensing means **48**. The voltage sensing means **48** is responsive to a magnitude of a.c. voltage at the adaptive clamp circuit means **24** input lower than a predetermined magnitude for turning on the controlled load means **50**

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to connect a low impedance load **60** in the controlled load means **50** across the clamp circuit output lines **26** and the voltage sensing means **48** is responsive to a magnitude of the a.c. voltage at the adaptive clamp circuit means **24** input equal to or greater than the predetermined magnitude for turning off the controlled load means **50** to disconnect the low impedance load **60** from the clamp circuit output lines **26**.

The apparatus **10** further includes a battery backup means **62** having an input for receiving a.c. power applied to the rectifier means **32** input and having an output at which d.c. power is generated, and a switch-over means **82** connected to the battery backup means **62** output and to the rectifier means **32** input, the battery backup means **62** being responsive to a failure of a.c. power at the battery backup means **62** input for controlling the switch-over means **82** to connect the battery backup means **62** output to the rectifier means **32** input to provide d.c. power to illuminate the LED array **12** and being responsive to a.c. power at the battery backup means **62** input for controlling the switch-over means **82** to disconnect the battery backup means **62** output from the rectifier means **32** input. The switch-over means **82** can be an electromechanical relay. The battery backup means **62** includes a time delay and restoration means **78** responsive to application of a.c. power at the battery backup means **62** input for controlling the switch-over means **82** to disconnect the battery backup means **62** output from the rectifier means **32** input and connect the a.c. power to the rectifier means **32** input after a predetermined time delay. The battery backup means **62** also includes a d.c. power switch-over and flasher means **80** connected to the switch-over means **82** for pulsing the d.c. power at a predetermined rate to flash the LED array **12** and a synchronizing pulse generator means **86** connected to the d.c. power switch-over and flasher means **80** for imposing marker pulses on the d.c. power at a predetermined rate.

The apparatus **10** also includes a half wave power detector means **88** having an input connected to the input of the rectifier means **32** and an output

connected to another input of the power factor correction converter means **38**, the half wave power detector means being responsive to a dimming signal at the rectifier means input for generating a control signal at said half wave power detector means output and the power factor correction converter means **38** being responsive to the control signal for decreasing the regulated d.c. power to dim the LED array **12**. If the apparatus **10** includes the pulse width modulated modulator means **46** connected to the power factor correction converter means **38** output and the LED array **12** input for modulating the regulated voltage d.c. power, the half wave power detector means **88** has its output connected to an input of the pulse width modulated modulator means **46** and is responsive to a dimming signal at the rectifier means input for generating a control signal at the half wave power detector means output and the pulse width modulated modulator means **46** is responsive to the control signal for decreasing the regulated d.c. power to dim the LED array **12**.

In accordance with the provisions of the patent statutes, the present invention has been described in what is considered to represent its preferred embodiment. However, it should be noted that the invention can be practiced otherwise than as specifically illustrated and described without departing from its spirit or scope.

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WHAT IS CLAIMED IS:

1. An apparatus for supplying regulated voltage d.c. electrical power to an LED array comprising:

a rectifier means **(32)** having an input and an output, said rectifier means **(32)** being responsive to a.c. power at said input for generating rectified d.c. power at said output;

a power factor correction converter means **(38)** having an input connected to said output of said rectifier means **(32)** and an output, said power factor correction converter means **(38)** being responsive to said rectified d.c. power at said power factor correction converter means input for generating regulated voltage d.c. power at said power factor correction converter means output; and

an LED array **(12)** having an input connected to said output of said power factor correction converter means **(38)** for receiving said regulated voltage d.c. power to illuminate said LED array **(12)**.

2. The apparatus according to claim 1 wherein said power factor correction converter means **(38)** is a power factor correcting and voltage regulating buck/boost switchmode converter.

3. The apparatus according to claim 1 including a pulse width modulated modulator means **(46)** connected to said output of said power factor correction converter means **(38)** and to said input of said LED array **(12)** for modulating said regulated voltage d.c. power.

4. The apparatus according to claim 1 including an electromagnetic interference filter means **(28)** connected to said input of said rectifier means **(32)** for preventing conducted interference from feeding back onto a.c. power lines **(22)** connected to said rectifier means input.

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5. The apparatus according to claim 1 including an adaptive clamp circuit means **(24)** connected to said input of said rectifier means **(32)** for eliminating leakage current problems.

6. The apparatus according to claim 5 wherein said adaptive clamp circuit means **(24)** has an input adapted to be connected to a pair of a.c. power lines **(22)**, a pair of clamp circuit output lines **(26)** connected to said adaptive clamp circuit means input, a voltage sensing means **(48)** connected across said input of said adaptive clamp circuit means **(24)**, and a controlled load means **(50)** connected across said clamp circuit output lines **(26)** and to said voltage sensing means **(48)**, said voltage sensing means **(48)** being responsive to a magnitude of a.c. voltage at said adaptive clamp circuit means input lower than a predetermined magnitude for turning on said controlled load means **(50)** to connect a low impedance load **(60)** in said controlled load means **(50)** across said clamp circuit output lines **(26)** and said voltage sensing means **(48)** being responsive to a magnitude of the a.c. voltage at said adaptive clamp circuit means input equal to or greater than said predetermined magnitude for turning off said controlled load means **(50)** to disconnect said low impedance load **(60)** from said clamp circuit output lines **(26)**.

7. The apparatus according to claim 1 including a battery backup means **(62)** having an input for receiving a.c. power applied to said input of said rectifier means **(32)** and having an output at which d.c. power is generated, and a switch-over means **(82)** connected to said output of said battery backup means **(62)** and to said rectifier means input, said battery backup means **(62)** being responsive to a failure of a.c. power at said battery backup means input for controlling said switch-over means **(82)** to connect said output of said battery backup means **(62)** to said input of said rectifier means **(32)** to provide d.c. power to illuminate said LED array **(12)** and being responsive to a.c. power at said battery backup means input for controlling

said switch-over means **(82)** to disconnect said battery backup means output from said rectifier means input.

8. The apparatus according to claim 7 wherein said switch-over means **(82)** is an electromechanical relay.

9. The apparatus according to claim 7 wherein said battery backup means **(62)** includes a time delay and restoration means **(78)** responsive to application of a.c. power at said input of said battery backup means **(62)** for controlling said switch-over means **(82)** to disconnect said output of said battery backup means **(62)** from said input of said full wave rectifier means **(32)** and connect the a.c. power to said full wave rectifier means input after a predetermined time delay.

10. The apparatus according to claim 7 wherein said battery backup means **(62)** includes a d.c. power switch-over and flasher means **(80)** connected to said switch-over means **(82)** for pulsing said d.c. power at a predetermined rate to flash said LED array **(12)**.

11. The apparatus according to claim 7 wherein said battery backup means **(62)** includes a synchronizing pulse generator means **(86)** connected to said d.c. power switch-over and flasher means **(80)** for imposing marker pulses on said d.c. power at a predetermined rate.

12. The apparatus according to claim 1 including a half wave power detector means **(88)** having an input connected to said input of said rectifier means **(32)** and an output connected to another input of said power factor correction converter means **(38)**, said half wave power detector means **(88)** being responsive to a dimming signal at said rectifier means input for generating a control signal at said half wave power detector means output and

said power factor correction converter means **(38)** being responsive to said control signal for decreasing said regulated d.c. power to dim said LED array **(12)**.

13. The apparatus according to claim 1 including a pulse width modulated modulator means **(46)** connected to said output of said power factor correction converter means **(38)** and to said input of said LED array **(12)** for modulating said regulated voltage d.c. power and a half wave power detector means **(88)** having an input connected to said input of said rectifier means **(32)** and an output connected to an input of said pulse width modulated modulator means **(46)**, said half wave power detector means being responsive to a dimming signal at said rectifier means input for generating a control signal at said half wave power detector means output and said pulse width modulated modulator means **(46)** being responsive to said control signal for decreasing said regulated d.c. power to dim said LED array **(12)**.

14. An apparatus for supplying regulated voltage d.c. electrical power to an LED array comprising:

a power supply means **(10)** having an input and an output, said power supply means **(10)** being responsive to a.c. power at said input for generating regulated voltage d.c. power at said output to illuminate an LED array **(12)** connected to said power supply means output; and

a dimming detector means **(88)** having an input connected to said input of said power supply means **(10)** and an output connected to another input of said power supply means **(10)**, said dimming detector means **(88)** being responsive to a dimming signal at said power supply means input for generating a control signal at said dimming detector means output and said power supply means **(10)** being responsive to said control signal for

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decreasing said regulated voltage d.c. power to dim the LED array **(12)**.

15. The apparatus according to claim 14 wherein said dimming detector means **(88)** is a half wave power detector means, said dimming signal is half wave rectified a.c. power and said power supply means **(10)** includes a rectifier means **(32)** having an input connected to said power supply means input and an output and a power factor correction converter means **(38)** having an input connected to said rectifier means output and an output connected to said power supply output, said power factor correction converter means **(38)** including said another input of said power supply means **(10)**, said power factor correction converter means **(38)** being responsive to said control signal for decreasing said regulated voltage d.c. power to dim the LED array **(12)**.

16. The apparatus according to claim 14 wherein said dimming detector means **(88)** is a half wave power detector means, said dimming signal is half wave rectified a.c. power and including a pulse width modulated modulator means **(46)** connected to said output of said power supply means **(10)** for modulating said regulated voltage d.c. power, said pulse width modulated modulator means **(46)** including said another input of said power supply means **(10)**, said pulse width modulated modulator means **(46)** being responsive to said control signal for decreasing said regulated voltage d.c. power to dim the LED array **(12)**.

17. An apparatus for supplying regulated voltage d.c. electrical power to an LED array comprising:

a rectifier means **(32)** having an input and an output, said rectifier means **(32)** being responsive to a.c. power at said input for generating rectified d.c. power at said output;

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a power factor correction converter means **(38)** having an input connected to said output of said rectifier means **(32)** and an output, said power factor correction converter means **(38)** being responsive to said rectified d.c. power at said power factor correction converter means input for generating regulated voltage d.c. power at said power factor correction converter means output;

a battery backup means **(62)** having an input for receiving a.c. power applied to said input of said rectifier means **(32)** and having an output at which d.c. power is generated; and

a switch-over means **(82)** connected to said output of said battery backup means **(62)** and to said input of said rectifier means **(32)**, said battery backup means **(62)** being responsive to a failure of a.c. power at said battery backup means input for controlling said switch-over means **(82)** to connect said battery backup means output to said rectifier means input to provide d.c. power to said power factor correction converter means **(38)** to illuminate an LED array connected to said output of said power factor correction converter means **(38)** and being responsive to a.c. power at said battery backup means input for controlling said switch-over means **(82)** to disconnect said battery backup means output from said rectifier means input.

18. The apparatus according to claim 17 wherein said power factor correction converter means **(38)** is a power factor correcting and voltage regulating buck/boost switchmode converter.

19. The apparatus according to claim 17 including an adaptive clamp circuit means **(24)** connected to said input of said rectifier means **(32)** for eliminating leakage current problems, said adaptive clamp circuit means

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(24) having an input adapted to be connected to a pair of a.c. power lines (22), a pair of clamp circuit output lines (26) connected to said adaptive clamp circuit means input, a voltage sensing means (48) connected across said adaptive clamp circuit means input, and a controlled load means (50) connected across said clamp circuit output lines (26) and to said voltage sensing means (48), said voltage sensing means (48) being responsive to a magnitude of a.c. voltage at said adaptive clamp circuit means input lower than a predetermined magnitude for turning on said controlled load means (50) to connect a low impedance load (60) in said controlled load means (50) across said clamp circuit output lines (26) and said voltage sensing means (48) being responsive to a magnitude of the a.c. voltage at said adaptive clamp circuit means input equal to or greater than said predetermined magnitude for turning off said controlled load means (50) to disconnect said low impedance load (60) from said clamp circuit output lines (26).

20. The apparatus according to claim 17 wherein said battery backup means (62) includes a time delay and restoration means (78) responsive to application of a.c. power at said input of said battery backup means (62) for controlling said switch-over means (82) to disconnect said output of said battery backup means (62) from said input of said rectifier means (32) and connect the a.c. power to said rectifier means input after a predetermined time delay.

21. The apparatus according to claim 17 wherein said battery backup means (62) includes a d.c. power switch-over and flasher means (80) connected to said switch-over means (82) for pulsing said d.c. power at a predetermined rate to flash said LED array (12).

22. The apparatus according to claim 17 wherein said battery backup means (62) includes a synchronizing pulse generator means (86)

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connected to said d.c. power switch-over and flasher means **(80)** for imposing marker pulses on said d.c. power at a predetermined rate.

23. An apparatus for supplying regulated voltage d.c. electrical power to an LED array comprising:

a rectifier means **(32)** having an input and an output, said rectifier means **(32)** being responsive to a.c. power at said input for generating rectified d.c. power at said output;

a power factor correcting and voltage regulating buck/boost switchmode converter **(38)** having an input connected to said output of said rectifier means **(32)** and an output, said switchmode converter **(38)** being responsive to said rectified d.c. power at said switchmode converter input for generating regulated voltage d.c. power at said switchmode converter output;

an LED array **(12)** having an input connected to said output of said switchmode converter **(38)** for receiving said regulated voltage d.c. power to illuminate said LED array **(12)**;

a battery backup means **(62)** having an input for receiving a.c. power applied to said input of said rectifier means **(32)** and having an output at which d.c. power is generated; and

a switch-over means **(82)** connected to said output of said battery backup means **(62)** and to said input of said rectifier means **(32)**, said battery backup means **(62)** being responsive to a failure of a.c. power at said battery backup means input for controlling said switch-over means **(82)** to connect said battery backup means output to said rectifier means input to provide d.c. power to said switchmode converter **(38)** to illuminate said LED array **(12)** and being responsive to a.c. power at said battery backup means input for controlling said switch-over

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means **(82)** to disconnect said battery backup means output from said rectifier means input.

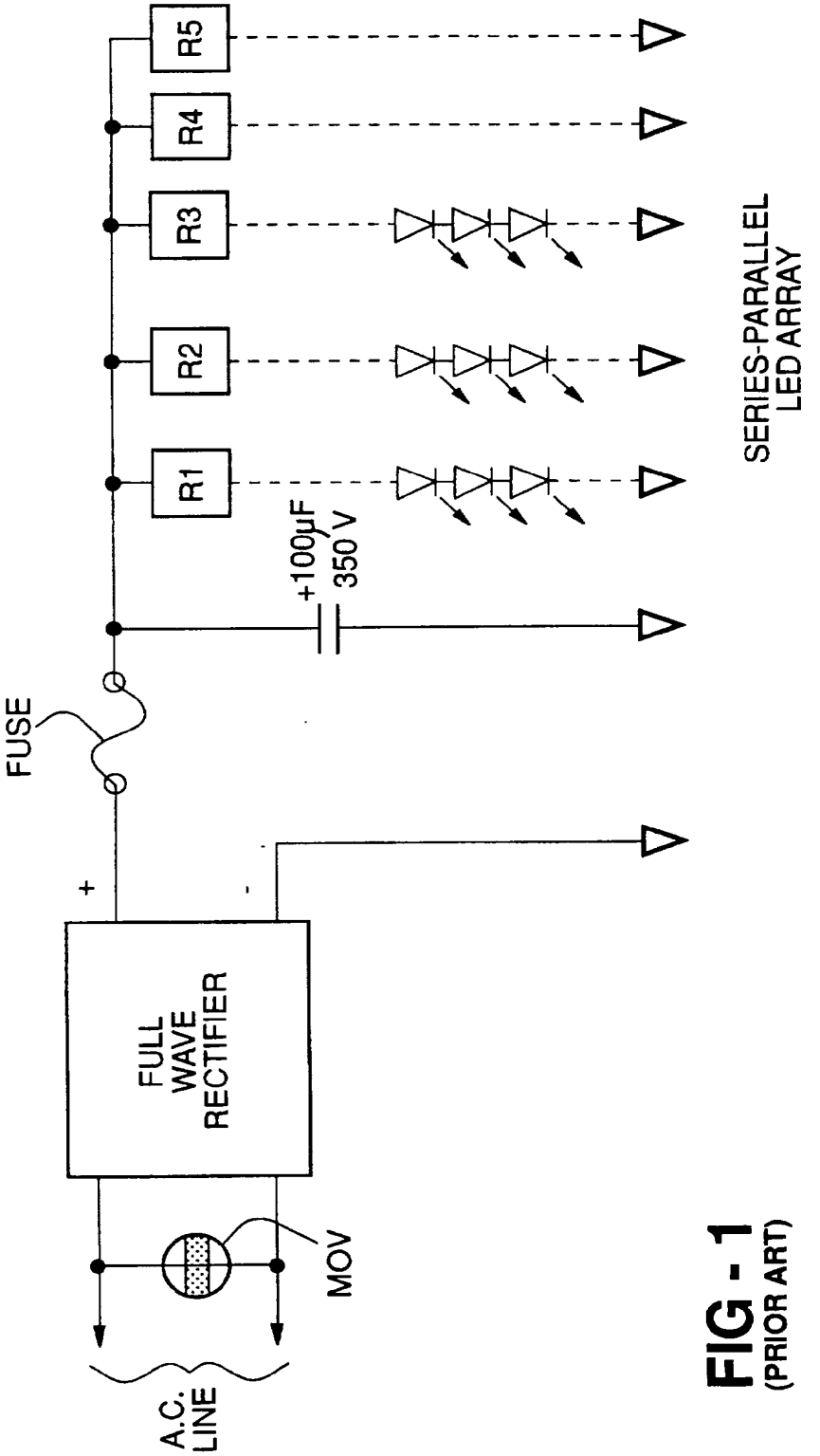


FIG - 1
(PRIOR ART)

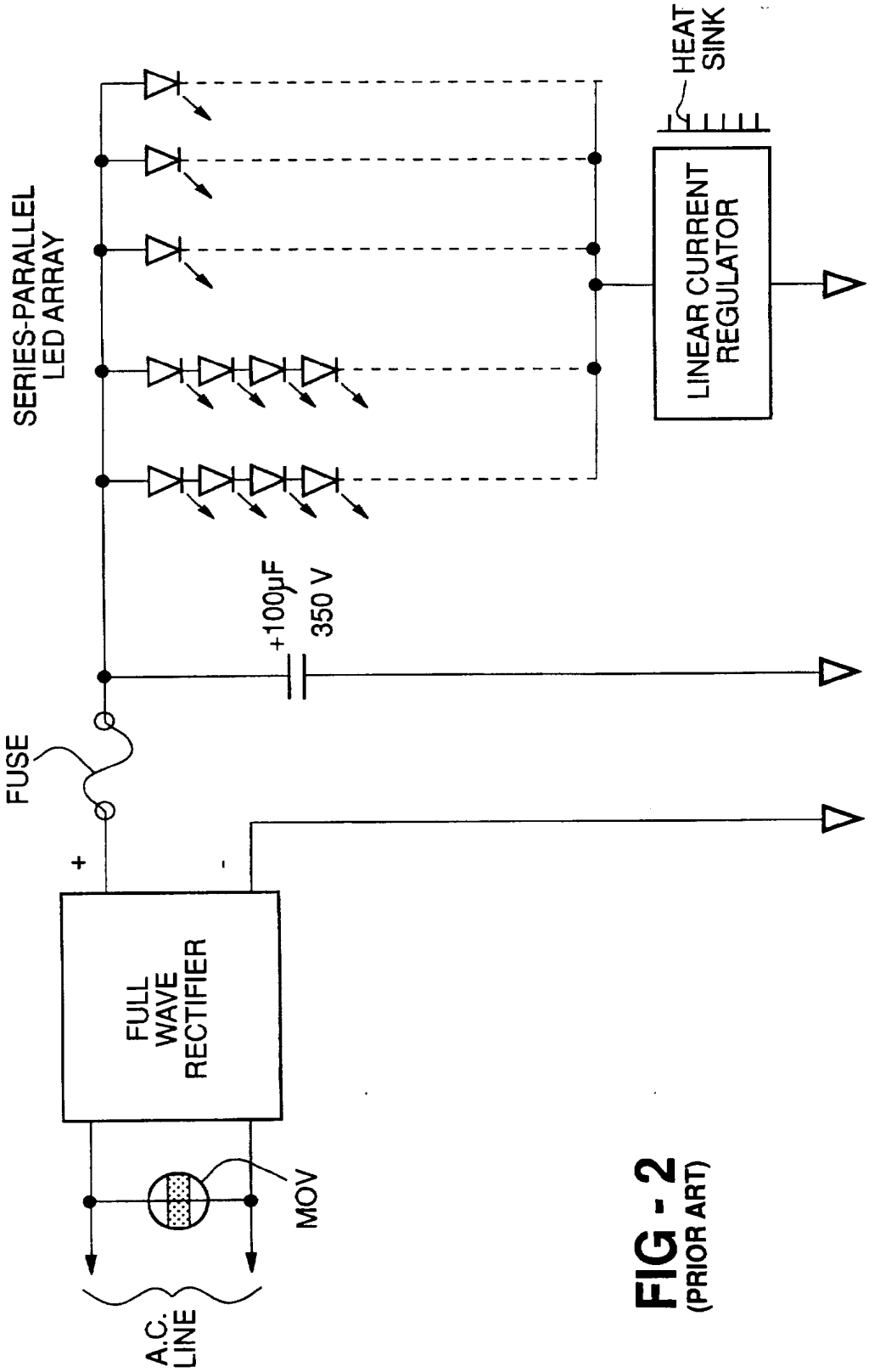


FIG - 2
(PRIOR ART)

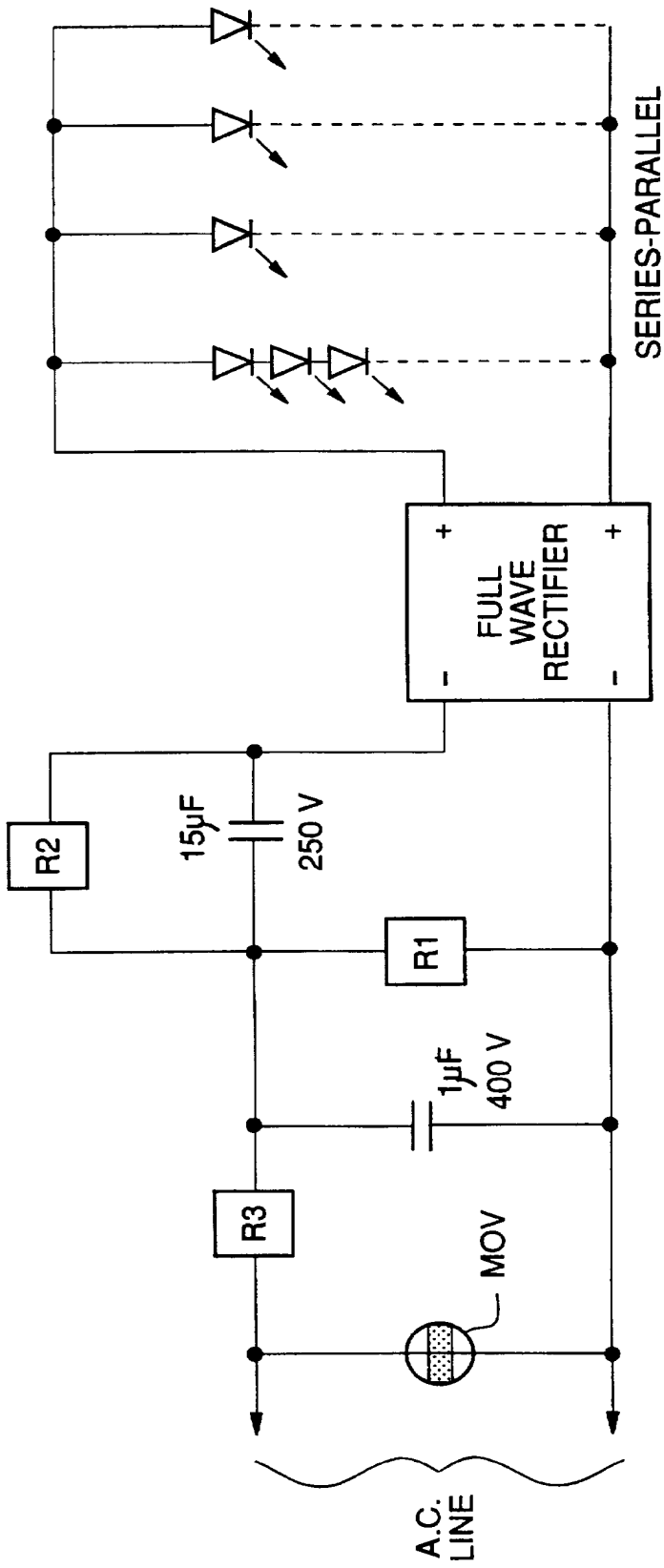


FIG - 3
(PRIOR ART)

FIG - 4

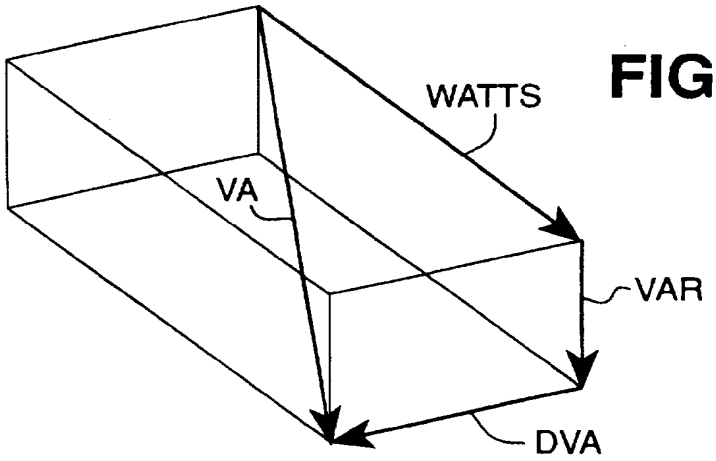


FIG - 6a

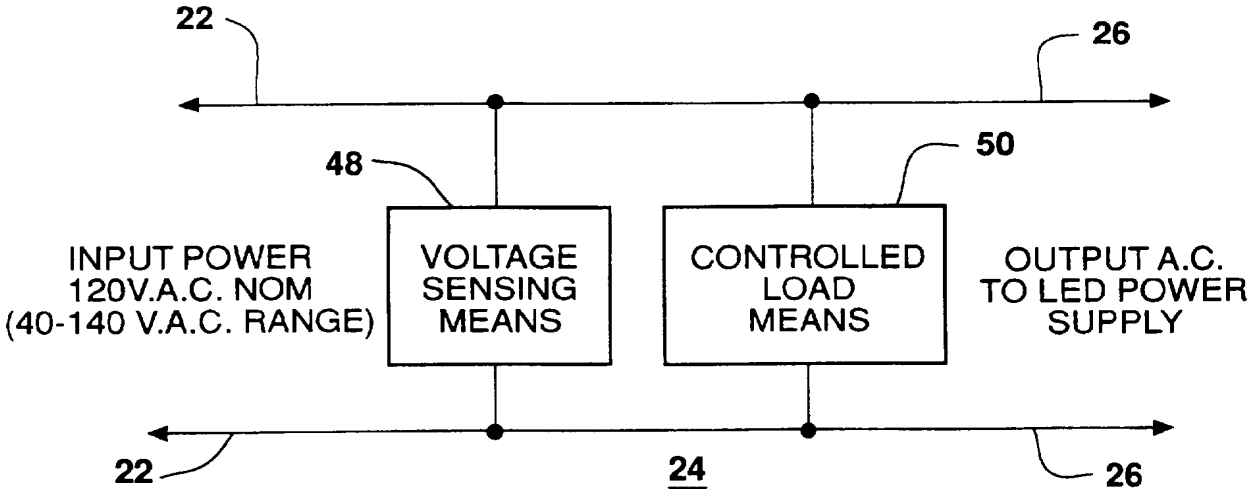
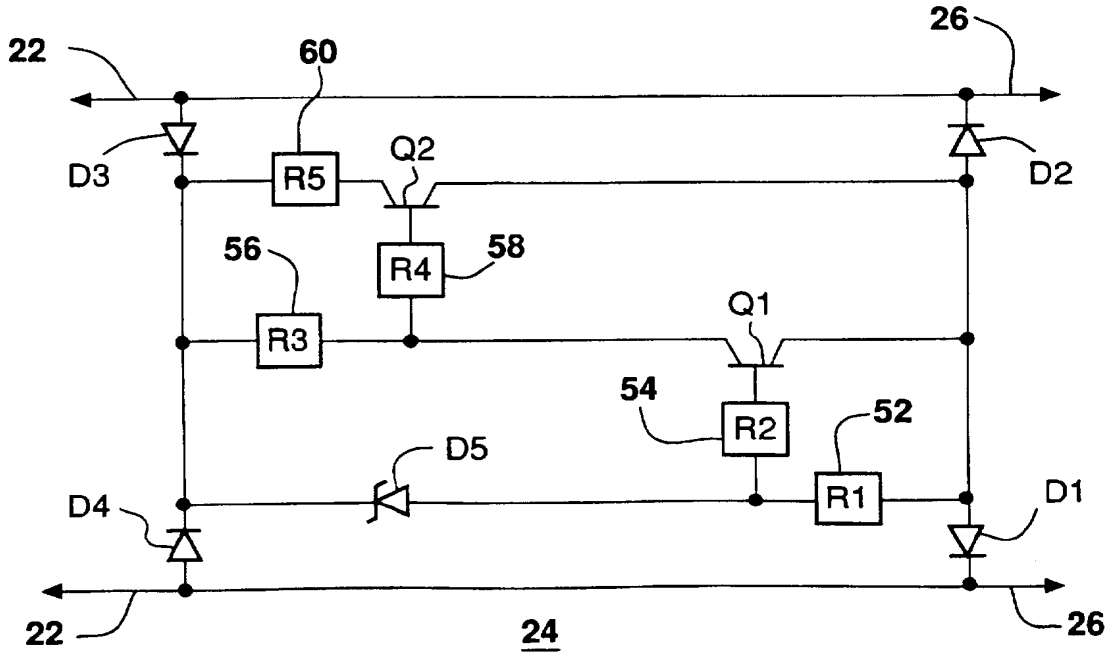


FIG - 6b



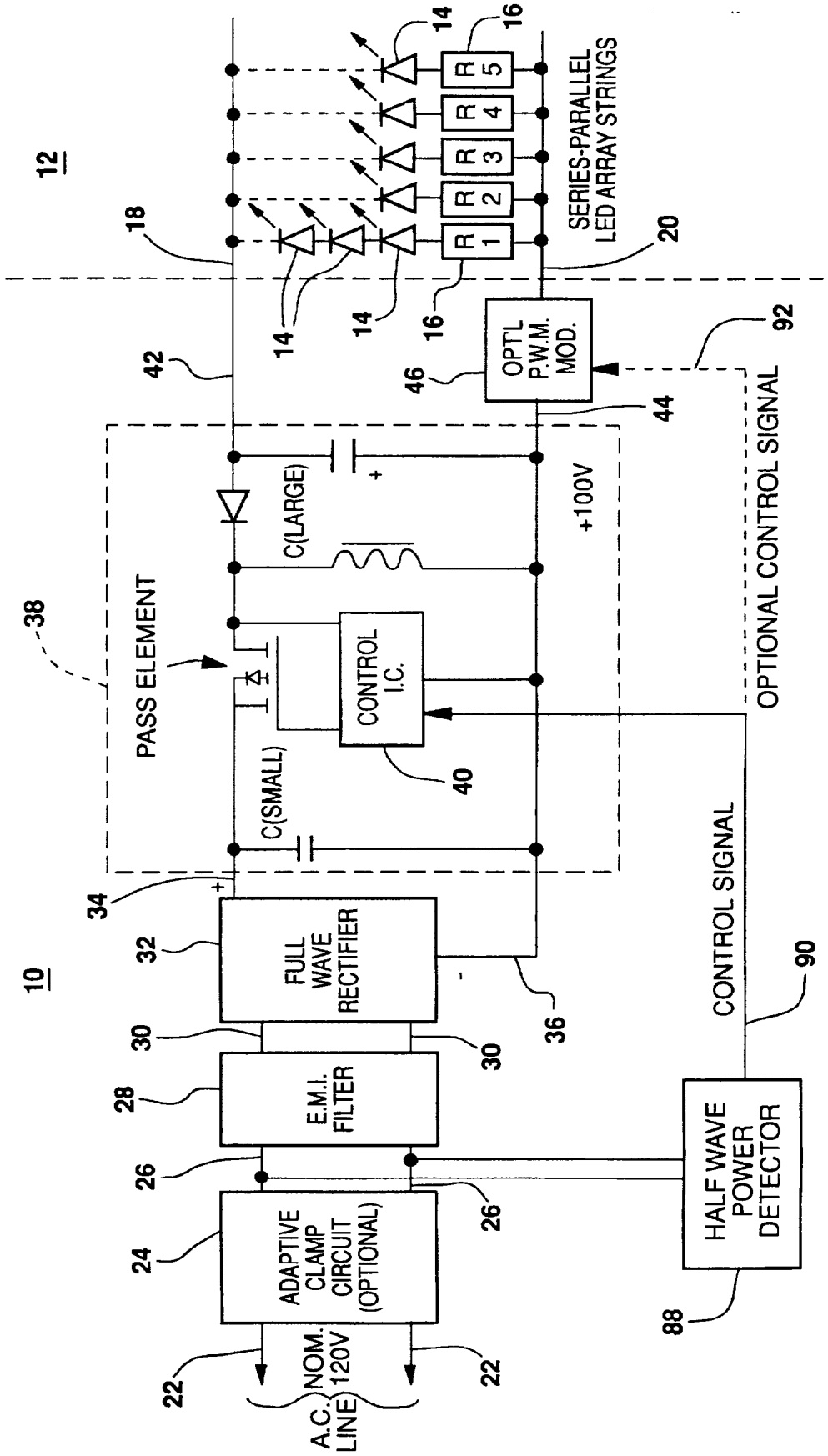

12
18
14
16
R 1
R 2
R 3
R 4
R 5
SERIES-PARALLEL LED ARRAY STRINGS
20
OPTL P.W.M. MOD.
46
44
92
OPTIONAL CONTROL SIGNAL
42
C(LARGE)
+100V
38
PASS ELEMENT
CONTROL I.C.
40
C(SMALL)
34
10
32
FULL WAVE RECTIFIER
36
30
E.M.I. FILTER
28
26
ADAPTIVE CLAMP CIRCUIT (OPTIONAL)
24
22
A.C. LINE
NOM. 120V
CONTROL SIGNAL
90
HALF WAVE POWER DETECTOR
88

FIG - 5

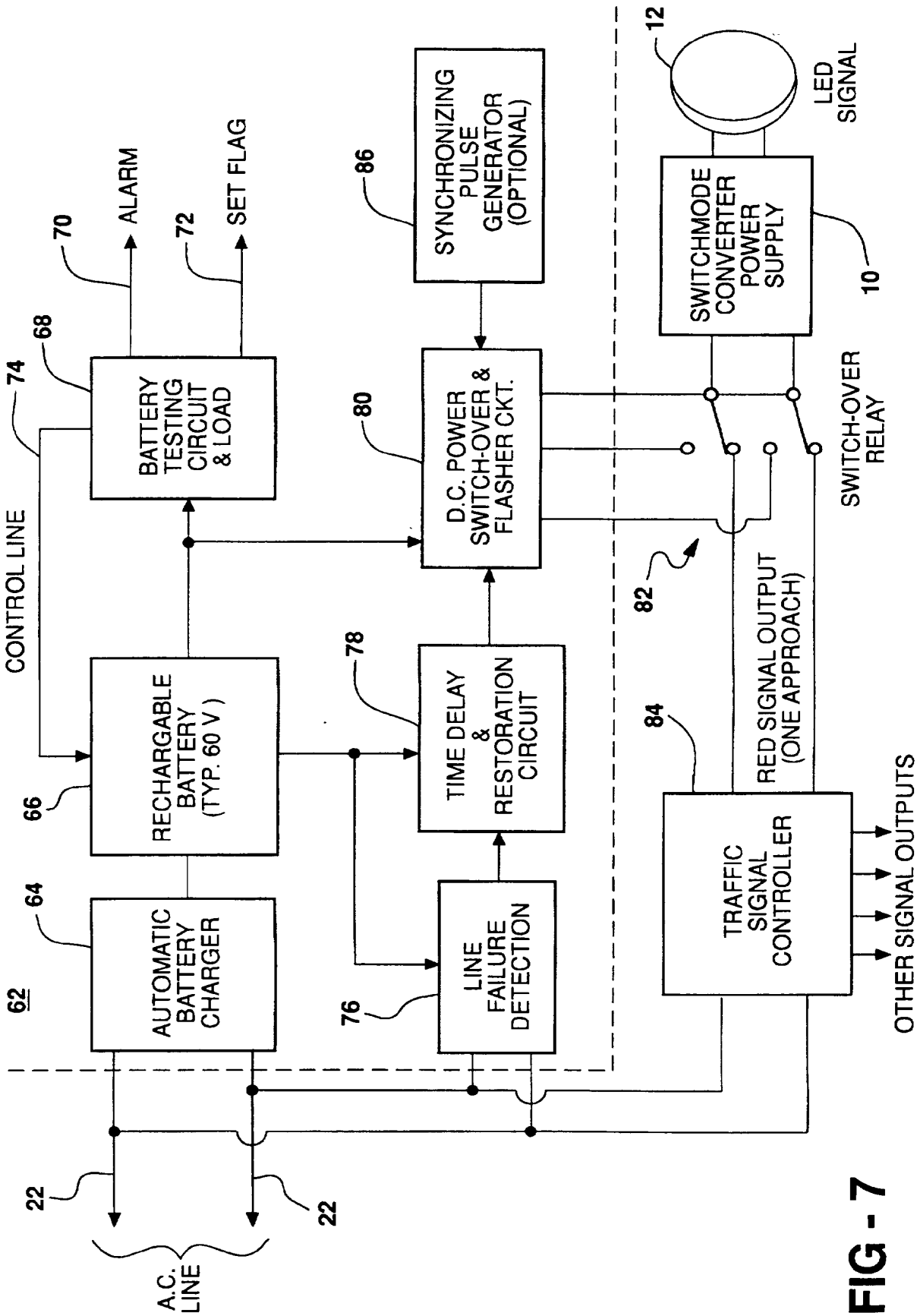


FIG - 7

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/US97/10514

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :H02M 5/42
US CL :363/89

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 363/89, 80, 126

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

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

APS

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5,321,600 A (Fierheller) 14 June 1994, seel entire document.	1-23
A,P	US 5,532,918 A (Mayrand et al) 02 July 1996, see entire document.	1-23
A,P	US 5,563,781 A (Clauter et al) 08 October 1996, see entire document.	1-23
A,P	US 5,572,416 A (Jacobs et at) 05 November 1996, see entire document.	1-23
A,P	US 5,587,895 A (Harkins) 24 December 1996, see entire document.	1-23

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document published on or after the international filing date

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"P" document published prior to the international filing date but later than the priority date claimed

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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
25 AUGUST 1997	0 2 OCT 1997
Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703) 305-3230	Authorized officer STUART N. HECKER Telephone No. (703) 305-3188

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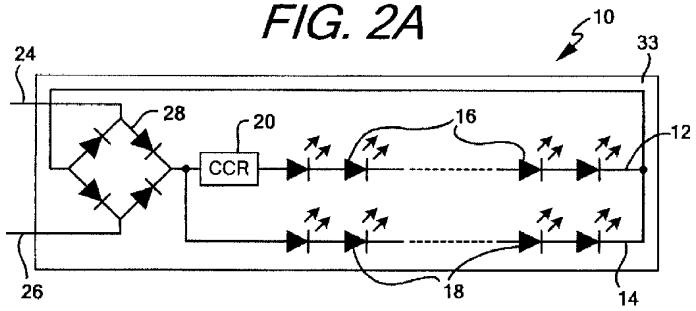
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Published:

— *with international search report (Art. 21(3))*

(54) Title: COLOR TEMPERATURE CONTROLLED AND LOW THD LED LIGHTING DEVICES AND SYSTEMS AND METHODS OF DRIVING THE SAME

FIG. 2A



(57) Abstract: The purposes of the devices described herein are to provide an LED lighting device capable of efficiently and economically emitting light having a selectable color temperature or a warm-on-dim feature when driven with AC power and to provide LED lighting devices which have an improved power factor and a reduced total harmonic distortion when powered with AC power.

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COLOR TEMPERATURE CONTROLLED AND LOW THD LED LIGHTING DEVICES AND SYSTEMS AND METHODS OF DRIVING THE SAME

RELATED APPLICATIONS

[Para 1] The application claims priority to U.S. Provisional Application No. 61/630,025 entitled "Drive Method for Low THD and Color Temperature Changing LED Lighting Device Method and Apparatus" filed December 2, 2011; U.S. Provisional Application No. 61/570,200 entitled "Drive Method for Low THD and Color Temperature Changing LED Lighting Device Method and Apparatus" filed December 13, 2011; and, PCT Application No. PCT/US2012/051531 entitled "Devices and Systems Having LED Circuits and Methods of Driving the Same" filed August 20, 2012 - the contents of all of which are expressly incorporated herein by reference.

TECHNICAL FIELD

[Para 2] The present invention generally relates to light emitting diode ("LED") circuits for use with AC voltage sources. More specifically, the present invention relates to LED devices capable of having color temperature control, low total harmonic distortion, and methods of driving the same.

FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

[Para 3] None.

BACKGROUND OF THE INVENTION

[Para 4] LEDs are semiconductor devices that produce light when a current is supplied to them. LEDs are intrinsically DC devices that only pass current in one polarity, and historically have been driven by constant current or constant voltage DC power supplies. When driven by these DC power supplies, LEDs are typically provided in a series string, in parallel strings or in series parallel configurations based on the drive method and LED lighting system design.

[Para 5] Recent advancements in the field of lighting have led to the use of LED circuits which are capable of using AC power to drive LEDs configured in particular devices and/or circuit arrangements such that some of the LEDs may operate during the positive

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phase of the AC power cycle, some LEDs may operate during the negative phase of the AC power cycle, and, in some cases, some or all LEDs may operate during both the positive and negative phases of the AC power cycle. LEDs powered with AC power typically last substantially longer than traditional halogen and incandescent devices or lamps, and typically require much less power to produce a substantially similar amount of light. However, LEDs powered by AC power sources act as a non-linear load. As a result of the non-linearity, LEDs powered using AC power sources may have a lower power factor, and may have a greater total harmonic distortion, than existing halogen or incandescent lighting devices. Having a low power factor and increased distortion may result in higher energy costs, transmission losses, and/or damage to electrical equipment. While the amount of power needed to drive an LED lighting device may be less than to drive a halogen or incandescent lighting device producing a substantially similar amount of light, the overall cost of operating an LED lighting device using AC power may be equal to or more than the amount required to drive the halogen or incandescent lighting device using the same AC power source.

[Para 6] Another advantage that traditional halogen and incandescent lighting devices have over present LED lighting devices driven with AC power is that halogen and incandescent lighting devises have the ability to change color temperature when the voltage provided to them is changed. Light in halogen and incandescent lighting devices are typically generated by a hot wire filament. As the power provided to the bulb is decreased, the temperature of the filament typically decreases, causing the color temperature of the emitted light to move down the color spectrum and make the light appear warmer, *i.e.* closer to yellow or amber or red than white or blue. In order to achieve this effect in LED lighting devices driven with AC power, complicated and expensive drive schemes are currently required which drive up the cost of the lighting device and the cost to operate the same. One example would be color mixing with red, green and blue LEDs referred to as "RGB" which typically uses pulse width modulation to create any color of light desired. However, the power supplies for this are very complex and larger in size. Other complex versions of constant current or constant voltage DC with only two different LED colors can also be used, however these power supplies can also be large and complex. These drive schemes may also be inefficient and waste additional power or electricity, further increasing operating costs.

[Para 7] Therefore, it would be advantageous to design a circuit, device, or system utilizing LEDs that maximizes power factor while reducing the total harmonic distortion resulting from driving the circuit, device or system using AC power.

[Para 8] It would also be advantageous to design a circuit, device, or system where the

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color temperature of the LEDs driven with AC power may be dynamically adjusted using simple control methods without having to utilize any complicated or expensive drive mechanisms.

[Para 9] The present invention is provided to solve these and other issues.

SUMMARY OF THE INVENTION

[Para 10] Accordingly, the present invention is provided to increase the performance of LED lighting devices driven by AC power. The LED lighting devices of the present invention seek to provide one or more of a color temperature controllable AC LED lighting device and/or an AC LED lighting device having an increased power factor and reduced total harmonic distortion.

[Para 11] According to one aspect of the invention, an LED lighting device having at least two LED circuits connected in parallel, each of the at least two LED circuits having one or more LEDs is provided. Each of the at least two LED circuits that are connected in parallel have a different forward operating voltage than the other LED circuit(s) within the device, and, each of the at least two LED circuits are capable of emitting light having one or more of a different color or wavelength than the other LED circuit(s) within the device. The device further includes at least one active current limiting device connected in series with at least one LED in at least one of the at least two LED circuits. The device and/or circuits are configured such that each LED circuit is capable of emitting light during both a positive and a negative phase of a provided AC voltage when the LED lighting device is connected to an AC voltage source.

[Para 12] According to another aspect of the invention, the at least one current limiting device may be, for example, a current limiting diode or a constant current regulator.

[Para 13] According to another aspect of the invention, each of the LED circuits and the at least one active current limiting device are integrated onto a single substrate to form the device.

[Para 14] According to another aspect of the invention, the device may include additional active current limiting devices, which may also be integrated on the single substrate. Each LED circuit in the device may be connected in series to at least one active current limiting device. Where each LED circuit is connected in series to at least one active current limiting device, each circuit may be connected to its own current limiting device which may each allow a similar or different amount of current to flow through each circuit, or

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multiple circuits may be connected to at least one common current limiting device which acts to limit the current for each of the circuits.

[Para 15] According to another aspect of the invention, the LED lighting device may include a bridge rectifier having at least one of the at least two LED circuits connected across the output of the bridge rectifier.

[Para 16] According to another aspect of the invention, at least one of the at least two circuits may include two or more LEDs connected in an anti-parallel configuration.

[Para 17] According to another aspect of the invention, at least one of the at least two circuits may include at least five diodes, at least four of the diodes being LEDs. The at least four LEDs may be connected in a bridge rectifier configuration and the at least fifth diode may be connected across the output of the bridge rectifier. The at least fifth diode connected across the output of the bridge rectifier may be a standard diode, an LED or a constant current diode, or may alternatively a constant current regulator.

[Para 18] According to another aspect of the invention, at least one of the at least two circuits may include seven or more diodes, at least six of the diodes being LEDs. The at least six LEDs being connected in an imbalanced bridge rectifier configuration, with the at least seventh diode being connected across the output of the imbalanced bridge rectifier. The at least seventh diode connected across the output of the bridge rectifier may be a standard diode, an LED or a constant current diode, or may alternatively a constant current regulator.

[Para 19] According to another aspect of the invention, the light emitted by the one or more LEDs forming at least one of the at least two LED circuits may be one or more of a different color or wavelength than the light emitted by the one or more LEDs of the other connected LED circuit(s) in the device. Using different colored of LEDs in each circuit will allow each circuit to emit different colors of light to contribute to the overall color temperature of light emitted by the device.

[Para 20] According to another aspect of the invention, each of the at least two circuits may be coated in phosphor, each of the at least two circuits having a different phosphor coating than the other connected at least two LED circuits. The different phosphor coating on each of the at least two circuits may cause each circuit to emit one or more of a different color or wavelength of light than the other connected LED circuits.

[Para 21] According to another aspect of the invention, the LED lighting device may be integrated into a lighting system, the lighting system having a dimmer switch capable of providing AC voltage to the LED lighting device, *i.e.* the dimmer switch be a connected AC power source or supply. The dimmer switch may be used to control the AC voltage provided

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to the at least two LED circuits to control the light output of each circuit to control a color temperature of light emitted by the LED lighting device.

(Para 22] According to one aspect of the invention, a method of controlling color temperature of light emitted by an LED lighting device is provided. In order to control the color temperature of the light emitted by the device, at least two LED circuits are connected in parallel. Each connected LED circuit has a different forward operating voltage and is capable of emitting light of one or more of a different color or wavelength than the other LED circuits connected in parallel. The current provided to at least one of the at least two LED circuits is limited, and at least one of the provided voltage and current to control the light output of the LED circuits connected in parallel is adjusted. The voltage and current provided to each circuit may be a direct AC voltage and current or a rectified AC voltage or current, with the possibility that some circuits in the device are provided a direct AC voltage and current and some of the circuits in the device are provided with a rectified AC voltage and current.

[Para 23] According to one aspect of the invention, an LED lighting device is provided. The LED lighting device may include at least one LED circuit having two or more LEDs connected in series, and at least one active current limiting device, the active current limiting device being connected in parallel with the at least one LED in the at least one LED circuit.

[Para 24] According to another aspect of the invention, the LED lighting device may include at least a second active current limiting device, the second active current limiting device being connected in series with the at least one LED circuit.

[Para 25] According to another aspect of the invention, the LED lighting device may further include a bridge rectifier, wherein the at least one LED circuit is connected across the output of the bridge rectifier. The bridge rectifier may be constructed using either standard diodes, LEDs or some combination thereof.

[Para 26] According to another aspect of the invention, the LED lighting device may include at least one additional LED circuit having two or more LEDs connected in series and at least one active current limiting device connected in parallel with at least one of the two or more LEDs, the at least one additional LED circuit being connected to the at least one LED circuit in parallel. The at least one additional LED circuit may be capable of emitting light having one or more of a different color or wavelength than the at least one LED circuit in the device.

[Para 27] According to another aspect of the invention, the at least one LED circuit may include at least three LEDs connected in series.

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[Para 28] According to another aspect of the invention, the LED lighting device may include a resistor connected in series with the at least one LED circuit.

[Para 29] According to another aspect of the invention, each active current limiting device may be a constant current regulator or a current limiting diode.

[Para 30] According to one aspect of the invention, an LED lighting device is provided. The LED lighting device includes at least one LED circuit having at least two LEDs connected in series and two sets of connection leads. The first set of connection leads in the device are configured to provide a connection to the at least two - as well as any additional - LEDs in the at least one LED circuit in order to provide a connection to all of the LEDs. The first set of connection leads having a first connection lead and a second connection lead, where the first connection lead is connected to an input of the at least one LED circuit and the second connection lead is connected to an output of the at least one LED circuit. The second set of connection leads in the device include a third connection lead and a fourth connection lead where the third connection lead is connected to the anode of at least one of the at least two LEDs and the fourth connection lead being connected to the cathode of at least one of the at least two LEDs. The second set of connection leads are configured to provide a connection to less than all of the LEDs in the at least one circuit, *i.e.* only one of two LEDs or only two of four LEDs, etc.

[Para 31] According to another aspect of the invention, at least two LEDs may be configured into at least two sets of LEDs connected in series. Each set of LEDs includes at least one LED, and may have multiple LEDs. The first connection leads may be configured to provide a connection to both of the at least a first and a second set of LEDs, while the second connection leads are configured to provide a connection to only one of the first or second set of LEDs.

[Para 32] According to another aspect of the invention, the at least one circuit may include at least three LEDs, the at least three LEDs being connected in series between the first and second connection lead. Each the at least three LEDs may be configured into at least three sets of LEDs, each set having at least one, and sometimes multiple, LED(s). When the at least one circuit includes at least three LEDs, the third connection lead may connected the anode of the first LED in one of the first, second or third sets of LEDs, *i.e.* the anode of the first LED in a particular set. The fourth connection lead may be connected to the cathode of the last LED in the same set of LEDs, *i.e.* if the third connection lead is connected to the anode of the first LED in the first set, the fourth connection lead may be connected to the cathode of the last LED in the first set.

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[Para 33] According to another aspect of the invention, the lighting device may be integrated into a lighting system. The lighting system may include a driver having a bridge rectifier, at least two active current limiting devices, and at least three sets of driver connection leads. The first active current limiting device may be connected to the output of the bridge rectifier while the second active current limiting device may be electrically unconnected to the bridge rectifier and the first constant current diode. The first set of driver connection leads may provide a connection for the bridge rectifier to connect to an AC voltage source. The second set of driver connection leads may include a third driver connection lead providing an output from the first active current limiting device connected in series with the output of the bridge rectifier and a fourth driver connection lead providing a return from a load to the bridge rectifier. The third set of driver connections leads may include a fifth driver connection lead providing an input to the second active current limiting device, and a sixth driver connection lead providing an output from the second active current limiting device. When integrating the lighting device, the third driver connection lead may connect to the first connection lead of the lighting device and the fourth driver connection lead may connect to the second connection lead of the lighting device to drive the LED circuit. The fifth driver connection lead may connect to the third connection lead of the lighting device and the sixth driver connection lead may connect to the fourth connection lead of the lighting device to provide a bypass or shunt of the one or more LEDs located between the third and fourth connection leads of the lighting device.

[Para 34] According to one aspect of the invention, an LED lighting device is provided. The LED lighting device includes a bridge rectifier and at least one LED circuit having at least two LEDs connected in series across the output of the bridge rectifier. The lighting device includes two sets of connection leads. The first set of connection leads may be configured to provide a connection to the bridge rectifier with a first connection lead and a second connection lead. The first and second connection leads may be connected to provide an electrical input to and output from the bridge rectifier from an AC power source. The second set of connection leads may be configured to provide a connection to at least one of the least two LEDs connected in series across the output of the bridge rectifier. The second set of connection leads include a third connection lead and a fourth connection lead with the third connection lead being connected to the anode of one of the at least two LEDs and the fourth connection lead being connected to the cathode of one of the at least two LEDs. The second set of connection leads may be configured to provide a connection to all or less than all of the LEDs connected in series across the output of the bridge rectifier. The bridge

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rectifier may be constructed using diodes, LEDs, or some combination thereof.

[Para 35] According to one aspect of the invention a method of reducing total harmonic distortion in LED lighting circuits and devices is provided. The method requires that at least two LEDs be connected in series and that a bypass around or shunt at least one of the at least two LEDs connected in series is provided. A substantially constant current may be maintained flowing through at least one LED having while at least one LED is bypassed or shunted.

[Para 36] According to another aspect of the invention, an active current limiting device may be used as the bypass or shunt and connected in parallel with at least one of the at least two LEDs to provide the bypass or shunt. The active current limiting device may be a constant current regulator or a current limiting diode.

[Para 37] Other advantages and aspects of the present invention will become apparent upon reading the following description of the drawings and detailed description of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[Para 38] FIG. 1 shows a block diagram of a constant current regulator which may be used with the invention;

[Para 39] FIG. 2A shows a color temperature controllable LED lighting device as contemplated by the invention;

[Para 40] FIG. 2B shows a color temperature controllable LED lighting device as contemplated by the invention;

[Para 41] FIG. 3A shows a color temperature controllable LED lighting device as contemplated by the invention;

[Para 42] FIG. 3B shows a color temperature controllable LED lighting device as contemplated by the invention;

[Para 43] FIG. 4 shows a color temperature controllable LED lighting device as contemplated by the invention;

[Para 44] FIG. 5 shows a color temperature controllable LED lighting device as contemplated by the invention;

[Para 45] FIG. 6 shows a graphical representation of the forward voltage versus forward current for various colors of LEDs;

[Para 46] FIG. 7 shows a graphical representation of the forward current versus the relative luminous flux for various colors of LEDs;

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[Para 47] FIG. 8 shows a diagram of a lighting system in which the color temperature controllable LED lighting devices of FIGs. 1-4 may be used;

[Para 48] FIG. 9 shows a lighting device having an increased power factor and reduced total harmonic distortion as contemplated by the invention;

[Para 49] FIG. 10 shows a lighting device having an increased power factor and reduced total harmonic distortion as contemplated by the invention;

[Para 50] FIG. 11 shows a lighting device having an increased power factor and reduced total harmonic distortion as contemplated by the invention;

[Para 51] FIG. 12 shows a lighting device having an increased power factor and reduced total harmonic distortion as contemplated by the invention;

[Para 52] FIG. 13 shows a lighting device having an increased power factor and reduced total harmonic distortion as contemplated by the invention;

[Para 53] FIG. 14 shows a lighting device having multiple power connection leads for increasing power factor and reducing total harmonic distortion as contemplated by the invention;

[Para 54] FIG. 15 shows a driver for driving to the device of FIG. 13;

[Para 55] FIG. 16 shows a lighting device having multiple power connection leads for increasing power factor and reducing total harmonic distortion as contemplated by the invention;

[Para 56] FIG. 17 shows a lighting device having multiple power connection leads for increasing power factor and reducing total harmonic distortion as contemplated by the invention;

[Para 57] FIG. 18 shows a graphical representation of an applied voltage and forward current in a known LED lighting device; and,

[Para 58] FIG. 19 shows a graphical representation of an applied voltage and forward current in an LED lighting device having an increased power factor and reduced total harmonic distortion as contemplated by the invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

[Para 59] While this invention is susceptible to embodiments in many different forms, there is described in detail herein, various embodiments of the invention with the understanding that the present disclosures are to be considered as exemplifications of the principles of the invention and are not intended to limit the broad aspects of the invention to the embodiments illustrated.

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[Para 60] The present invention is directed to multiple lighting devices or systems, the light emitting circuits contained therein, and methods of driving and operating the same. As discussed herein, a lighting device may include any device capable of emitting light no matter the intention. Examples of lighting devices which are contemplated by this invention include, but are not limited to, LED chips, LED packages, LED chip on board assemblies, LED assemblies or LED modules. The devices may also include any required power connections or leads or contacts, or drivers, required to provide power to the circuits and allow the circuits within the device to emit light. A lighting system may include multiple such devices, and some or all of the required parts to drive such a device or multiple devices, including but not limited to, power supplies, transformers, inverters, rectifiers, sensors or light emitting circuitry discussed herein. While a lighting device may be incorporated into a lighting system or into a lamp or light bulb, it is contemplated that any required light emitting elements may be included within the system directly, whether in the form of a device as a chip or package, or as circuits within the system.

[Para 61] The purposes of the devices described herein are twofold, and may be accomplished independent of each other. One intention of the devices described herein is to provide an LED lighting device capable of efficiently and economically emitting light having a selectable color temperature or a warm-on-dim feature when driven with AC power. The second intention of the devices described herein is to provide LED lighting devices which have an improved power factor and a reduced total harmonic distortion when powered with AC power.

[Para 62] In order to achieve either of the goals of the devices described herein, it may be necessary to include one or more active current limiting devices within each LED lighting device, regardless of whether the device is designed to allow color temperature control, increase power factor while reducing THD, or both. While any known current limiting device which sets a substantially upper limit on the current which is allowed to flow through a circuit may be used with any of the circuits or devices described herein, the devices in the present application will primarily discuss using a constant current regulator (CCR), like for example those sold by ON Semiconductor or operating having the internal structures as shown in the block diagram of FIG. 1, and a current limiting or current controlled diode (CLD). Both CCRs and CLDs actively limit the current flowing through a particular circuit or device by substantially limiting the current to, and maintaining the current at, a threshold level once the current in a connected circuit or device has reached or exceeded a particular value. Using such devices is advantageous over using current limiting resistors insofar as

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CCRs and CLDs both cap the total current which is allowed to flow through a connected circuit or device, while the resistor only acts to reduce any every climbing current. With a current limiting resistor, as the input voltage to the circuit continues to increase, the current will likewise continue to increase without limit, albeit it at a lower value than without the resistor. With a CCR or a CLD, once the current reaches a threshold maximum, the current will remain substantially constant until the input voltage is reduced, even if the input voltage continues to climb. As will be described herein, in some cases the combination of a CCR or CLD and a current limiting resistor may be beneficial or required.

[Para 63] While both CCRs and CLDs may be used interchangeably to accomplish the goals of the devices described herein, there are differences between the devices. The primary difference between the devices is that CCRs, like those sold by ON Semiconductor, typically have internal transistor based control circuits and have little or no turn on voltage. CLDs are a form of a diode which are based in part on a JFET having a gate shorted to the power source and have a measurable turn on voltage. While the CLDs may be utilized with any of the devices described herein, it may be advantageous to use a CCR when possible in order to avoid the additional turn on voltage requirements of the CLD. However, CCRs and CLDs may be used interchangeably to accomplish the goals of the invention.

[Para 64] FIGs. 2-5 show exemplary LED lighting devices capable of emitting color temperature controlled light. As seen in FIG. 2A, lighting device 10 includes at least two LED circuits 12, 14 which are connected in parallel. Each LED circuit 12, 14 includes one or more LEDs 16, 18 respectively. Each LED circuit 12, 14 has a different forward operating voltage and is capable of emitting light having one or more of a different color or a different wavelength than the other circuit. For example, LED circuit 12 may emit amber or yellow light, while LED circuit 14 emits white or blue light. In order to limit the current within either LED circuit 12, 14, an active current limiting device such as a CCR or CLD, shown as CCR 20 connected in series with at least one LED 16 in first circuit 12, may be provided. As seen in FIG. 2B, additional active current limiting devices, like for example CCR 22, may be added to the device so that each LED circuit is connected in series with an active current limiting device. LED device 10 may further include connection leads 24, 26 for connecting the device to an AC power source, like for example mains power or a switch or dimmer connected to mains power. In order to fully utilize AC power and produce a substantially constant light output, device 10 and/or circuits 12, 14 should be configured such that each circuit 12, 14 is capable of emitting light during both a positive and negative phase of the provided AC voltage.

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[Para 65] In devices where one or both of LED circuits 12, 14 include only a single LED, or, as shown in FIGs. 2A and 2B a series string of LEDs 16, 18 respectively, in order to insure each circuit emits light during both the positive and negative phase of the provided AC power device 10 may include bridge rectifier 28. The electrical inputs of bridge rectifier 28 may connect directly to leads 24, 26, while the output and return of the bridge rectifier connects to parallel circuits 12, 14, providing rectified AC power to each circuit. Providing the rectified power insures that each circuit is capable of emitting light during both the positive and negative when device 10 is electrically connected to an AC power source. When utilized herein, unless otherwise noted, connecting an LED circuit across the output of a bridge rectifier refers to connecting the LED circuit to both the output and return of the bridge rectifier, such that the circuit receives power from the output of the bridge rectifier at one end and has a return path to the return of the bridge rectifier, effectively creating a closed loop between the LED circuit and the bridge rectifier.

[Para 66] While single LEDs or series strings like LED circuits 12, 14 may require device 10 to include a bridge rectifier to utilize both phases of connected AC power, one or more of circuits 12, 14 may be modified to use direct AC power without the requirement of rectification. For example, as seen in FIGs. 3A and 3B, device 10' may include LED circuits 12', 14' where each circuit includes at least one LED 16', 18' respectively, connected in an antiparallel configuration. With LEDs 16', 18' connected in an anti-parallel configuration, LED circuits 12', 14' are capable of emitting light during both phases of AC power without the need for rectification as each circuit has one or more LEDs configured to use both the positive and negative phase of a connected AC power source. As a result, circuits 12', 14' may be directly connected to leads 24', 26' as shown in FIGs. 3A and 3B without an intervening rectifier. When utilizing an anti-parallel configuration, however, in order to protect the LEDs during both phases of AC power in at least one of circuit 12', 14', more than one active current limiting device may be required. For example, as seen in FIG. 3A, each anti-parallel branch in circuit 12' (or 14') may include an active current limiting device, which may be either a CCR or CLDs 30'. Rather than connect one current limiting device in series with each branch of anti-parallel circuit 12', back-to-back CLDs or CCRs may be attached at one end of the circuit, between circuit 12' and either lead 24' or 26' as seen in FIG. 3B. Inasmuch as both CLDs and CCRs have very low reverse breakdown characteristics, it is possible to connect CLDs or CCRs in a back-to-back fashion and realize the current protecting features of the forward-biased CLD or CCR.

[Para 67] Other circuit configurations which may directly use AC power may be utilized

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in the LED lighting device as well. For example, rather than use a separate bridge rectifier connected to circuits having a single LED or series string of LEDs, one or more of the LED circuits may be configured in a bridge rectifier configuration with an additional diode, LED, CLD or CCR connected across the output of the rectifier. As seen in FIG. 4 LED lighting device 10" may include circuits 12", 14" which each include at least five diodes, at least four of the diodes being LEDs 16", 18" respectively. LEDs 16", 18" may be configured in a bridge rectifier configuration with a fifth diode, which may be a standard diode, LED 32" as shown in circuit 12", or CLD 30" as shown in circuit 14". Configuring circuit 10" in a bridge configuration with a diode, LED, or active current limiting device across the output of the rectifier allows for AC power to be used during both the positive and negative phase when provided to device 10". As a result, like the device shown in 10', circuits 12", 14" may be directly connected to connection leads 24", 26" without an intervening bridge rectifier. As seen in each circuit, unlike the circuits shown in FIG. 2, a single active current limiting device may be used to protect each of circuit 12", 14" if it is located across the output of each rectifier circuit. Inasmuch as current will flow through the at least fifth diode during both the positive and negative phases, placing the active current limiting device in series with the at least fifth diode (or making the at least fifth diode the active current limiting device) will insure that current during both phases of provided AC power flows through the current limiting device, effectively limiting the current for each LED within the circuit.

[Para 68] In order to further protect the LEDs in a circuit directly using AC power, each circuit in the LED lighting device may be configured in an imbalanced bridge configuration. As seen in FIG. 5, device 10"' may include circuits 12"', 14"' which each include at least diodes, at least six of which are LEDs connected in an imbalanced bridge configuration. The imbalanced bridge configuration will act substantially similar to, and have substantially the same characteristics as the circuits described in FIG. 4 with the added benefit of reverse breakdown protection for the LEDs forming the bridge. In order to imbalance the bridge, at least one additional LED is placed in series with one input LED (shown as the left branch of circuits 12"', 14"') than the other input LED, and at least one additional LED is placed in series with the opposing output LED (output LED during the opposite phase) than the aligned output LED. Configuring the LEDs forming the bridge in this manner helps reduce reverse breakdown of any of the LEDs in the circuit. Like a standard bridge, the cross-connecting branch across the output of the imbalanced bridge may be a standard diode, LED 32"', CLD 30"', or some combination thereof.

[Para 69] While FIGs. 2-5 show each of the aforementioned circuits in pairs, it is

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contemplated that the circuits disclosed in each FIG. may be mixed and matched within a single device as desired. For example, an LED lighting device may be made using circuits 12, 14" or 12', 14"'. Additional circuits may further be connected in parallel within a single device, the additional circuits having a different forward operating voltage than the other connected circuits, and each additional circuit being capable of emitting light of a different color than the other connected LED circuits within the device. The additional circuits may be configured in any manner shown in FIGs. 2-5 and connected to or include any rectifiers or connection leads as needed to receive power and emit light during both phases of any provided AC power.

[Para 70] Regardless of how many circuits are connected in parallel and the configuration of each circuit, any circuits forming an LED lighting device, along with the at least one active current limiting device, the connection leads and any required rectifiers or additional current limiting devices may be integrated on a single substrate 33 (FIGs. 2A, 2B), 33' (FIGs. 3A, 3B), 33" (FIG. 4), or 33"'(FIG. 5). The single substrate may then be directly incorporated into a lighting system or fixture, or a lamp or light bulb as desired.

[Para 71] While any known method for creating LED circuits capable of emitting light of a different color within a single device is contemplated by the invention, two examples will be discussed herein.

[Para 72] The first method by which the light emitted by each circuit may be made different is by using a different phosphor coating on each circuit. When using a phosphor coating, the color of the LEDs used in each circuit, for example LEDs 16, 18 in FIG. 2A, may emit a substantially similar color, like for example blue, or different colors, as the phosphor coating substantially creating the different colors of emission light for each circuit. Though the device and circuits of FIG. 2A will be used for examples herein, it should be appreciated that the devices and circuits of FIG. 2B-5, or any combination of circuits as discussed above, may be used in substantially the same manner to achieve substantially the same effect.

[Para 73] In order to create different forward operating voltages when using a phosphor coating, different colored LEDs having a different turn on voltage may be used, or the circuits may utilize a different number of similar colored LEDs. For example, a first circuit, like circuit 12 in FIG. 2A, may include five blue LEDs and be coated in yellow or amber phosphor, while circuit 14 may include 10 blue LEDs and be coated in white phosphor. Since the first circuit includes fewer LEDs, it will begin operating first as it will have a lower turn on voltage, causing the emission of light by device 10 substantially equal to the color of the phosphor coating on circuit 12, or yellow or amber. As the voltage provided to device 10

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increases, the current flowing through circuit 12 will increase, causing the yellow or amber light to more brightly emit. The current flowing through circuit 12 will continue to increase until the current threshold of the at least one active current limiting device (CCR 20) connected in series therewith is reached. It should be noted that when only a single active current limiting device is used, it is important that the current limiting device be connected to the circuit having the lower turn on voltage in order to protect and prevent the LEDs of the circuit from overdriving as the voltage is increased to turn on and intensify the LEDs of the LED circuit having the higher turn on voltage.

[Para 74] Using the example of a five blue LED circuit coated in yellow or amber phosphor and a ten blue LED circuit coated in white phosphor for circuits 12, 14 given above, as is known in the art, each blue LED has a turn on voltage of approximately 2.2V and will reach a nominal operating current at approximately 3.2V. The total turn on voltage for circuit 12 having five blue LEDs would therefore be approximately 1IV (2.2V time five LEDs) while the nominal current would reached at approximately 16V. The turn on voltage for circuit 14 would be approximately 22V with the nominal current being reached at approximately 32V. Using this example, as voltage is applied to device 10 in FIG. 2A, once the applied voltage reaches 1IV (assuming a CCR is connected as the active current limiting device, otherwise slightly higher than 1IV if a CLD is used), LEDs 16 of circuit 12 will begin to emit light, which will be yellow or amber as a result of the phosphor coating applied to the circuit. The brightness of the light emitted by device 10 and circuit 12 will increase until the current flowing through circuit 12 reaches the maximum threshold of CCR 20. If the maximum threshold current of CCR 20 is matched to nominal current of LEDs 16, this means that the current will be capped once 16V input is reached, which is well below the turn on or voltage for nominal current in circuit 14. Having the CCR connected in series with circuit 12 will prevent the overdrive of LEDs 16, protecting them from early burnout resulting from overdrive or overheating as the voltage increases to turn on circuit 14.

[Para 75] Once the input voltage is increased to 22V, LEDs 18 of circuit 14 will begin emitting white light as a result of the white phosphor coating. As circuit 14 begins emitting white light, the combination of yellow or amber and white light will be emitted by device 10, causing the color temperature to begin moving towards the cooler end of the color spectrum. As the voltage continues to increase to device 10, the amount of white light mixed in with the already fully emitted yellow or amber light will continue to increase as the current in circuit 14 increases, causing the color temperature to become cooler and cooler. As is shown in FIG. 2B, an additional or second active current limiting device may be included in device 10,

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CCR 22, which may limit the current within circuit 14 to the nominal current which will be reached at approximately 32V. Using this example, if CCR 22 is used in device 10, the maximum light output of device 10 will be reached at 32V along with the coolest possible temperature color. If the provided voltage increases over 32V, substantially no additional current will flow through either circuit, setting the uppermost light output of each circuit. When the voltage begins to be reduced and device 10 is dimmed, once the voltage begins falling below 32V, circuit 14 will begin emitting less white colored light as the current will drop below nominal level. As the current in circuit 14 decreases and circuit 14 dims, the light emitted by device 10 will both dim and become warmer as the yellow or amber component will become a larger percentage of the light emitted. Eventually at approximately 22V, circuit 14 will turn off and the only light emitted by device 10 will come from circuit 12, providing less light and creating a warmer yellow or amber light than when both circuit 12 and 14 were emitting light.

[Para 76] By using a set amount of LEDs in each LED circuit and setting the current at a level for one or more of the circuits, the amount of each color of light emitted by the device may be controlled by controlling the input voltage, and the color temperature change and light intensity characteristics can be known and tailored to a desired output.

[Para 77] The second method by which the color of the light emitted by the circuits may be made different is by using different colored LEDs in each circuit. The different colored LEDs will emit light of different colors, thereby causing each circuit to emit light of different colors. However, rather than using different numbers of LEDs to different forward operating voltages, the turn on voltage characteristics of the different colored LEDs may utilized to create the difference depending on the colors of the LEDs in the circuits. As is known in the art, there are two common turn on voltages for LEDs emitting colored light. The first turn on voltage is approximately 1.5V for InP diodes which are typically red, amber and yellow LEDs which each reach their nominal operating current at about 2.2V. The second turn on voltage is approximately 2.2V for GaN diodes which are typically green or blue which reach their nominal operating current at about 3.2V.

[Para 78] When using different colored LEDs, in order to create the amber-white device like that described above, circuit 12 may include five LEDs 16 which emit amber light while circuit 14 may include five LEDs 18 which emit blue light and are coated in white phosphor. Using this example, circuit 12 will begin emitting light at approximately 7.5V (again, if a CCR is connected in series, and at a higher voltage if a CLD is used) and reach nominal current at approximately 11V. Circuit 14 will begin emitting light at 11V but will not reach

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nominal current until approximately 16V. As circuit 12 begins to emit, a low level of amber light will be emitted by device 10 until the current value of the series active current limiting device is reached. The active current limiting device connected in series with the LEDs of circuit 12 may be set to prevent the current from rising higher than the nominal current value for the circuit, effectively fixing the intensity of light emitted by circuit 12 while protecting the one or more LEDs therein from overdrive as the voltage increases. As the voltage increases to 11V, circuit 14 will begin emitting white light, cooling the color temperature of the light emitted by device 10. The cooling will continue until either the voltage stops rising, or an active current limiting device connected in series with circuit 14 prevents the current flowing through circuit 14 from rising higher. As the voltage is decreased, the current and intensity of light emitted by circuit 14 will fall, causing the light to both dim and become warmer as the amount of light emitted from the amber LEDs will provide a greater percentage of the light emitted, creating a warmer color temperature colored light. At approximately 11V circuit 14 will turn off, and only circuit 12 and the amber LEDs will continue to emit light, creating a warmer and dimmer light as only the amber colored LEDs will be emitting light at this voltage. As the voltage continues to drop towards 7.5V, the amber LEDs will become dimmer and eventually turn off.

[Para 79] FIGs. 6 and 7 show the forward operating voltage and current characteristics for red (lines indicated by 34), blue (lines indicated by 36), and green (lines indicated by 38) LEDs. These graphical representations of the forward voltage for each LED vs. the forward operating current for each LED and the forward operating current for each LED vs. the luminous flux of each LED show the operating characteristics of different colored LEDs and the importance of connecting an active current limiting device in series with at least the lowest turn on voltage in the device. As seen in FIG. 7, each LED color reaches approximately 100% relative luminous flux, *i.e.* nominal flux, at around 350 mA. Less current than this will cause the LEDs to emit less than 100% flux while more current will overdrive the LEDs, causing more than 100% flux and unwanted heat and eventual breakdown or premature failure. FIG. 5 shows that red LEDs typically reach 350 mA around 2.2V (which is substantially similar for yellow or amber LEDs), blue LEDs around 3.1V, and green LEDs around 3.3V. Using the example above with circuit 12 having five amber LEDs and circuit 14 having five blue LEDs and being coated in white phosphor, by the time the blue LEDs reach nominal current and luminosity, approximately 15.5V-16V will be applied to each of circuit 12, 14 as they are connected in parallel. Assuming each amber LED will have an approximately equal amount of voltage across it, this means that each amber LED

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will have approximately 3.1V-3.2V like the blue LEDs. As seen in FIG. 6, this will cause a current of greater than 1000 mA to flow through each amber LED, and as seen in FIG. 7 cause of luminous flux of greater than 200%. This places the amber LEDs at significant risk for overheating and overdriving, causing potential premature failure of the LEDs. By placing the active current limiting device in series with circuit 12, the current is effectively limited at the selected value, *i.e.* the nominal value, and as the voltage applied to circuit 12 increases, the circuits are current limited and the one or more LEDs therein are protected. However, as seen in FIG. 6, slight variations in voltage across each LED can cause significant increases in the current through each LED. Therefore, it may be advantageous to place an active current limiting device in series with each LED circuit in the device, in order to protect each circuit against increases or spikes in voltage.

[Para 80] In order to control the power provided to device 10, and therefore the voltage and current provided to each circuit and the overall color temperature of the light emitted by device 10 (or 10', 10", 10"'), the power provided to device 10 may be adjusted and controlled using any means known in the art. For example, device 10 may be integrated into a lighting system or fixture 40 having a dimmer switch providing the AC power to device 10. As seen in FIG. 8, dimmer switch 42 may be connected to AC power source 44, which may be, for example, mains power or a dimmer switch connected to mains power, and may be used to control the voltage provided to device 10. The dimmer switch may be any known in the art, like for example, a phase dimmer switch. The dimmer switch may be used to control the voltage to the circuit, causing more or less voltage to be applied to device 10. As the dimmer switch is turned to provide more voltage to the circuit, circuit 12 which may have amber colored LEDs or be coated in amber phosphor may be turned on and increased in intensity. As the switch continues to be turned and provide more power and voltage to the device, circuit 14, which may have blue LEDs or be coated in white phosphor, will turn on and add to the intensity of light emitted by device 10. As the dimmer switch is continually turned up and the light emitted by circuit 14 increases, the intensity of the light emitted by device 10 will increase while the color temperature decreases. When dimmer switch 42 is finally turned down and less voltage is provided to device 10, eventually circuit 14 will begin decreasing in intensity, causing the circuit 12 to produce a greater percentage of the light emitted by device 10, causing the light to have a warmer color temperature.

[Para 81] While the circuits, devices and systems described above will provide an AC LED lighting device option having the ability warm on dim, AC LED devices may be further or alternatively enhanced by increasing the power factor and reducing the total harmonic

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distortion (THD) of the devices and light emitting circuits therein.

[Para 82] FIGs. 9-13 show LED lighting devices which have both an increased power factor and a reduced THD regardless of the color of the LEDs contained therein. As seen in FIG. 9, device 100 includes at least one LED circuit, LED circuit 102, having at least two or more LEDs, LEDs 104, 106, 108, connected in series. Connected in parallel with at least one of the LEDs, shown as LEDs 106, is an active current limiting device, shown as CCR 110. As discussed throughout, though a CCR may be advantageous due to its low or non-existent turn on voltage, using a CLD may replace CCR and accomplish similar results. When using a CLD, however, the turn on voltage of the CLD will at least somewhat lower the power factor gains and reduction of THD realized by using a CCR. When connected in parallel with LEDs 106 (and any additional LEDs), the active current limiting device will provide a current bypass around the LEDs until the turn on voltage for the bypassed or shunted LEDs is reached. This will allow LEDs 104, 108 in circuit 102 to turn on earlier than if all LEDs had to be turned on before any LEDs emit light when a voltage is applied to connection leads 112, 114, increasing the power factor of the circuit. For as long as the active current limiting device is utilized to bypass or shunt LEDs 106, the current flowing through LEDs 104, 108 will be effectively limited and controlled. The controlled current will protect LEDs 104, 108 as the voltage is increased to turn on LEDs 106 and substantially reduce the effect of any harmonic currents created by the non-linear reacting LEDs. The harmonic currents and current gains and non-linearity can be effectively reduced by controlling a threshold amount current flowing through the circuit until the additional LEDs are ready to turn on. As with color temperature controlled LED lighting devices, all elements of any low THD LED lighting devices may be integrated on a single substrate 115, not matter the configuration and elements included within the device.

[Para 83] While CCR 110 will help keep the current limited to a threshold value while LEDs 106 are bypassed, once the input voltage to device 100 reaches a level where LEDs 106 will turn on with LEDs 104, 108, the current will be allowed to increase unimpeded through circuit 102 as current will substantially flow through LEDs 104, 106, 108 without a limiter in place to maintain the current. In order to protect all the LEDs in circuit 102 once LEDs 106 reach their turn on voltage, a second active current limiting device, shown in FIG. 9 as CLD 116 though it may advantageously be a CCR substantially eliminating any turn on voltage, and/or a current limiting resistor 118 (as shown in FIG. 10 for example) may be connected in series with LEDs 104, 106, 108 and formed as part of circuit 102. The additional current limiting device or current limiting resistor will help keep the current in the

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circuit down once LEDs 106 turn on, with the active current limiting device having the added benefit of creating an upper threshold of current flowing through the circuit.

[Para 84] While circuit 102 in FIGs. 9 and 10 are capable of being driven off of DC power, in order to connect and drive device 100 with AC power where THD and power factor present a greater problem, like for example mains power, device 100 may be integrated into a system or connected to a driver having a bridge rectifier, wherein rectified power is provided to circuit 102 through connection leads 112, 114. Alternatively, an additional circuit substantially identical to circuit 102 may be connected to circuit 102 in an anti-parallel configuration (like for example circuits 12' in FIG. 3A) to utilize both the positive and negative phases of a supplied AC power. Each circuit may then have a connection to leads 112, 114 to receive a provided AC power and operate during its respective phase.

[Para 85] Alternatively, as seen in FIGs. 12 and 13, device 100' may include a bridge rectifier 120 or 122 with circuit 102 connected across the output, either internally or externally. When a bridge rectifier is incorporated into the device, leads 112, 114 may connect to the inputs of the rectifier, allowing the rectifier to receive AC power from an AC power source. Circuit 102 may then connect across the output of the rectifier, receiving and utilizing the rectified AC power. The bridge rectifier may be made using standard diodes, LEDs or some combination thereof.

[Para 86] As seen in FIG. 11, a THD lowering active current device may be utilized in devices having color changing LEDs as well. As seen in FIG. 11, circuits 124, 126 may be substantially identical and placed in parallel with each other. Like circuits 12, 14 in FIG. 2A, for example, circuit 124, 126 may each have a different forward operating voltage and be capable of emitting light of a different color. Circuits 124, 126 may be incorporated into a system or driven by a driver having a bridge rectifier, or may be used to replace any of circuits 12, 14 or 12', 14' in FIGs. 2-3. The parallel current limiting device in each circuit will have substantially the same effect as described above, allowing some of the LEDs in the lower voltage circuit to turn on at a lower voltage than all of the LEDs, and reduce the harmonic distortion current resulting from the non-linearity of the LEDs. A portion of the LEDs in the higher voltage circuit may likewise turn on earlier, creating further temperature control as more intermediate levels of color may be realized as only some LEDs in the higher voltage circuit may turn on at first before all LEDs in the higher voltage circuit turn on. This configuration may allow for some or all LEDS in the lower voltage circuit to turn on, followed by some LEDs in the higher voltage circuit to turn on, beginning a cooling or warming of the light emitted by the device before all the LEDs are turned on. Eventually,

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shunted LEDs will turn on, further cooling or warming the light emitted by the device as it provided power and voltage increase.

[Para 87] An example of a driver and alternative lighting device which may be used to create a lower THD LED lighting device when driven with AC power may be seen in FIGs. 14 and 15. As seen in FIG. 14, LED lighting device 200 may include LED circuit 202 having at least two LEDs, shown as LEDs 204 connected in series. Device 200 may include a first set of connection leads 206, 208 which are connected to the input and output of circuit 202, effectively providing a connection to all of the LEDs within the circuit. A second set of connection leads 210, 212 may be provided as well. Connection leads 210, 212 may provide a connection to the anode of one LED and a connection to the cathode of one LED respectively. Connection leads 210, 212 may be configured, as seen in FIG. 14, to provide a connection to less than all of the LEDs in circuit 202. The first set of connection leads may be used to receive and return power for circuit 202, while the second set of connection leads may be used to connect a bypass or shunt, like for example an active current limiting device, to a subset or a portion of the LEDs forming circuit 202. Though shown as extending outside device 200, it should be understood that where power connections are used herein, whether with device 200, driver 220, or alternative devices 200', that any power connections may extend outside the device or include contacts formed as a portion of the device on or inside the substrate.

[Para 88] Each group of LEDs located either inside or outside the second set of connection leads may get categorized as a group, and may include additional connection leads as needed. For example, group 214 may comprise a first set of LEDs, group 216 may comprise a second group of LEDs and group 218 may comprise a third group of LEDs. Though shown in FIG. 14 as providing a connection to group 216, it should be appreciated that connection leads 210, 212 may be moved to provide a connection to group 214 or group 218. A third set of connection leads may also be provided to provide a connection to a second group, to create a further bypass or shunt if needed.

[Para 89] Providing device 200 with second connection leads 210, 212 instead of a fixed active current limiting device allows for an end user to better control the current that will flow through circuit 202 when the LEDs between connection leads 210, 212 are bypassed or shunted. The connection leads will allow an end user to select a driver or active current limiting bypass which will allow a particular amount of current to flow through the non-bypassed LEDs to create a desired level of luminance from device 200. Creating devices 200 with connection leads instead of bypasses also allows for different LED circuits to be

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connected to the same bypass or driver if the light needs of device 200 change. For example, device 200 may initially include a circuit which includes 20 LEDs, 10 of which are bypassed, but now requires a circuit of 40 LEDs, 10 of which are bypassed, to provide more light. Rather than have to buy a new LED lighting device having the active current limiting device already incorporated into the device, which may be more costly, the end user would be able to purchase a new LED lighting device having connection leads capable of connecting some of the LEDs to an active current limiting device the end user already has. Such is particularly advantageous if the LEDs in the lighting device fail before the active current limiting device, as a cheaper LED lighting device may be purchased to replace the failed device and the still operational current limiting device may be utilized with the new LED lighting device. Likewise, if the driver or bypass or shunt active current limiting device fails, the LED lighting device may be disconnected from the failed driver or bypass and be re-used with a new driver or bypass.

[Para 90] In order to drive device 200 in FIG. 14, device 200 should be integrated into a lighting system or fixture having a driver having a bridge rectifier and one or more active current limiting devices. An exemplary driver can be seen in FIG. 15. As seen in FIG. 15, driver 220 may include bridge rectifier 222 and at least two active current limiting devices, shown as CCRs 224, 226. CCR 224 may be connected to an output of the bridge rectifier to control any current flowing from the bridge rectifier, while CCR 226 may be electrically unconnected to both the bridge rectifier and CCR 224 to effectively be able to provide a bypass or shunt for LEDs in circuit 202. In order to receive and provide power, and provide an effective bypass, driver 220 may include three sets of driver connection leads. A first set of driver connection leads 228, 230 may be utilized to provide a connection between the bridge rectifier and an AC power source. A second set of driver connection leads 232, 234 may be used to connect the rectifier and associated CCR to the circuit. Connection lead 232 may, for example, extend from the output of CCR 224 and connect to connection lead 206 of device 200 to provide rectified AC power from rectifier 222 to circuit 202. Connection lead 234 may, for example, extend from the return of rectifier 222, and connect to connection lead 208 of circuit 202 to receive a return form circuit 202 to complete the circuit. Connecting leads 232, 234 and 206, 208 in this manner will provide power to each LED and active current limiting device in circuit 202 and enable the circuit to be driven.

[Para 91] In order to provide a bypass or shunt for one or more of the LEDs in circuit 202, the third set of connection leads 236, 238 in driver 220 should connect to the input and output of CCR 226 respectively. Connection lead 236 may then connect to connection lead

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210 while connection lead 238 connects to connection 212 to effectively provide a bypass around the LEDs connected between leads 210, 212 in circuit 202. Since CCR 226 is electrically unconnected to rectifier 222 and CCR 224, it will effectively act as a bypass when connected across one or more of the LEDs in circuit 202 in a substantially identical manner as bypass CCR 110 does in FIG. 9.

[Para 92] As seen in FIGs. 16 and 17, the bypass connections may likewise be utilized in circuit 100' with a first set of connection leads 210', 212' being connected to the inputs of the bridge rectifier and one or more of the LEDs 250' connected across the output of the bridge rectifier being connected to a second set of connection leads 214', 216' in device 200'. Such a configuration would allow an end user to select a bypass of choice, with particular current limiting characteristics for driving any LEDs formed as part of the bridge rectifier 248', and/or any LEDs 250' connected across the output of the rectifier which are not bypassed by the parallel current limiting device. As described above, connection leads may also help keep the costs of the device down as end users will be able to purchase a separate active current limiting device and use it with multiple rectifier devices.

[Para 93] Regardless of whether an active current limiting bypass is incorporated into a device, like in FIGs. 9-13, or is externally connected to connection leads like in FIGs. 14, 16, and 17, it has been found by the inventors that the ratio of circuit efficiency is inversely proportional to the THD realized by the circuit as more or less LEDs are bypassed. For example, in a circuit having 20 LEDs, if five are bypassed the circuit may be highly efficient but realize a smaller reduction in THD. If 15 LEDs are bypassed, the circuit may be less efficient, but have a greater reduction in THD. It is therefore contemplated that the number of the two or more LEDs which are bypassed in any given circuit may be adjusted to match the desired characteristics of the end user of the lighting device. If a more efficient light is desired, then a device having fewer bypassed LEDs may be provided, while if lower THD is required a device having more LEDs bypassed may be provided. This inverse reaction to more or less LEDs being bypassed provides a further advantage to using devices having connection leads which attach to external active current limiting device bypasses, as it allows an end user to use a single active current limiting device to bypass different LED devices which may operate with greater efficiency or lower THD as is currently needed by the end user.

[Para 94] The improvement of any circuit using an active current limiting device bypass, again regardless of whether it is integrated within the device or externally connected, can be seen in FIGs. 18 and 19. FIG. 18 shows curve 240 which represents an AC input voltage to a

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known LED lighting device not using an active current limiting bypass and instead using a current limiting resistor, for example, and the current response curve 242 of the same device. FIG. 19 shows the same two curves, curve 244 showing an AC input voltage and curve 246 showing current, when a device having an identical number of LEDs to the circuit producing the curve in FIG. 18 is used with an active current limiting bypass as described herein. As seen in FIGs. 18 and 19, utilizing the bypass in the present invention increases power factor, as current begins flowing through the device much closer to the voltage turn on point when a bypass is used than when it is not. This better power factor is the result of the device having the bypass circuit beginning to emit light much earlier as only enough voltage to turn on the non-bypasssed (and CLD if used instead of a CCR) is required for the device to begin emitting light. If each circuit includes 20 LEDs which each turn on at 2.2V, for example, and 10 LEDs are bypassed in a circuit and device as described herein, it will turn on once the provided AC voltage reaches 22V whereas the device not having the bypass will not turn on until provided AC voltage reaches 44V. The bypass allows the device to turn on much earlier, allowing light to be emitted much earlier in the provided voltage waveform, *i.e.* increasing the power factor. As a result of the bypass, the current response using a bypass also has a substantially reduced THD, as the current waveform better approximates the provided AC voltage.

[Para 95] While the foregoing there has set forth embodiments of the invention, it is to be understood that the present invention may be embodied in other forms without departing from the spirit or central characteristics thereof. The present embodiments, therefore, are to be considered in all respects as illustrative and not restrictive, and the invention is not to be limited to the details given herein. While specific embodiments have been illustrated and described, numerous modifications come to mind without significantly departing from the characteristics of the invention and the scope of protection is only limited by the scope of the accompanying claims.

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CLAIMS

What is claimed is:

1. An LED lighting device comprising:

at least two LED circuits connected in parallel, each of the at least two LED circuits having one or more LEDs, each LED circuit

having a different forward operating voltage than the other LED circuits, and,

being capable of emitting light having one or more of a different color or wavelength than the other LED circuits;

at least one active current limiting device being connected in series with at least one LED in at least one of the at least two LED circuits,

wherein each LED circuit is capable of emitting light during both a positive and a negative phase of a provided AC voltage when the LED lighting device is connected to an AC voltage source.

2. The LED lighting device of claim 1 wherein the at least one current limiting device is a current limiting diode.

3. The LED lighting device of claim 1 wherein the at least one current limiting device is a constant current regulator.

4. The LED lighting device of any one of claims 1-3 wherein the at least two LED circuits and the at least one active current limiting device are integrated onto a single substrate.

5. The LED lighting device of any one of claims 1-4 wherein each of the at least two circuits are connected in series to at least one active current limiting device.

6. The LED lighting device of any one of claims 1-5 further comprising a bridge rectifier, wherein at least one of the at least two LED circuits is connected across the output of the bridge rectifier.

7. The LED lighting device of any one of claims 1-6 wherein at least one of the at least two circuits includes two or more LEDs connected in an anti-parallel configuration.

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8. The LED lighting device of any one of claims 1-7 wherein at least one of the at least two circuits includes at least five diodes, at least four of the diodes being LEDs, the at least four LEDs being connected in a bridge rectifier configuration and the at least fifth diode being connected across the output of the bridge rectifier.

9. The LED lighting device of claim 8 wherein the at least fifth diode connected across the output of the bridge rectifier is an LED.

10. The LED lighting device of claim 8 wherein the at least fifth diode connected across the output of the bridge rectifier is a constant current diode.

11. The LED lighting device of any one of claims 1-10 wherein at least one of the at least two circuits includes seven or more diodes, at least six of the diodes being LEDs, the at least six LEDs being connected in an unbalanced bridge rectifier configuration, with the at least seventh diode being connected across the output of the unbalanced bridge rectifier.

12. The LED lighting device of claim 11 wherein the at least seventh diode connected across the output of the bridge rectifier is an LED.

13. The LED lighting device of claim 11 wherein the at least seventh diode connected across the output of the bridge rectifier is a constant current diode.

14. The LED lighting device of any one of claims 1-13 wherein light emitted by the one or more LEDs forming at least one of the at least two LED circuits is one or more of a different color or wavelength than the light emitted by the one or more LEDs of the other connected LED circuits in the device.

15. The LED lighting device of any one of claims 1-14 wherein each of the at least two circuits are coated in phosphor, each circuit having a different phosphor coating than the other connected at least two LED circuits, the different phosphor coating on each of the at least two circuits causing each circuit to emit one or more of a different color or wavelength of light than the other connected LED circuits.

16. The LED lighting device of any one of claims 1-15 being integrated into a lighting system, the lighting system having a dimmer switch capable of providing AC voltage to the

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LED lighting device, wherein the dimmer switch may be used to control the AC voltage provided to the at least two LED circuits to control the light output of each circuit to control a color temperature of light emitted by the LED lighting device.

17. A method of controlling color temperature of light emitted by an LED lighting device, the method comprising the steps of:

connecting at least two LED circuits in parallel, with each LED circuit having a different forward operating voltage and being capable of emitting light of one or more of a different color or wavelength than the other LED circuits;

providing a voltage and a current to the at least two LED circuits;

limiting the current provided to at least one of the at least two LED circuits;

adjusting at least one of the provided voltage and current to control the light output of the LEDs connected in parallel.

18. The method of claim 17 further comprising the step of providing an AC voltage and current to at least one of the at least two LED circuits.

19. The method of claims 17 or 18 further comprising the step of rectifying an AC voltage and current before providing the voltage and current to at least one of the at least two LED circuits.

20. An LED lighting device comprising:

at least one LED circuit having at least two or more LEDs connected in series;

at least one active current limiting device, the active current limiting device being connected in parallel with the at least one LED in the at least one LED circuit.

21. The LED lighting device of claim 20 further comprising at least a second active current limiting device, the second active current limiting device being connected in series with the at least one LED circuit.

22. The LED lighting device of claims 20 or 21 further comprising a bridge rectifier, wherein the at least one LED circuit is connected across the output of the bridge rectifier.

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23. The LED lighting device of claim 23 wherein the bridge rectifier is constructed using LEDs.

24. The LED lighting device of any one of claims 20-23 further comprising at least one additional LED circuit having two or more LEDs connected in series and at least one active current limiting device connected in parallel with at least one of the two or more LEDs, the at least one additional LED circuit being connected to the at least one LED circuit in parallel.

25. The LED lighting device of claim 24 wherein the at least one LED circuit is capable of emitting light having one or more of a different color or wavelength than the at least one additional LED circuit.

26. The LED lighting device of any one of claims 20-25 wherein the at least one LED circuit includes at least three LEDs connected in series.

27. The LED lighting device of any one of claims 20-26 further comprising a resistor, the resistor being connected in series with the at least one LED circuit.

28. The LED lighting device of any one of claims 20-27 wherein the at least one active current limiting device is a constant current regulator.

29. The LED lighting device of any one of claims 20-27 wherein the at least one active current limiting device is a current limiting diode.

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30. An LED lighting device comprising:

at least one LED circuit having at least two LEDs connected in series;

a first set of connection leads configured to provide a connection to the at least two LEDs in the at least one LED circuit, the first set of connection leads having a first connection lead and a second connection lead,

the first connection lead being connected to an input of the at least one LED circuit and,

the second connection lead being connected to an output of the at least one LED circuit; and,

a second set of connection leads, the second set of connection leads having a third connection lead and a fourth connection lead,

the third connection lead being to the anode of at least one of the at least two LEDs

the fourth connection lead being connected to the cathode of at least one of the at least two LEDs,

wherein the second set of connection leads are configured to provide a connection to less than all of the LEDs in the at least one circuit.

31. The LED lighting device of claim 30 wherein the at least two LEDs are configured into at least two sets of LEDs connected in series, each set of LEDs having at least one LED, wherein the first connection leads are configured to provide a connection to both of the at least a first and a second set of LEDs and the second connection leads are configured to provide a connection to only one of the first or second set of LEDs.

32. The LED lighting device of claims 30 or 31 wherein the at least one circuit includes at least three LEDs, the at least three LEDs being connected in series between the first and second connection lead.

33. The LED lighting device of claim 32 wherein each the at least three LEDs of the at least one LED circuit are configured into at least three sets of LEDs, each set having at least one LED.

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34. The LED lighting device of claims 33 wherein the third connection lead is connected the anode of the first LED in one of the first, second or third sets of LEDs, and the fourth connection lead is connected to the cathode of the last LED in the same set of LEDs.

35. A lighting system comprising the lighting device of any one of claims 30-34, the lighting system further comprising:

a driver, the driver having

a bridge rectifier;

a first active current limiting device connected to the output of the bridge rectifier:

a second active current limiting device electrically unconnected to the bridge rectifier and the first constant current diode;

a first set of driver connection leads, the first set of driver connection leads providing a connection for the bridge rectifier to connect to an AC voltage source;

a second set of driver connection leads, the second set of driver connection leads having a third driver connection lead providing an output from the first active current limiting device and a fourth driver connection lead providing a return from a load to the bridge rectifier;

a third set of driver connections leads, the third set of driver connection leads having a fifth driver connection lead providing an input the second active current limiting device and a sixth driver connection lead providing an output the second active current limiting device;

wherein the third driver connection lead connects to the first connection lead of the lighting device and the fourth driver connection lead connects to the second connection lead of the lighting device to drive the LED circuit, and the fifth driver connection lead connects to the third connection lead of the lighting device and the sixth driver connection lead connects to the fourth connection lead of the lighting device to provide a bypass of one or more LEDs.

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36. An LED lighting device comprising:

a bridge rectifier;

at least one LED circuit having at least two LEDs connected in series across the output of the bridge rectifier;

a first set of connection leads configured to provide a connection to the bridge rectifier, the first set of connection leads having a first connection lead and a second connection lead, the first and second connection leads being connected to provide an electrical input and output from the bridge rectifier;

a second set of connection leads configured to provide a connection to at least one of the least two LEDs connected in series across the output of the bridge rectifier, the second set of connection leads having a third connection lead and a fourth connection lead;

the third connection lead being connected to the anode of one of the at least two LEDs

the fourth connection lead being connected to the cathode of one of the at least two LEDs.

37. The LED lighting device of claim 36 wherein the second set of connection leads are configured to provide a connection to less than all of the LEDs connected in series across the output of the bridge rectifier.

38. The LED lighting device of claims 36 or 37 wherein the bridge rectifier is constructed using LEDs.

39. A method of reducing harmonic distortion in LED lighting circuits and devices, the method comprising the steps of:

connecting at least two LEDs in series;

providing a bypass around at least one of the at least two LEDs connected in series; and,

maintaining a substantially constant current flowing through at least one LED having while at least one LED is bypassed.

40. The method of claim 39 further comprising the step of connecting an active current limiting device in parallel with at least one of the at least two LEDs to provide the bypass.

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41. An LED circuit as described herein.

42. An LED lighting device as claimed and described herein.

43. An LED lighting system as claimed and described herein.

44. A method of driving an LED lighting device or system as claimed and described herein.

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FIG. 1

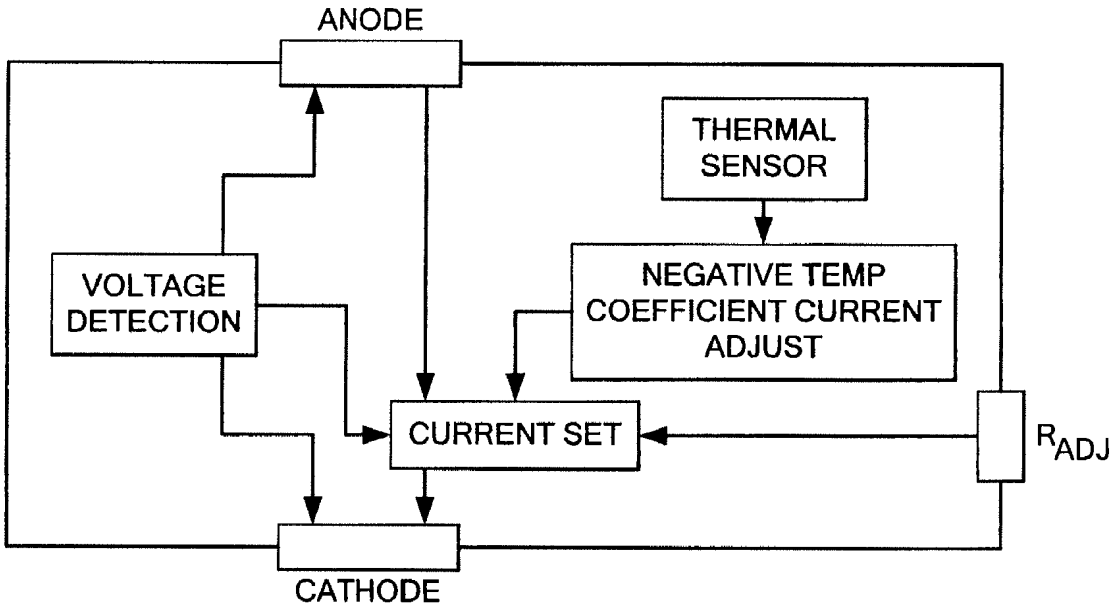


FIG. 2A

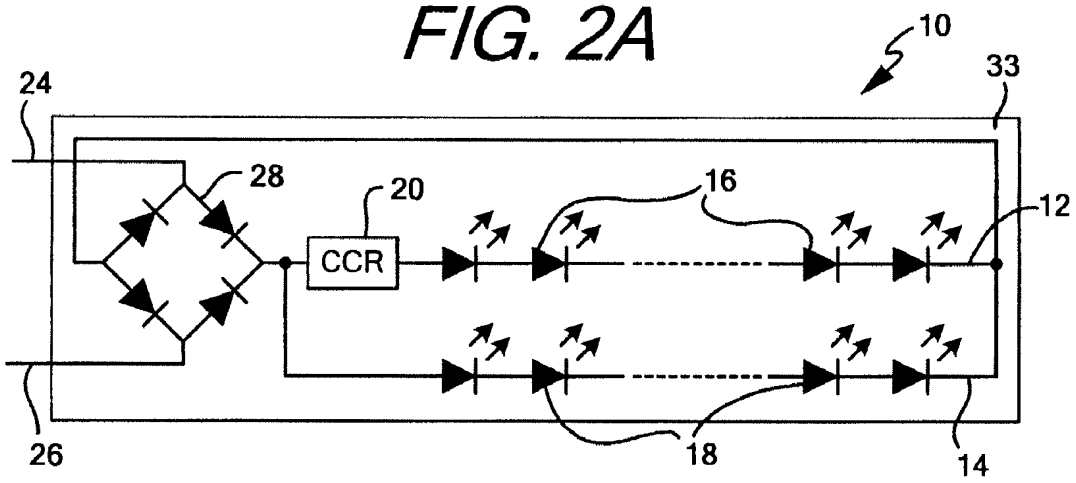


FIG. 2B

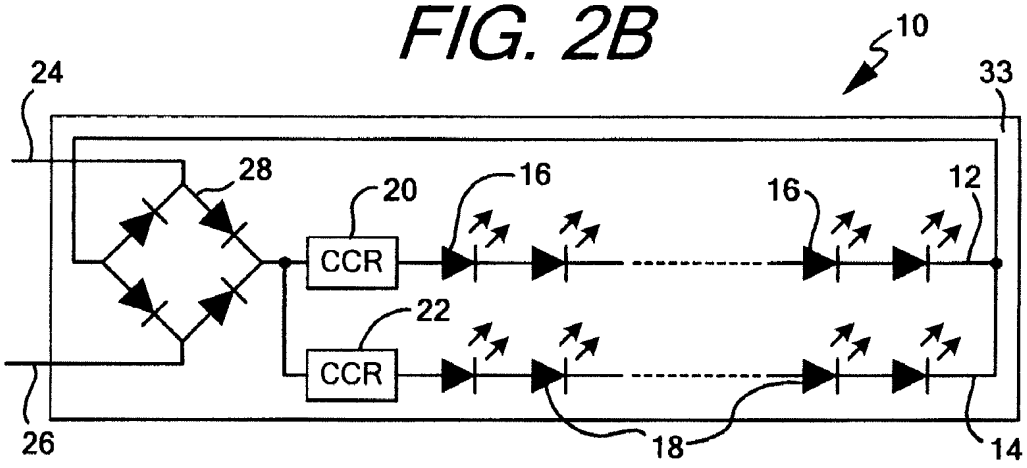


FIG. 3A

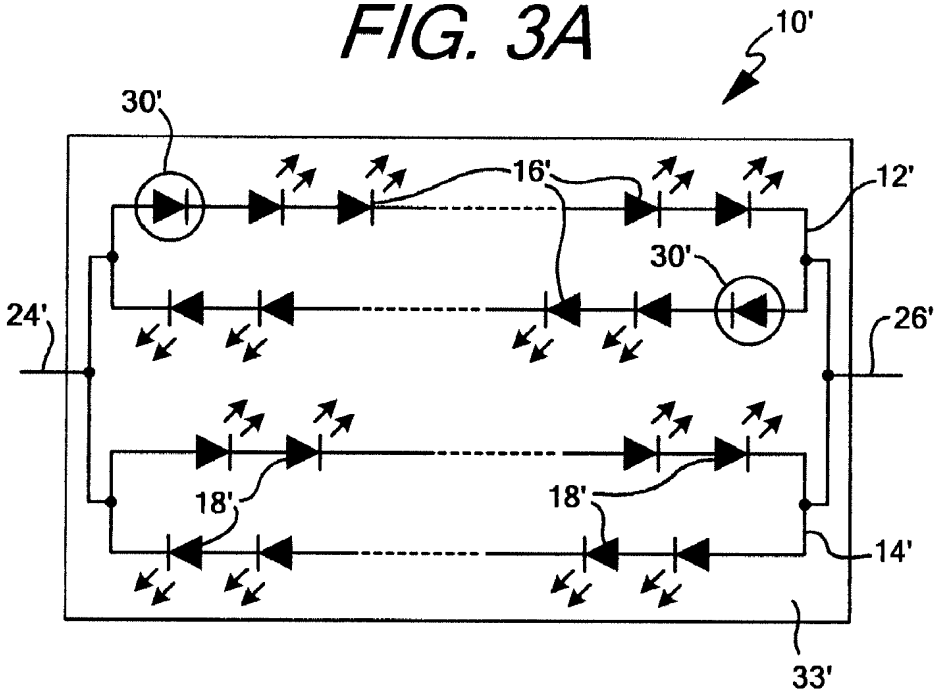


FIG. 3B

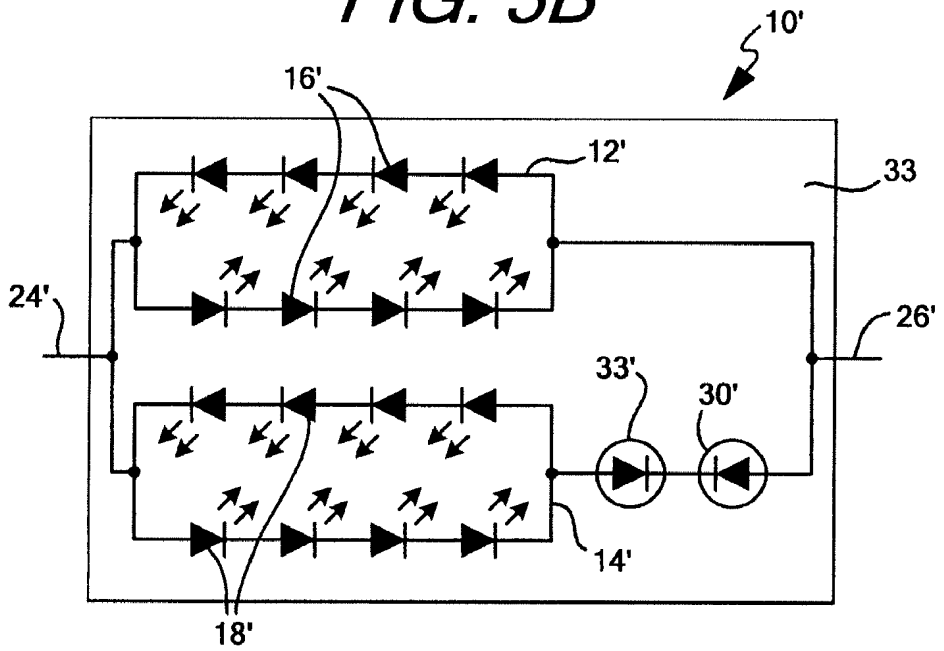


FIG. 4

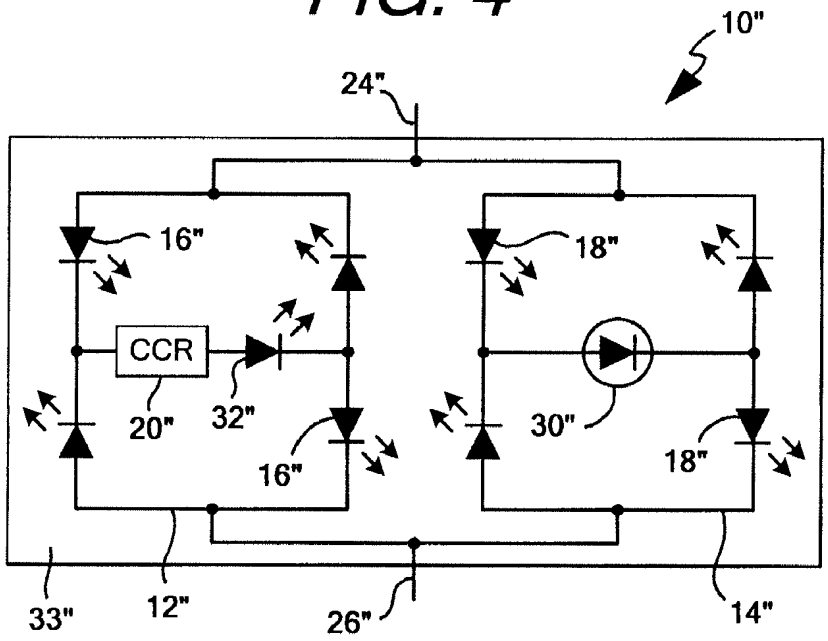

10"
24"
16"
18"
CCR
20"
32"
30"
16"
18"
33"
12"
26"
14"

FIG. 5

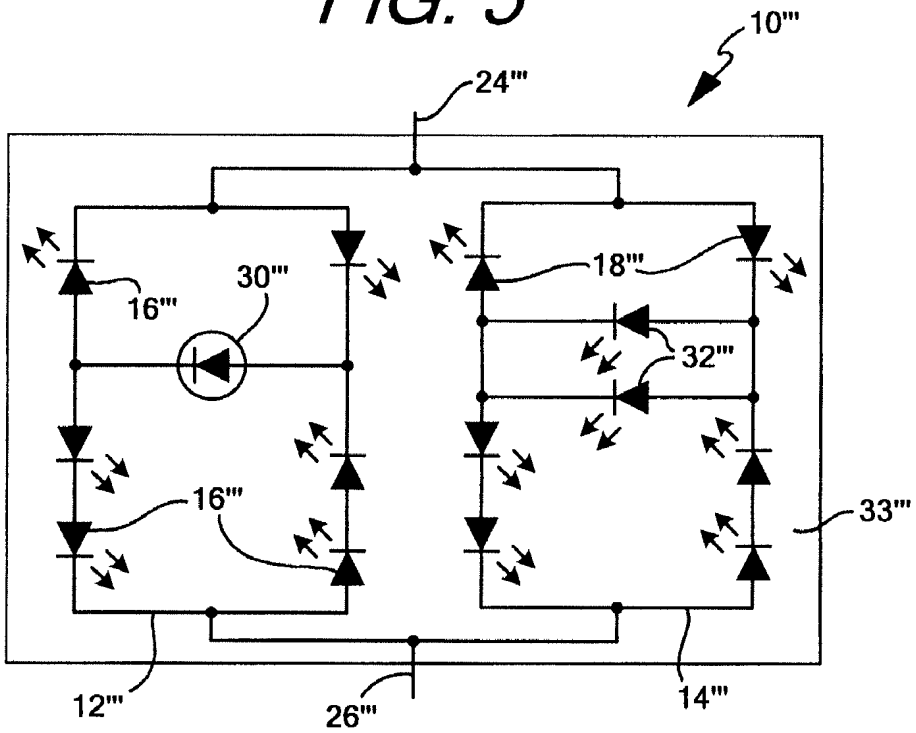

10'''
24'''
16'''
30'''
18'''
32'''
16'''
33'''
12'''
26'''
14'''

FIG. 6

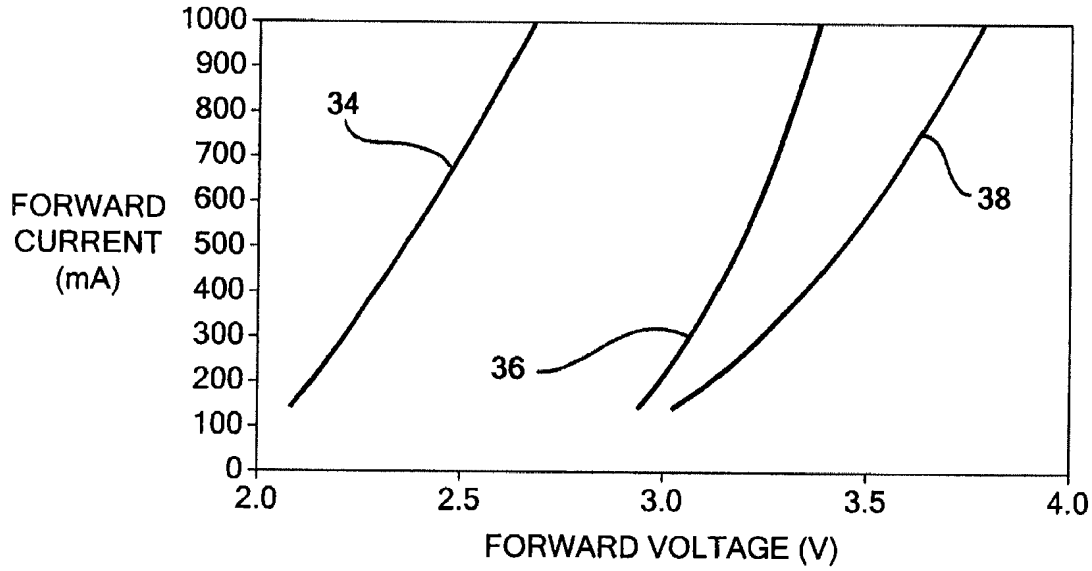

FORWARD CURRENT (mA)
1000
900
800
700
600
500
400
300
200
100
0
2.0
2.5
3.0
3.5
4.0
FORWARD VOLTAGE (V)
34
36
38

FIG. 7

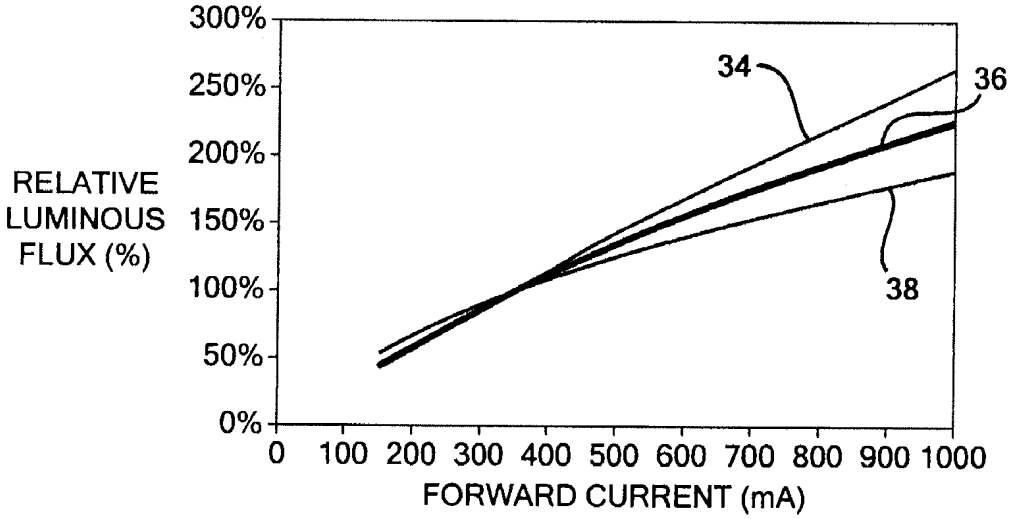

RELATIVE LUMINOUS FLUX (%)
300%
250%
200%
150%
100%
50%
0%
0 100 200 300 400 500 600 700 800 900 1000
FORWARD CURRENT (mA)
34
36
38

FIG. 8

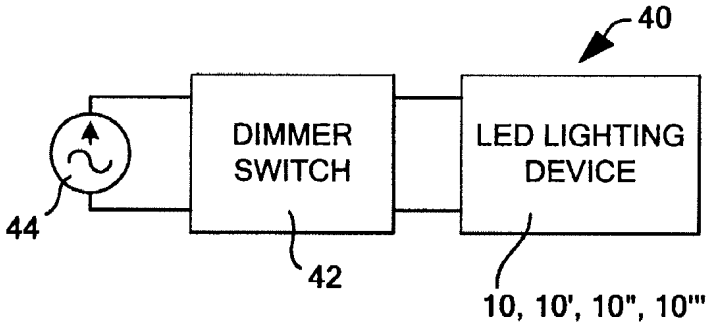


FIG. 9

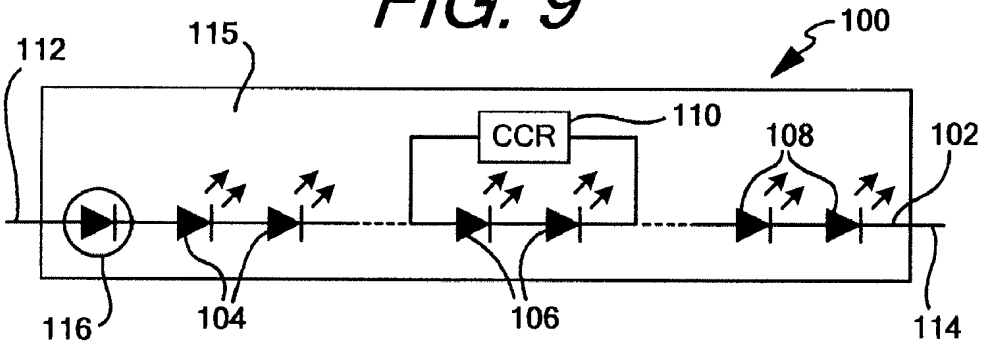


FIG. 10

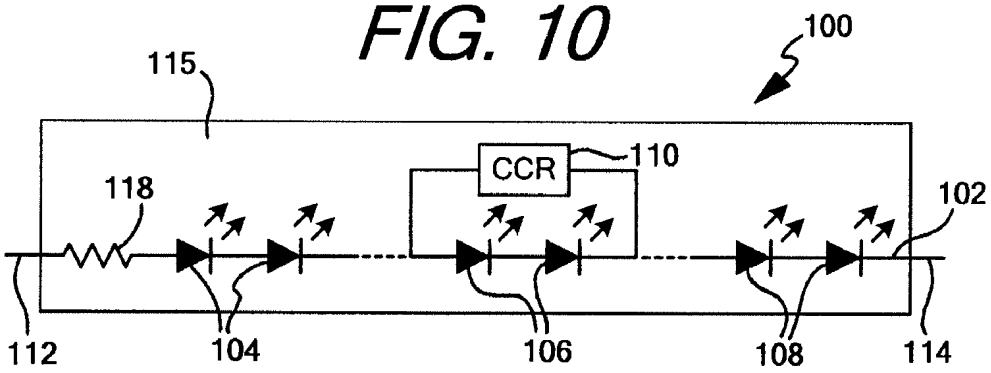
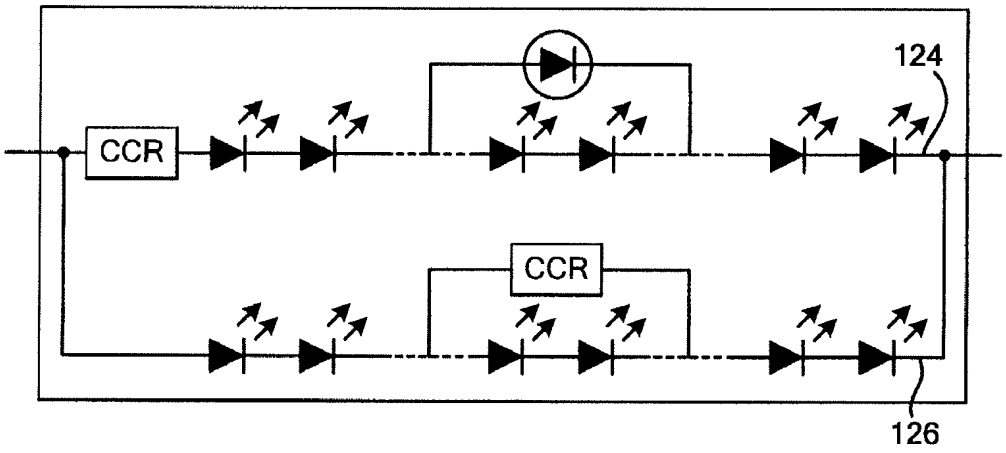


FIG. 11



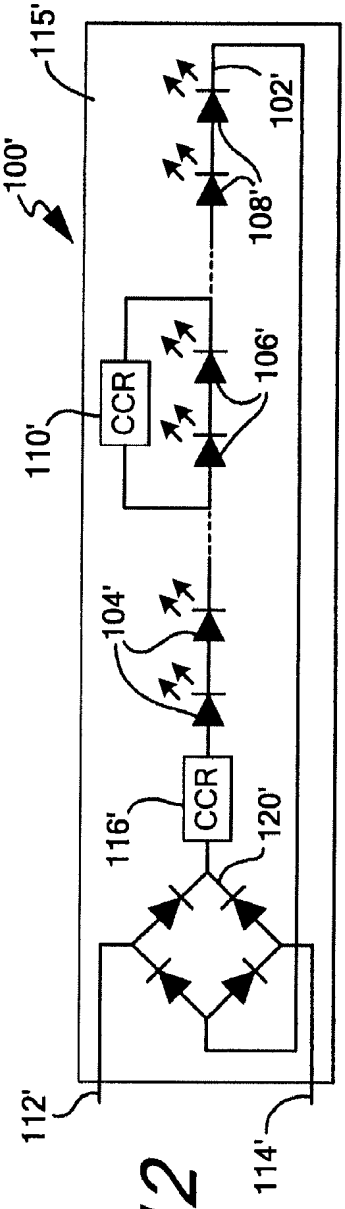


FIG. 12

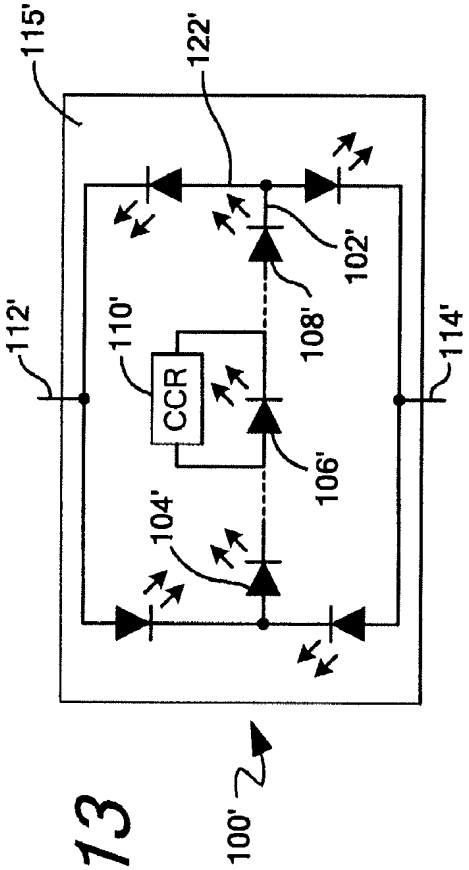


FIG. 13

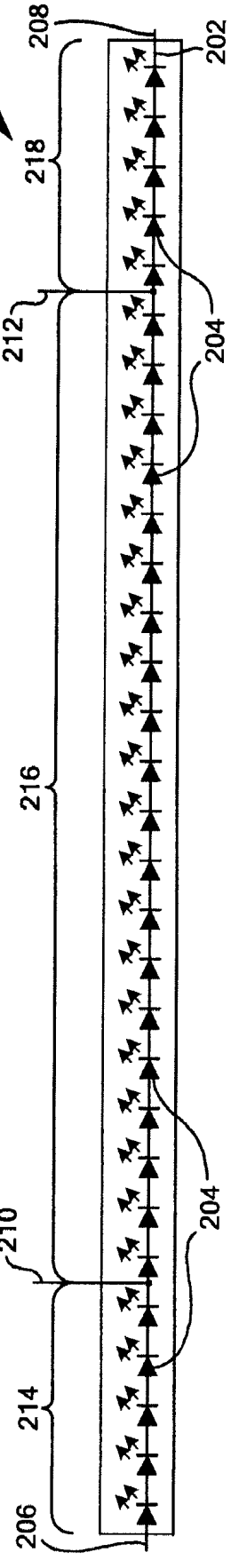


FIG. 14

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FIG. 15

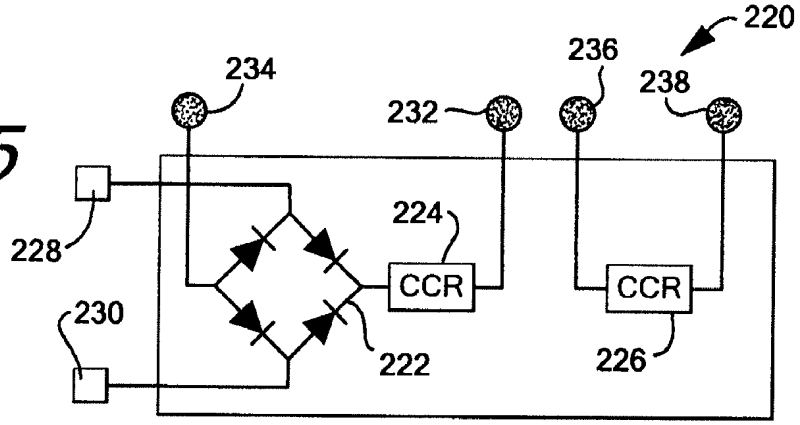


FIG. 16

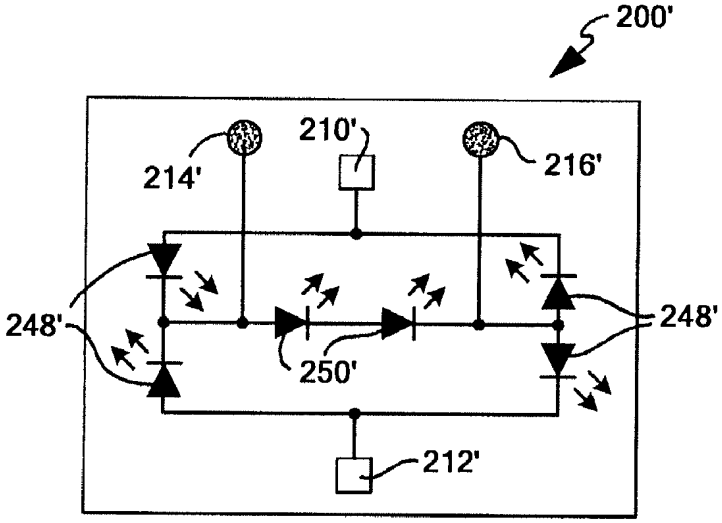


FIG. 17

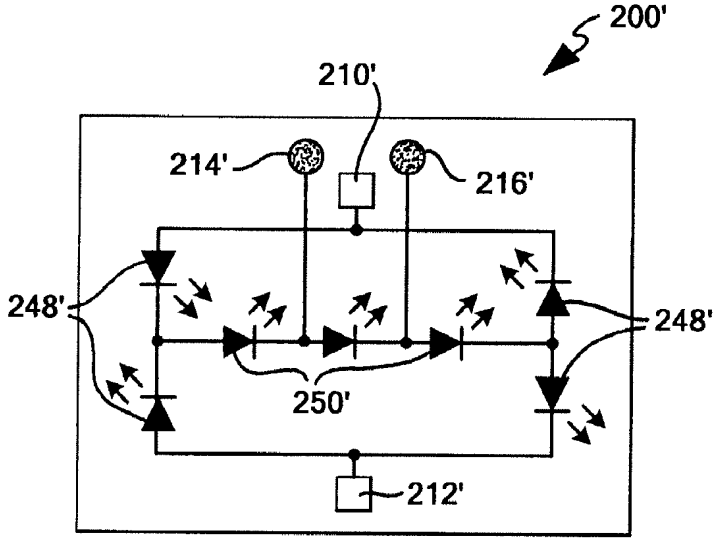


FIG. 18
PRIOR ART

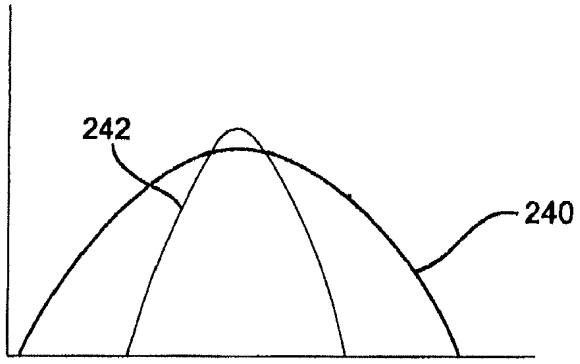
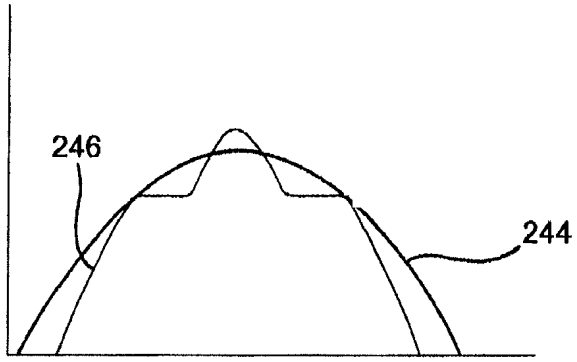


FIG. 19



INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 12/67623

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - H05B 37/00, H05B 39/00 (2012.01)
USPC - 315/192
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC(8): H05B 37/00, H05B 39/00 (2012.01)
USPC: 315/192

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
IPC(8): H05B 37/00, H05B 39/00 (2012.01) (keyword limited, see terms below)
USPC: 315/64, 69, 185, 192 (keyword limited, see terms below)

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
PatBase, Google Scholar. PubWest (PGPB,USPT,EPAB,JPAB) Search terms used: LED, light, emitting, diode, lighting, color, wavelength, AC, alternating, current, limit, regulate, series, parallel, lead, harmonic, vary, modify, adjust, increase, decrease, anode, cathode, substrate, temperature, controlled, low, thd, distortion, bypass, Lynk Labs, Michae

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X — Y	WO 2010/13821 1 A1 (Miskin et al.) 02 December 2010 (02.12.2010) entire document, especially: Fig 3, 8, para [0015], [0023]-[0028], [0053], [0054], [0058]	30-34, 36-38 ——————— 1-4, 17-23, 39, 40
Y	US 2010/0109558 A1 (CHEW) 06 May 2010 (06.05.2010) para [0092]-[0094], [0140], [0149]	1-4, 17-23, 39, 40
A	US 2007/0273299 A1 (MISKIN et al.) 29 November 2007 (29.1 1.2007) entire document	1-4, 17-23. 30-34, 36-40

☐ Further documents are listed in the continuation of Box C. ☐

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
21 January 2013 (21.01.2013)	19 FEB 2013
Name and mailing address of the ISA/US Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-3201	Authorized officer: Lee W. Young PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774

Form PCT/ISA/2 10 (second sheet) (July 2009)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 12/67623

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following **reasons**:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☒ Claims Nos.: 41-44
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

because they are improper omnibus claims, not drafted in accordance with Rule 6.2(a).

3. ☒ Claims Nos.: 5-16, 24-29, 35
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.

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21 February 2013 (21.02.2013)

WIPO | PCT

(10) International Publication Number
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PCT/US2012/051531

(22) International Filing Date:
20 August 2012 (20.08.2012)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
61/575,273 18 August 2011 (18.08.2011) US

(71) Applicant *(for all designated States except US)*: **LYNK LABS, INC.** [US/US]; 2511 Technology Dr., Suite 108, Elgin, IL 60123 (US).

(72) Inventor; and

(75) Inventor/Applicant *(for US only)*: **MISKIN, Michael** [US/US]; 2 Pinecone Lane, Sleepy Hollow, IL 60118 (US).

(74) Agent: **FACTOR, Jody, L.**; Factor Intellectual Property Law Group, Ltd., 1327 W. Washington Blvd., Suite 5G/II, Chicago, IL 60607 (US).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

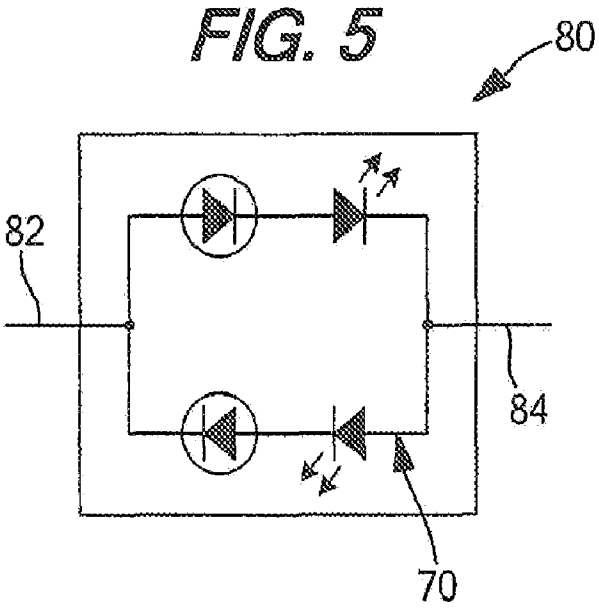
(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

— *with international search report (Art. 21(3))*

— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))*

(54) Title: DEVICES AND SYSTEMS HAVING AC LED CIRCUITS AND METHODS OF DRIVING THE SAME



(57) Abstract: A lighting device and system having at least one circuit, the circuit having at least two LEDs connected in series, parallel or anti-parallel configuration and at least one current limiting diode. The device or system may be driven with AC or DC power and may further include a sensor and polarity switching circuit to utilize all LEDs within the circuit when drive by DC power.

WO 2013/026053 A1

DEVICES AND SYSTEMS HAVING AC LED CIRCUITS AND METHODS OF DRIVING THE SAME

RELATED APPLICATIONS

[Para 1] The application claims priority to U.S. Provisional Application No. 61/575,273 entitled "DC Powered AC LED Lighting Circuits and Devices Method and Apparatus" filed August 18, 2011 – the contents of which are expressly incorporated herein by reference.

TECHNICAL FIELD

[Para 2] The present invention generally relates to light emitting diode ("LED") circuits for both AC and DC operation. More specifically, the present invention relates to driving LED circuits, devices, and systems using both AC and DC power, with or without a current limiting element included in the LED circuit.

FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

[Para 3] None.

BACKGROUND OF THE INVENTION

[Para 4] LEDs are semiconductor devices that produce light when a current is supplied to them. LEDs are intrinsically DC devices that only pass current in one polarity, and historically have been driven by DC power supplies. When driven by DC power supplies, LEDs are typically provided in a string or parallel strings of LEDs which operate in the forward direction such that each LED is continuously operable. Once one LED within a string of LEDs burns out, the entire string will be rendered inoperable and the device containing the string may have to be replaced.

[Para 5] Recent advancements in the field of lighting have led to the use of LED circuits which are capable of using AC power to drive LEDs configured in particular circuit arrangements such that some of the LEDs operate during the positive phase of the AC power cycle and some LEDs operate during the negative phase of the AC power cycle. While this may extend the life of some LEDs within the circuit(s) as they will be turned on or off, flicker may become an issue as the voltage raises up and down, and the other known LED problems

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are realized.

[Para 6] Whether powered by AC or DC power sources, the amount of current flowing through an LED may dramatically affect the light output of and lifespan of the LED. This is because LEDs emit light based on the amount of current passing through them – the more current that passes through the LED, the brighter the LED will shine. Also, as the current passing through each LED increases, the heat produced by each LED generally increases. Exposure to high or constantly changing heat levels may affect how long an LED will remain operational and reduces efficacy.

[Para 7] In order to control the current flowing through each LED, it is known in the art to place a resistor in series with the LED circuit. While the resistor will provide some current protection in the circuit, it will not prevent the current from reaching higher levels if an increased amount of voltage is applied to the circuit. A resistor will also waste energy and raise heat levels within the circuit. As the voltage applied to the circuit ultimately increases, so will the current and heat within the circuit.

[Para 8] Therefore, it would be advantageous to design a circuit, device, or system utilizing LEDs that limits and controls the current in an LED circuit.

[Para 9] It would also be advantageous to design a circuit, device, or system where AC LED circuits may be used with DC power in a manner which may extend device or system life.

[Para 10] The present invention is provided to solve these and other issues.

SUMMARY OF THE INVENTION

[Para 11] Accordingly, the present invention is directed to a lighting device or system having at least one circuit capable of emitting light when powered by an AC power source. The at least one circuit may include a constant current or current limiting diode in order to substantially maintain a constant and an "upper limit" of current within the circuit, no matter how high the voltage provided by the AC power source gets.

[Para 12] According to one aspect of the invention, a lighting device having at least one circuit capable of emitting light when powered by an AC power source is provided. The circuit may include at least two LEDs connected in a series, a parallel, or an anti-parallel configuration, and at least one current limiting diode connected in series or parallel with at least one of the at least two LEDs. The circuit may be configured in any configuration whereby at least one of the at least two LEDs emits light during a positive phase of provided

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AC power, and at least one of the at least two LEDs emits light during a negative phase of provided AC power. It is contemplated that the circuit configuration itself may allow for light to be emitted by at least one LED during both the positive and negative phase, or alternatively that a bridge rectifier having diodes, LEDs or a combination thereof, may rectify both the positive and negative phases of the LEDs and provide the rectified power to a string of at least two LEDs.

[Para 13] According to another aspect of the invention, the at least one circuit within the lighting device includes at least first and second branches connecting at first and second common points, the common points providing an input and an output for a driving voltage for the circuit. The first branch of the LED circuit may include at least a first and a second LED connected in opposing series relationship such that the inputs of the first and second LEDs define a first branch junction. Similarly, the second branch may include at least a third and a fourth LED connected in opposing series relationship such that the outputs of the third and fourth LEDs define a second branch junction. The first and second branches connect to one another such that the output of the first LED is connected to the input of the third LED at the first common point, and the output of the second LED is connected to the input of the fourth LED at the second common point. The at least one current limiting diode may be connected in a manner which forms a first cross-connecting circuit branch. The input of the at least one current limiting diode may be connected to the second branch junction while the output may be connected to the first branch junction.

[Para 14] According to another aspect of the invention, the at least one circuit may include at least one additional LED connected in series with each of the second and fourth LEDs than is connected in series with each of the first and third LEDs between each LEDs respective common point and branch junction. Alternatively, one additional LED may be connected in series with each of the first and third LEDs than is connected in series with each of the second and fourth LEDs between each LEDs respective common point and branch junction. The at least one LED circuit may further include n additional LEDs, in pairs, wherein the pairs are configured among the first and second branch circuits of the first circuit such that that the current draw through the first circuit during both AC phases is substantially the same.

[Para 15] According to another aspect of the invention, the at least one LED circuit may include x additional cross-connecting circuit branches. Each cross-connecting circuit branch may have one or more diodes and be connected in parallel to the first cross-connecting circuit branch. The diodes connected in any additional cross-connecting circuit branches may be

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standard diodes, LEDs or additional current limiting diodes.

[Para 16] According to one aspect of the invention, the lighting device may include at least one circuit having the at least two LEDs connected in an anti-parallel configuration. At least one current limiting diode in the circuit may be connected in series with the anti-parallel LED circuit, or alternatively, at least one current limiting diode may be connected in series with each of the at least two LEDs. At least one additional LED may be connected in series with each anti-parallel LED to form anti-parallel series strings of LEDs. Like an anti-parallel circuit having two LEDs, at least one current limiting diode may be connected in series with both series string of LEDs, *i.e.* the anti-parallel series strings, or at least one current limiting diode may be connected in series with each series string of LEDs.

[Para 17] According to another aspect of the invention, the lighting device may be powered by a DC power supply or may include a bridge rectifier connected in series with the anti-parallel LEDs so that at least one LED is forward biased by power provided by the DC power supply or bridge rectifier and at least one LED is reverse biased by power provided by the DC power supply or bridge rectifier. The DC power supply or lighting device may further include a load sensor for sensing operation of the at least one forward biased LED. The load sensor, either by itself or using additional TTL logic, switches, relays, and/or circuitry, may be capable of reversing the polarity of the power provided by the bridge rectifier to forward bias the at least one LED that was reversed biased if the sensor fails to detect that the at least one forward biased LED is operating.

[Para 18] According to one aspect of the invention, regardless of what circuit is utilized in the lighting device, the at least one circuit may be integrated into a single chip. The chip may include at least two power connection leads, the power connection leads being connected to opposite sides of the at least one circuit to allow the circuit to connect to an AC or DC power supply.

[Para 19] According to another aspect of the invention, the at least one circuit may be formed by placing individual LED die and at least one current limiting diode on a substrate to form an LED package. The LED may be flip chip or wire bond type LED die. Once on the substrate, the LEDs formed thereon may be coated with phosphor in order to affect the illumination color of the LEDs. Power connection leads may likewise be integrated on the substrate and connected to opposing ends of the at least one circuit formed thereon.

[Para 20] According to yet another aspect of the invention, two or more circuits connected in series or parallel may be formed on a single chip or substrate. When two or more circuits are formed on a single chip or substrate, two power connection leads may be

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provided and electrically connected to the two or more circuits to enable the two or more circuits to connect to an AC or DC power supply. The circuits may be connected in series, parallel, or series-parallel configurations. Alternatively, the at least two circuits on the chip or substrate may be electrically unconnected and be provided with separate and distinct power connection leads connected at the opposite ends of each circuit, allowing the circuits to be connected in any manner desired or required by an end user.

[Para 21] According to another aspect of the invention, the lighting device may be integrated within a lamp or bulb for use in a lighting system. The lamp may include a base having at least two power connection leads, the power connection leads being capable of connection to the device and at least one circuit so as to be capable of providing power to the at least one circuit from a power source. The lamp may be designed for a specific use, such as general lighting type incandescent replacement lamps and/or a brake light or head light in an automobile. It should be appreciated by those having ordinary skill in the art that any lamp design known in the art may be created utilizing any of the circuits described herein, and that the lamps may be used for any use. Examples of lamps that may be designed using the circuits, chips, packages and other LED devices described herein, include but are not limited to, Edison or E-base type lamps, festoon lamps, bi-pin lamps, or wedge base lamps.

[Para 22] According to one aspect of the invention, a lighting system is provided. The lighting system may include at least one circuit having at least two LEDs electrically connected and configured so that when the LEDs are connected to a DC power source, at least one LED within the circuit is forward biased by the DC power source, and at least one LED within the circuit is reversed biased by the DC power source. For example, the at least two LEDs in the lighting system may be connected in an anti-parallel configuration, however the at least two LEDs may be connected or configured in any manner known in the art, so long as at least one LED is forward biased and at least one LED is reverse biased when the circuit is connected to a DC power source.

[Para 23] The lighting system may also include a load sensor connected to the at least two LEDs. The load sensor may sense the operation of the at least one LED forward biased by the DC power source, and may be capable of reversing the polarity from the DC power source to forward bias the at least one LED previously reverse biased if the operation of the at least one LED which is forward biased fails. Rather than reverse the polarity itself, the load sensor may trip a relay, switch or provide a signal to TTL logic circuits or devices and/or additional circuitry which may reverse the polarity of the DC power provided to the circuit.

[Para 24] In order to provide DC power, the DC power source may include a bridge

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rectifier for rectifying AC power. The bridge rectifier may be part of the lighting system itself, or may be contained in a driver or external power source or supply. Alternatively, the rectifier may be contained in any lighting devices within the lighting system. The DC power source may also include the load sensor and any circuitry, switches or relays or TTL logic required to dynamically reverse the polarity of the provided DC power should the at least one LED that is forward biased fail.

[Para 25] According to another aspect of the invention, the lighting system may include at least one current limiting diode connected in series with the at least one circuit, or at least one current limiting diode connected in series with each of the at least one LED forward biased by the DC power source and the at least one LED is reversed biased by the DC power source.

[Para 26] According to another aspect of the invention, the at least one circuit in the lighting system may include at least four LEDs configured in a bridge configuration.

[Para 27] According to one aspect of the invention, a method for driving a lighting device or system is provided. At least two LEDs are connected such that at least one of the at least two LEDs is capable of emitting light during a positive phase of power provided by an AC power source, and at least one of the at least two LEDs is capable of emitting light during a negative phase of power provided by an AC power source. Rather than provide AC power, DC power may then be provided to the at least two LEDs. The at least two LEDs form a load on the DC power such that at least one of the at least two LEDs is forward biased and at least one of the at least two LEDs is reversed biased. The polarity of the DC power across the load may then be reversed to forward bias the at least one LED that was previously reverse biased and reverse bias the at least one LED that was previously forward biased in order to use the previously reverse biased LED should, for example, the previously forward biased LED fail.

[Para 28] According to another aspect of the invention, the load output may be monitored or sensed to insure that the at least one LED configured to be forward biased by the DC power is operational and conducting. If the at least one forward biased LED fails and is no longer operational, the polarity of the DC power across the load may be dynamically reversed so as to forward bias the at least one LED that was previously reverse biased. The dynamic reversal of the polarity of the DC power may be done at a DC power supply, may be accomplished using TTL logic devices or circuitry connected to the load within the device or system, or may be accomplished using circuitry connected to the DC power supply and/or load external to the device or system.

[Para 29] According to yet another aspect of the invention, the polarity of the DC power

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across the load may be reversed manually using a switch capable of controlling the connection between the DC power supply and the at least one load. Manually switching a system switch to an alternate setting may forward bias the at least one LED that was previously reverse biased if the at least one LED previously configured to forward biased is no longer emitting light. It is contemplated by the invention that the switch may be configured to forward bias either LED, regardless of whether either LED has failed. Alternatively, the DC power may be manually reversed by disconnecting the load, *i.e.* a circuit or device, from the DC power supply, and reconnecting it in a reversed configuration so that the power connection previously connected to ground or the low side of the DC supply is then connected to the high voltage side of the DC supply.

[Para 30] According to another aspect of the invention, the at least two LEDs in the system may be connected in an anti-parallel configuration, and may have at least one current limiting diode in series with the anti-parallel circuit, or may have at least one current limiting diode connected in series with each of the at least two LEDs.

[Para 31] According to another aspect of the invention, at least four diodes may be configured in a bridge configuration in the system. At least two of the at least five diodes may be LEDs with at least one of the at least two LEDs is capable of emitting light when forward biased by the connected DC power, and at least one of the at least two LEDs is reversed biased by the connected DC power.

[Para 32] Other advantages and aspects of the present invention will become apparent upon reading the following description of the drawings and detailed description of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[Para 33] FIG. 1 shows a schematic view of a circuit as contemplated by the invention;

[Para 34] FIG. 2 shows a schematic view of a circuit as contemplated by the invention;

[Para 35] FIG. 3 shows a schematic view of a circuit as contemplated by the invention;

[Para 36] FIG. 4 shows a schematic view of a circuit as contemplated by the invention;

[Para 37] FIG. 5 shows a schematic view of a chip as contemplated by the invention;

[Para 38] FIG. 6 shows a schematic view of a chip as contemplated by the invention;

[Para 39] FIG. 7 shows a schematic view of a package as contemplated by the invention;

[Para 40] FIG. 8 shows a schematic view of a package as contemplated by the invention;

[Para 41] FIG. 9 shows a schematic view of a chip as contemplated by the invention;

[Para 42] FIG. 10 shows a schematic view of a chip as contemplated by the invention;

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[Para 43] FIG. 11 shows a schematic view of a chip as contemplated by the invention;

[Para 44] FIG. 12A shows a lighting system as contemplated by the invention;

[Para 45] FIG. 12B shows a lighting system as contemplated by the invention;

[Para 46] FIG. 12C shows a lighting system as contemplated by the invention;

[Para 47] FIG. 12D shows a lighting system as contemplated by the invention;

[Para 48] FIG. 12E shows a lighting system as contemplated by the invention;

[Para 49] FIG. 13A shows a schematic view of a circuit as contemplated by the invention;

[Para 50] FIG. 13B shows a schematic view of a circuit as contemplated by the invention;

[Para 51] FIG. 13C shows a schematic view of a circuit as contemplated by the invention;

[Para 52] FIG. 13D shows a schematic view of a circuit as contemplated by the invention;

[Para 53] FIG. 14 shows a lighting system as contemplated by the invention;

[Para 54] FIG. 15 shows a lighting system as contemplated by the invention;

[Para 55] FIG. 16 shows a lighting system as contemplated by the invention; and,

[Para 56] FIG. 17 shows a lighting system as contemplated by the invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

[Para 57] While this invention is susceptible to embodiments in many different forms, there is described in detail herein, preferred embodiments of the invention with the understanding that the present disclosures are to be considered as exemplifications of the principles of the invention and are not intended to limit the broad aspects of the invention to the embodiments illustrated.

[Para 58] The present invention is directed to a lighting device or system, the light emitting circuits contained therein, and methods of driving and operating the same. As discussed herein, a lighting device may include any device capable of emitting light no matter the intention. Examples of devices which are contemplated by this invention include, but are not limited to, chips, packages, chip on board assemblies, LED assemblies or LED modules. The devices may also include any required power connections or drivers for the circuits emitting light within the device. A lighting system may include multiple such devices, and some or all of the required parts to drive such a device, including but not limited to, power supplies, rectifiers, sensors or light emitting circuitry discussed herein. A system may be, for

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example, a lamp or light bulb, a portable hand held light unit or indoor and outdoor lighting fixtures. While a lighting device may be incorporated into a lighting system, it is contemplated that any required light emitting elements may be included within the system directly, whether in the form a device as a chip or package, or as circuits within the system.

[Para 59] FIG. 1 discloses an embodiment of a circuit for use in a lighting device or system as contemplated by the invention. Circuit 10 includes LEDs 12, 14 connected at first branch junction 16 in opposing series relationship forming first branch 18, and LEDs 20, 22 connected at second branch junction 24 in an opposing series relationship forming second branch 26. First and second branch junctions 16, 24 are connected by cross-connecting branch 28 which includes current limiting (or constant current) diode 30. The first and second branches also connect at common points 32, 34 – LEDs 12, 20 connecting at first common point 32 and LEDs 14, 22 connecting at second common point 34. In this configuration, when AC power is applied to the circuit, current limiting diode 30 is in series with LEDs 12, 22 during one phase (positive or negative) allowing those diodes to emit light. During the opposite AC phase (negative or positive), current limiting diode is in series with LEDs 14, 20, allowing those diodes to emit light. Although only a single cross-connecting branch is shown in FIG. 1, it is contemplated by the invention that any number of cross-connecting branches may be added in parallel to cross-connecting branch 28.

[Para 60] Using current limiting diode 30 as cross-connecting branch 28 insures that the current flowing through circuit 10 during both the positive and negative phase of any provided AC power remains substantially below a threshold level which may adversely affect the life of the LEDs. While a resistor or resistors connected as the cross-connecting circuit or between either common point and the power source may have an effect on the total amount of current flowing through the circuit, *i.e.* make it less than if no resistor was there, resistors can not prevent the current in the circuit from continually rising with the voltage. Resistors will not create an "upper limit" like a current limiting diode substantially does. A resistor will merely lower the value of the current in the circuit resulting from an applied voltage. In order to reduce the current in the circuit, resistors may also waste energy in the form of heat which can adversely affect the LEDs if contained within a device or system. While some heat and energy may be wasted by the internal resistance of the current limiting diode, the amount may be much less than that of a resistor.

[Para 61] Additionally, using current limiting diode 30 as cross-connecting branch 28 has the advantage of allowing a substantially constant current to flow during both the positive and negative phases as well. A substantially constant current may extend the lifespan of each

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LED. Inasmuch as the amount of light emitted by an LED is determined by the amount of current flowing through the LED, allowing a substantially constant amount of current through the circuit helps to mitigate any flicker effect caused by the AC voltage cycling. With a current limiting diode, the amount of light emitted by each LED will remain substantially constant during its respective conducting phase. A standard resistor is incapable of maintaining a substantially constant current.

[Para 62] FIGs. 2 and 3 disclose another embodiment of a circuit similar to circuit 10. Similar to circuit 10, circuit 40 includes first and second branches 42, 44 respectively. First branch 42 includes LEDs 46, 48 connected at first branch junction 50 while second branch 44 includes LEDs 52, 54 connected at second branch junction 56. First branch 42 is connected to second branch 44 at common points 60, 62 – LEDs 46, 52 connect at common point 60, and LEDs 48, 54 connect at common point 62. Like in circuit 10, cross-connecting branch 58 may include a current limiting diode 64. In order to protect the LEDs within circuit 40 against reverse biasing, as shown in FIGs. 2 and 3, at least one additional LED may be connected in series with LEDs 48, 54 than LEDs 46, 52 between the associated common point and the branch junction or vice versa. As shown in FIG. 2, for example, this is embodied as LED 66 connected in series with LED 48 between branch junction 50 and common point 62 (one more than is connected in series with LED 46 between branch junction 50 and common point 60) and LED 68 connected in series with LED 54 between branch junction 56 and common point 62 (one more than is connected in series with LED 52 between branch junction 56 and common point 60).

[Para 63] As is seen in FIG. 3, any number *n* of additional LEDs may be added, in pairs in the first and second branches of the circuits such that the current draw through the first circuit during both AC phases is substantially the same. As also seen in FIG. 3, any number x of cross-connecting branches may be added in parallel to cross-connecting branch 58.

[Para 64] FIG. 4 shows yet another embodiment of a circuit as contemplated by this invention. Circuit 70 includes two LEDs, 72, 74 connected in an anti-parallel configuration. Connected in series with each LED is current limiting diode 76, 78 respectively. Connecting a current limiting diode in series with each LED insures that the current flowing through each LED is both substantially limited, and substantially constant, while the combination is forward biased.

[Para 65] It is contemplated by the invention that rather than have just two LEDs connected in an anti-parallel configuration, any number of additional LEDs may be added in series with LEDs 72, 74. In such embodiments, each series string of LEDs may include at

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least one current limiting diode in order to realize the advantages as discussed herein.

[Para 66] For use as a lighting device or in a lighting device or system, any of the circuits shown or described herein may be integrated on a single chip as shown in FIGs. 5 and 6. Chips 80 and 90 include circuits 70 and 10 respectively, integrated on a single chip. Power connection leads 82, 84 and 92, 94 are provided respectively, at opposing ends of each circuit 70, 10, in order to allow power to be provided thereto. It should be appreciated that circuit 40 in FIGs. 2 and 3 may likewise be integrated on a single chip as shown in FIGs. 5 and 6.

[Para 67] Rather than integrate on a single chip, it is contemplated by the invention that individual LED die and current limiting LEDs may be placed on a substrate forming a circuit in an LED package as shown in FIGs. 7 and 8. LED packages 100, 110 may include individual LED die 102, 112 and current limiting diodes 104, 114, which may be wire bonded together on substrate 106, 116. Substrate 106, 116 may include, or be attached to, a heat sink forming part of Packages 100, 110. LED packages 100, 110 may further include power connection leads 108, 109 and 118, 119 connected to opposing ends of the formed circuits for connecting the circuits and packages to a driver, power source or the like. Alternatively, rather than have power connection leads extending from each end, packages 100, 110 may be flip chips having power connections located on a bottom surface. As with chips 80, 90, it is contemplated that the circuits shown in FIGs. 2-4 may likewise be formed on a substrate by wire bonding individual LED die and current limiting diodes in the disclosed configuration.

[Para 68] Whether using chips or LED packages formed as described above, using the power connection leads may allow for multiple circuits, chips, and/or packages to be connected together in series, parallel, or series-parallel configurations. In operation, when connecting multiple chips in series or series-parallel, it is advantageous to insure that all current limiting diodes in each circuit in the series are substantially matched. While not required, substantially matching each current limiting diode will insure that each circuit is provided with the amount of current it is designed for. If one current limiting diode in a circuit allows less current than the current limiting diodes connected in series circuits, chips or packages, the amount of current in the series circuits may be less than ideal for those circuits. The light emitted from each circuit may be determined by the lowest value of current limiting diode in the series connection, as this value will substantially determine the current for the entire series.

[Para 69] As shown in FIGs. 9 and 10, rather than have to connect multiple chips or packages, it is contemplated that multiple circuits may be integrated onto a single chip or

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multiple circuits may be formed using multiple discrete LED die and current limiting diodes on a single substrate. It is also contemplated that multiple circuits may be formed by using multiple discrete packaged LEDs and current limiting diodes on a single substrate. FIGs. 9 and 10 show chips 120, 130 respectively. Though shown as chips, LED packages may be formed in the same manner as a single circuit package as described above. Chips 120, 130 each include at least two circuits 70, 10 respectively. The individual circuits may be connected in series (as shown in FIG. 10), parallel (as shown in FIG. 9), or where three or more circuits are included in the chip, series-parallel configuration. Power connection leads 122, 123 and 132, 133 may be provided and connected to the circuits as required to create the desired series or parallel configuration.

[Para 70] Alternatively, as shown in FIG. 11, rather than use a single power lead connection pair for multiple circuits on a single chip or in a single package, each circuit contained on the chip or within the package may be provided with its own power connection leads. As seen in FIG. 11, chip 140 may be provided with at least circuits 70, each circuit having its own power connection lead, 142, 144 and 146, 148. The power connection leads from each circuit may then be connected to any driver or power source for the chip in any manner desired by an end user. For example, circuits 70 may be connected in series with each other at power connection leads 144 and 148 while leads 142 and 146 connect to a power source. Alternatively, circuits 70 may be connected in parallel where leads 142, 144 and 146, 148 all connect to a power source. As additional circuits are added to the single chip or package, the additional circuits may be connected in series or parallel as provided above, depending on the needs or requirements of the system.

[Para 71] The chips and packages shown and described in FIGs. 5-10 may comprise lighting devices which may be packaged or utilized in a lighting system. As shown in FIGs. 12A-E, the lighting system may be embodied as any form of lamp or light bulb known and used in the art. The lighting device may include two power connection leads (see for example power connection leads 150, 152 in devices FIGs. 12A, 12B, 12D, and 12E) which correspond to the power connection leads on any enclosed chip, package or circuits. Alternatively, the lighting system may include Edison or E-base 154 as shown in FIG. 12C which includes two power connection leads inside the screw base which connects to a lighting fixture, driver or power source. Any lighting circuits, devices, or other required drivers or circuitry may be located within housing 156 of any of the systems shown in FIGs. 12A-E.

[Para 72] While the foregoing has been directed to protecting and enhancing LED

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circuits which are driven by AC power, it is contemplated by the present invention that the same or similar LED circuits and devices may be driven by DC power. For example, a DC power supply may be connected to common points 32, 34 in FIG. 1 and power connection leads 92, 94 in FIG. 6 so that one combination of LEDs (for example 12, 22 in FIG. 1) is forward biased and one combination of LEDs (for example 14, 20 in FIG. 1) is reverse biased. Likewise, a DC power supply may be connected to circuit 70 in FIG. 4 or power connection leads 82, 84 in FIG. 5 so that one LED (for example 72 in FIG. 4) is forward biased and one LED (for example 74 in FIG. 4) is reverse biased. Where series strings of LEDs are used in anti-parallel circuit 70, the additional LEDs would be forward or reverse biased based upon their configuration and which LED they are connected in series with.

[Para 73] In order to provide DC power to the circuits, it is contemplated by the invention that the circuits or devices may be connected to a DC power source, incorporated into a lighting system using DC power, may be powered from a bridge rectifier or some combination thereof. When DC power is provided by a bridge rectifier, it is contemplated that the bridge rectifier may be incorporated into the lighting device, a lighting system into which the circuit(s) and/or device(s) is incorporated into, or be formed as part of a power supply or driver which is formed in, or connected externally to, the device or system.

[Para 74] If the circuits or devices are connected to a direct DC power supply or incorporated into a system having a direct DC power source, like for example a flashlight or automobile which may use battery power, it may be unnecessary to use current limiting diodes. As such, when being powered with DC power, the circuits shown in FIGs. 13A-D may be substituted for any of the circuits shown in FIGs. 1-4 in any lighting device or system. Inasmuch as a direct DC power supply will provide substantially constant current, the need to limit or maintain the current at a substantially constant level is substantially lessened.

[Para 75] If, however, the DC power is rectified AC power, like for example from the mains, which will have a changing component as the AC power cycles, it may be advantageous to utilize a current limiting diode as shown, for example, in FIGs. 1-4. Utilizing the current limiting diode in the circuits will insure that the rectified DC current remains at a substantially limited level as the AC power cycles, protecting and extending the life of the LEDs as discussed herein.

[Para 76] When connecting any of the devices, circuits, chips, packages, or lamps shown in FIGs. 1-12 to DC power, only one half of the LEDs will emit light, while the remaining LEDs will be reversed biased and not operational. Using the example in [Para 58] above, if

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LEDs 12, 22 in FIG. 1 are forward biased and LEDs 14, 20 are reverse biased or LED 72 is forward biased and LED 74 in FIG. 4 is reverse biased, LEDs 14, 20 and LED 74 will remain off and unused as long as they are reverse biased.

[Para 77] In order to use these LEDs and maximize the lifespan of the circuit, chip, package, lamp or bulb, device or system, it is contemplated by the invention that the polarity of the DC power applied to the circuit, chip, package, lamp or bulb, or device may be reversed to forward bias the previously reverse biased LEDs. Reversing the polarity of the provided DC power will cause the previously reverse biased LEDs to enter into a forward biased state, causing the previously reversed biased and unused LEDs to emit light. The essentially creates a circuit, chip, package, lamp, device or system which has twice the life of an ordinary DC powered LED light as it contains essentially two light emitting elements or circuits within a single circuit, chip, package, lamp, device or system – the first circuit being the first set forward biased LED(s) and the second circuit being the first set of reverse biased LED(s).

[Para 78] In order to take full advantage of this aspect of the invention when utilizing the circuits shown in FIGs. 1-3 for example, it may be desirable to replace the current limiting diode 30 in cross-connecting branch 28 with a common wire. Putting a common wire between the first and second branch junctions will eliminate the possibility the current limiting diode will burnout long before the previously reversed biased LEDs become forward biased after the polarity of the DC power is reversed across the circuit. Inasmuch as the cross-connecting branch must conduct current, *i.e.* be forward biased, both before and after the DC power polarity is reversed, the lifetime of any type of diode in the cross-connecting circuit will be substantially less than the initially reverse biased diodes once the polarity is reversed.

[Para 79] In order to reverse the DC power provided to the LEDs, where a chip, package, lamp or other device that utilizes power connection leads to establish a clear polarity connection to a power supply, like for example the lamps shown in FIGs. 12A, 12B, 12D and 12E, it is contemplated that the chip, package, lamp or other device may simply be manually disconnected from the DC power source to which it is attached, or from the device or system into which it is incorporated, and reconnected in the reverse polarity configuration. For example, the power connection lead 150, 152 in FIGs. 12A, 12B, 12D, or 12E that was initially connected to the negative terminal or ground of the provided DC power may simply be connected to the positive terminal of the DC power source in order to forward bias the previously reversed biased LED(s). Such reversal may be done, for example, in automobile

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head lights, tail lights or brake lights, or a light within a battery powered hand held lighting device like a flashlight or a lantern by disconnecting the lamp or bulb and replacing it in a reverse fashion.

[Para 80] Rather than have to remove the bulb, chip, package, circuit or device, it is contemplated by the invention that the device or system into which the circuit(s) is incorporated may include a switch or the like capable of connecting the DC power to the load in both a "positive" and a "negative" polarity where "positive" polarity forward biases at least a first LED and reverse biases at least a second LED, and "negative" polarity forward biases at least the second LED and reverses biases at least the first LED. A switch embodiment may be realized as simply as controlling two pairs of switches or relays controlled by a manual external switch, each pair having a switch or relay connected to an opposite end of the circuit, or by using a double pole double throw (DPDT) switch with an off position. Moving the manual external switch to a first position may close a first pair of switches or relays which will create the "positive" polarity while moving the manual external switch to a second position will close a second pair of switches or relays which will create the "negative" polarity. When the first pair of switches or relays are closed the second pair of switches or relays will remain open and vice versa. A third switch position or an off position may leave both pairs of switches or relays open, allowing both the at least first and the at least second LEDs to be off.

[Para 81] When utilizing a switch, if the forward biased LEDs fail and stop emitting light within the device or system, the switch may be moved to a secondary position, or a reverse position, to reverse the polarity of the DC power provided to the LED circuit and forward bias the previously reverse biased LED(s). It is contemplated that during operation, the switch may be moved to any position, allowing either set of LED(s) to be forward biased without waiting for one set to fail. For example, a flashlight may be provided with a switch that when pushed forward from an off position will forward bias a first LED or string of LEDs and reverse bias a second LED or string of LEDs, and when pushed forward further to a second position or backwards from an off position will forward bias the second LED or string of LEDs and reverse bias the first LED or string of LEDs.

[Para 82] Rather than manually switch the circuit, chip, package, lamp, device or system by disconnecting it or using a switch, it is contemplated by the invention that the lighting device or system may include a sensor to monitor or "sense" the load (the circuit or device) and determine whether the circuit (*i.e.* the forward biased LED(s)) are operational and conducting current. If the sensor determines that the forward biased LED(s) (*i.e.* the load) is

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not operational and providing a voltage and/or current, using a signal provided (or not provided) to TTL logic gates, devices or circuits or a microcontroller may control a switch, relay or other circuitry to reverse the polarity of the DC power dynamically and forward bias and the previously reverse biased LED(s). For example, a sensor within the device or system may detect that the forward biased LED(s) are no longer conducting current and provide a signal (or stop providing a signal) to a TTL logic gate or circuit or a microcontroller which may cause a DPDT relay to dynamically change the polarity of power provided to the at least one circuit. The DPDT switching the polarity of the power will cause the previously reverse biased LED(s) to become forward biased and emit light.

[Para 83] One example of how a device with an internal sensor and dynamic polarity reversing can be seen in FIG. 14. As seen in FIG. 14, System 160 may include a DC power supply 162 connected to device 164 which includes circuit 166 which may be any circuit discussed herein. In order to detect the operation of the currently forward biased LED(s), load sensor 168 may be included within device 164. So long as load sensor 168 detects that the forward biased LEDs are operational, *i.e.* conducting current and/or voltage, the polarity of the power provided by the DC power supply will remain the same, and the forward biased diodes will be used to emit light. Once load sensor 168 fails to detect an output from the forward biased LED(s) in circuit 166 (*i.e.* the LED(s) burnout), load sensor 168 will trigger polarity switching circuit 170 which may include any required logic gates, circuitry or devices, any switches or relays, and/or any other required circuitry, to reverse the polarity of the DC power provided to circuit 166 so that the previously reverse biased LED(s) may be forward biased and begin emitting light. Once the load sensor fails to detect an output from the previously reversed biased LEDs, the lighting device is defective and needs to be replaced.

[Para 84] FIGs. 15 and 16 show alternative embodiment systems 180 and 190 where DC power supply 162 is replaced with an AC power supply 182 and bridge rectifier 184 is used to provide DC power to the device or circuit. As seen in FIG. 15, system 180 may include bridge rectifier 184 which is located external of device 164, between AC power supply 182 and device 164. The AC power provided by AC power supply 182 may be provided to rectifier 184, and the rectified DC power may then be provided on to device 164. Alternatively, as seen in FIG. 16, bridge rectifier 182 may be located internally within device 164. In such embodiments, AC power would be received by device 164 and rectified by rectifier 182 before being provided as DC power to circuit 166.

[Para 85] FIG. 17 shows yet another embodiment, system 200. In system 200, DC

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power supply or driver 202 may include load sensor 168 and polarity switching circuit 170 internally. The feedback from device 164 may be used to determine whether the forward biased LED(s) in circuit 166 are operational. If the forward biased LED(s) fail, polarity switching circuit 170 may be triggered, and the polarity of the DC power provided to device 164 may be reversed.

[Para 86] Load sensor 168 and polarity switching circuit 170 may be provided within device 164 as a driver, with any additional circuitry required to efficiently drive circuit 166. For example, a driver within device 164 may include bridge rectifier 184 when necessary, as well as any step-up or step-down transformers to adjust an incoming AC voltage. In devices like those show in FIGs. 12A-12E, the driver circuitry may be located within the base (see for example base 210 in FIGs. 12A-E) or housing (see for example housing 156 in FIGs. 12A-E) and integrated in any manner known in the art. The driver may be, for example, a package or chip having any necessary components to connect to the power connection leads of the device and/or any connection leads required to connect to any circuits, chips or packages discussed herein.

[Para 87] While in the foregoing there has been set forth a preferred embodiment of the invention, it is to be understood that the present invention may be embodied in other specific forms without departing from the spirit or central characteristics thereof. The present embodiments, therefore, are to be considered in all respects as illustrative and not restrictive, and the invention is not to be limited to the details given herein. While specific embodiments have been illustrated and described, numerous modifications come to mind without significantly departing from the characteristics of the invention and the scope of protection is only limited by the scope of the accompanying claims.

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CLAIMS

What is claimed is:

1. A lighting device comprising:

at least one circuit capable of emitting light when powered by an AC power source,

the at least one circuit having

at least two LEDs connected in a series, a parallel, or an anti-parallel configuration, and

at least one current limiting diode connected in series or parallel with at least one of the at least two LEDs.

2. The lighting device of claim 1 wherein the at least one circuit includes

at least first and second branches connecting at first and second common points, the common points providing an input and an output for a driving voltage for the circuit,

the first branch having at least a first and a second LED, the first LED being connected to the second LED in opposing series relationship, with the inputs of the first and second LEDs defining a first branch junction,

the second branch having at least a third and a fourth LED, the third LED being connected to the fourth LED in opposing series relationship, with the outputs of the third and fourth LEDs defining a second branch junction,

the first and second branches being connected to one another such that the output of the first LED is connected to the input of the third LED at the first common point and the output of the second LED is connected to the input of the fourth LED at the second common point; and,

the at least one current limiting diode forming a first cross-connecting circuit branch, the first cross-connecting circuit branch being configured such that the input of the at least one current limiting diode is connected to the second branch junction and the output of the constant current diode is connected to the first branch junction.

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3. The lighting device of claim 2 wherein the at least one circuit further includes at least one additional LED connected in series with:

each of the second and fourth LEDs than is connected in series with each of the first and third LEDs between each LEDs respective common point and branch junction, or

each of the first and third LEDs than is connected in series with each of the second and fourth LEDs between each LEDs respective common point and branch junction.

4. The lighting device of claim 2 or 3 wherein the at least one LED circuit includes n additional LEDs, in pairs, wherein the pairs are configured among the first and second branches of the at least one circuit such that that the current draw through the at least one circuit during both AC phases is substantially the same.

5. The lighting device of claim 2 or 3 wherein the at least one circuit includes x cross-connecting circuit branches, each cross-connecting circuit branch

having one or more constant current diodes, and

being connected in parallel to the first cross-connecting circuit branch.

6. The lighting device of claim 1 wherein the at least two LEDs are connected in an anti-parallel configuration.

7. The lighting device of claim 6 wherein at least one current limiting diode is connected in series with each of the at least two LEDs.

8. The lighting device of claim 6 wherein at least one additional LED is connected in series with each anti-parallel LED forming series strings of LEDs connected in anti-parallel configuration.

9. The lighting device of claim 8 wherein at least one current limiting diode is connected in series with each series string of LEDs.

10. The lighting device of any one of claims 6-9 further comprising a bridge rectifier connected in series with the anti-parallel LEDs so that at least one LED is forward biased by power provided by the bridge rectifier and at least one LED is reverse biased by power provided by the bridge rectifier.

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11. The lighting device of claim 10 further comprising a load sensor for sensing operation of the at least one forward biased LED.

12. The lighting device of claim 11 further comprising a polarity switching circuit capable of reversing the polarity of the power provided by the bridge rectifier to forward bias the at least one LED that was reversed biased if the sensor fails to detect that the at least one forward biased LED is operating.

13. The lighting device of any one of claims 1-12 wherein the at least one circuit is integrated in a single chip.

14. The lighting device of claim 13 wherein the chip includes at least two power connection leads, the power connection leads being connected to opposite sides of the at least one circuit.

15. The lighting device of any one of claims 1-12 wherein the at least one circuit is formed by integrating individual LED die on a substrate forming an LED package.

16. The lighting device of claim 15 wherein the substrate and LEDs formed thereon are coated in phosphor.

17. The lighting device of any one of claims 13-16 comprising at least two circuits, the at least two circuits being connected in series or parallel, and formed on a single chip or substrate.

18. The lighting device of claims 13-16 further comprising at least two circuits electrically unconnected to each other, each of the at least two circuits having power connection leads connected to opposite ends of the circuit.

19. The lighting device of any one of claims 1-18 wherein the lighting device is integrated within a lamp.

20. The lighting device of claim 19 wherein the lamp includes a base having at least two power connection leads, the power connection leads being connected to the at least one circuit so as to be able to provide power to the at least one circuit from a power supply.

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21. The lighting device of claim 19 wherein the lamp is a brake light for an automobile.

22. The lighting device of claim 19 wherein the lamp is a headlight for an automobile.

23. A lighting system comprising:

at least one circuit having at least two LEDs, the at least two LEDs electrically connected and configured so that when the LEDs are connected to a DC power source at least one LED within the circuit is forward biased by the DC power source, and at least one LED within the circuit is reversed biased by the DC power source;

a load sensor connected to the at least two LEDs, wherein the load sensor senses the operation of the at least one LED forward biased by the DC power source; and,

a polarity switching circuit capable of reversing the polarity from the DC power source to forward bias the at least one LED previously reverse biased if the operation of the at least one LED which is forward biased fails.

24. The lighting system of claim 23 wherein the at least two LEDs are connected in an anti-parallel configuration.

25. The lighting system of claim 24 wherein the DC power source includes a bridge rectifier to rectify power provided by an AC power source.

26. The lighting system of claim 25 wherein the bridge rectifier is part of the lighting system.

27. The lighting system of claim 26 wherein the DC power source includes the load sensor.

28. The lighting system of any one of claims 25-27 further comprising at least one current limiting diode connected in series with each of the at least one LED forward biased by the DC power source, and the at least one LED is reversed biased by the DC power source.

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29. The lighting device of claim 23 comprising at least four LEDs, the four LEDs being configured in a bridge configuration.

30. The lighting device of claim 29 further comprising at least one additional LED, the at least one additional LED being connected across the output of the bridge rectifier.

31. The lighting device of claim 29 further comprising at least one current limiting diode, the at least one current limiting diode being connected across the output of the bridge rectifier.

32. The lighting device of claim 29 further comprising a wire connected across the output of the bridge rectifier.

33. A method of driving a lighting device or system, the method comprising the steps of:

connecting at least two LEDs such that at least one of the at least two LEDs is capable of emitting light during a positive phase from an AC power source, and at least one of the at least two LEDs is capable of emitting light during a negative phase from an AC power source;

providing DC power across the at least two LEDs, the at least two LEDs forming a load such that at least one of the at least two LEDs is forward biased by the DC power and at least one of the at least two LEDs is reversed biased by the DC power;

reversing the polarity of the DC power across the load so as to forward bias the at least one LED that was previously reverse biased and reverse bias the at least one LED that was previously forward biased.

34. The method of claim 33 further comprising the steps of
sensing the load to insure that the at least one LED configured to be forward biased by the DC power is operational; and,
reversing the polarity of the DC power across the load dynamically so as to forward bias the at least one LED that was previously reverse biased if the at least one LED previously configured to forward biased is no longer operational.

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35. The method of claim 34 further comprising the steps of
sensing the load at a DC power supply to insure that the at least one LED configured to be forward biased by the DC power is operational; and,
reversing the polarity of the DC power across the load dynamically at the DC power supply so as to forward bias the at least one LED that was previously reverse biased if the at least one LED previously configured to forward biased is no longer operational.

36. The method of claim 33 further comprising the step of:
reversing the polarity of the DC power across the load manually using a switch so as to forward bias the at least one LED that was previously reverse biased.

37. The method of claim 33 further comprising the step of:
reversing the polarity of the DC power across the load by manually disconnecting the circuit from the DC power and reconnecting the circuit to the DC power in a reversed configuration so that the at least one LED that was previously reverse biased is now forward biased.

38. The method of any one of claims 33-37 further comprising the step of connecting the at least two LEDs in an anti-parallel configuration.

39. The method of claim 38 further comprising the step of connecting at least one current limiting diode in series with each of the at least two LEDs.

40. The method of any one of claims 33-37 further comprising the step of connecting at least four diodes in a bridge configuration, wherein at least two of the at least five diodes are LEDs and at least two of the at least four LEDs are forward biased when connected to DC power, and at least two of the at least two LEDs are reversed biased when connected to DC power.

41. The method of claim 40 further comprising the step of connecting at least one constant current diode across the output of the bridge rectifier.

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42. The method of claim 40 further comprising the step of connecting at least one wire across the output of the bridge rectifier.

43. An LED circuit comprising:

at least two LEDs electrically connected and configured so that at least one LED is capable of emitting light during a positive phase if AC power is connected and at least one LED within the circuit is capable of emitting light during a negative phase if AC power is connected; and,

at least one current limiting diode connected in series or parallel with at least one of the at least two LEDs.

44. The LED circuit of claim 43 further comprising:

at least first and second branches connecting at first and second common points, the common points providing an input and an output for a driving voltage for the circuit,

the first branch having at least a first and a second LED, the first LED being connected to the second LED in opposing series relationship, with the inputs of the first and second LEDs defining a first branch junction,

the second branch having at least a third and a fourth LED, the third LED being connected to the fourth LED in opposing series relationship, with the outputs of the third and fourth LEDs defining a second branch junction,

the first and second branches being connected to one another such that the output of the first LED is connected to the input of the third LED at the first common point and the output of the second LED is connected to the input of the fourth LED at the second common point; and,

the at least one current limiting diode forming a first cross-connecting circuit branch, the first cross-connecting circuit branch being configured such that the input of the at least one current limiting diode is connected to the second branch junction and the output of the constant current diode is connected to the first branch junction.

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45. The LED circuit of claim 44 wherein at least one additional LED connected in series with:

each of the second and fourth LEDs than is connected in series with each of the first and third LEDs between each LEDs respective common point and branch junction, or each of the first and third LEDs than is connected in series with each of the second and fourth LEDs between each LEDs respective common point and branch junction.

46. The LED circuit of claims 44 or 45 further comprising *n* additional LEDs, in pairs, wherein the pairs are configured among the first and second branches of the at least one circuit such that that the current draw through the at least one circuit during both AC phases is substantially the same.

47. The LED circuit of claims 44 or 45 further comprising *x* cross-connecting circuit branches, each cross-connecting circuit branch

having one or more diodes, and
being connected in parallel to the first cross-connecting circuit branch.

48. The LED circuit of claim 43 wherein the at least two LEDs are connected in an anti-parallel configuration.

49. The LED circuit of claim 48 wherein at least one current limiting diode is connected in series with each of the at least two LEDs.

50. The LED circuit of claim 48 wherein at least one additional LED is connected in series with each anti-parallel LED forming series strings of LEDs connected in anti-parallel configuration.

51. The LED circuit of claim 50 wherein at least one current limiting diode is connected in series with each series string of LEDs.

52. The LED circuit of any one of claims 43-51 wherein the at least one circuit is integrated in a single chip.

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53. The LED circuit of claim 52 wherein the chip includes at least two power connection leads, the power connection leads being connected to opposite sides of the at least one circuit.

54. The LED circuit of any one of claims 43-51 wherein the at least one circuit is formed by integrating individual LED die on a substrate forming an LED package.

55. The LED circuit of claim 54 wherein the substrate and LEDs formed thereon are coated in phosphor.

56. An LED circuit as claimed and described herein.

57. A lighting device as claimed and described herein.

58. A lighting system as claimed and described herein.

59. A method of driving a lighting device or system as claimed and described herein.

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FIG. 1

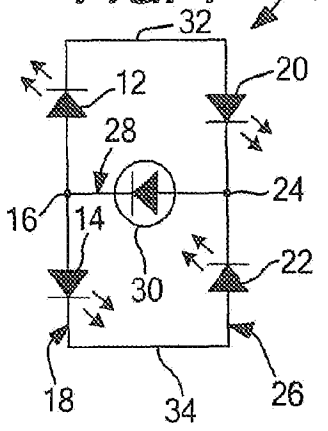


FIG. 2

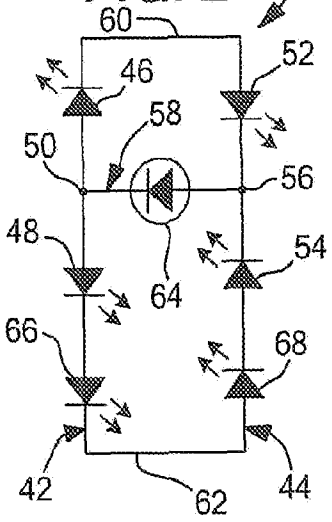
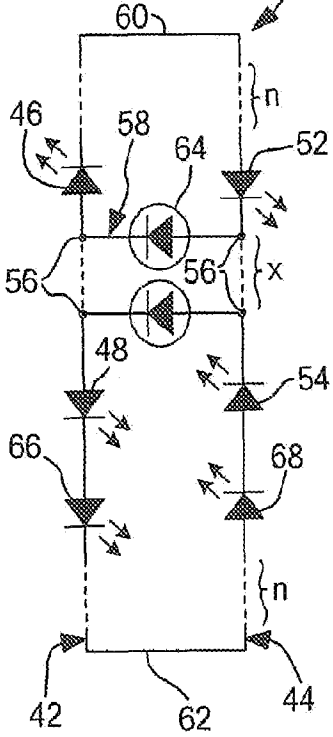


FIG. 3



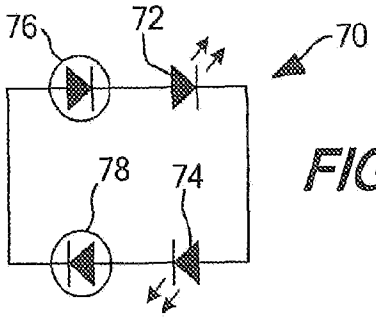


FIG. 4

FIG. 5

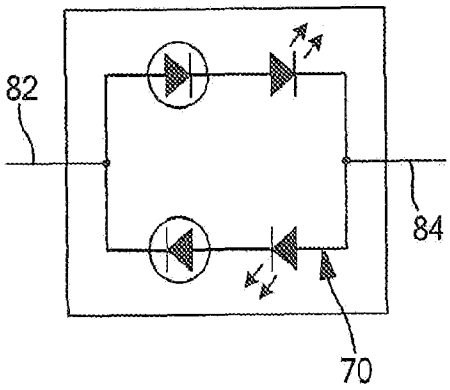
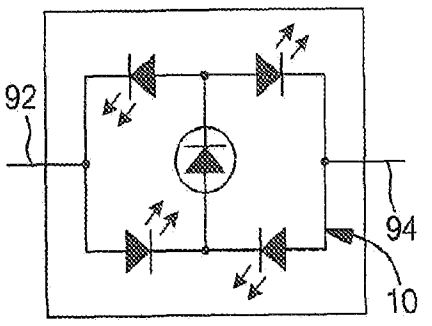


FIG. 6



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FIG. 7

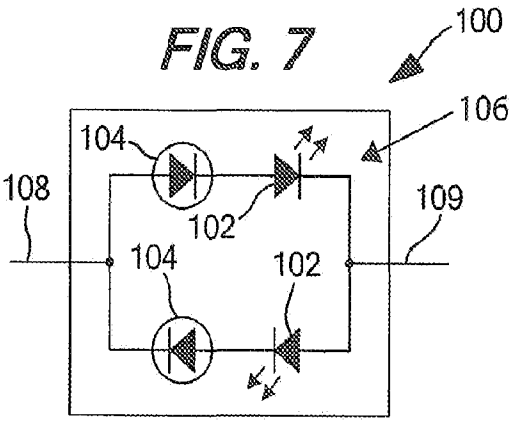
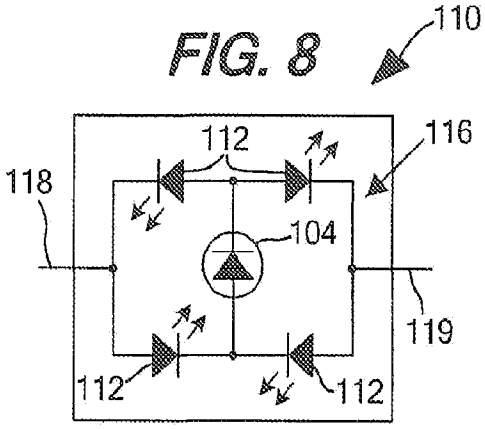


FIG. 8



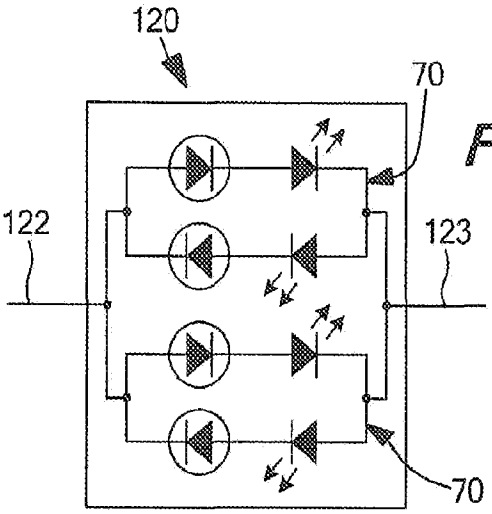


FIG. 9

FIG. 10

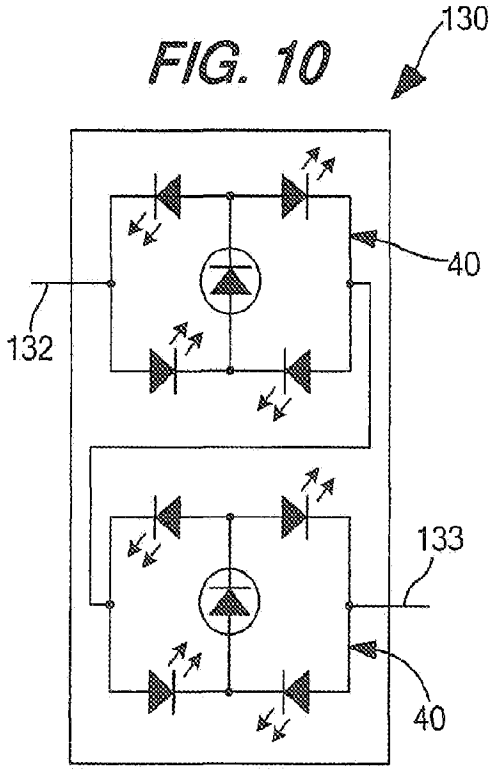
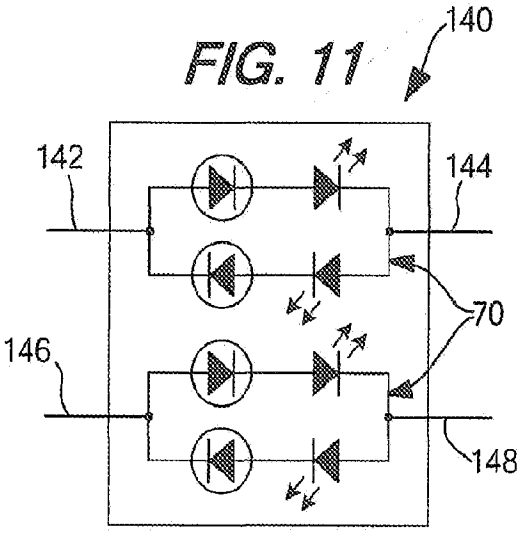


FIG. 11



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FIG. 12A

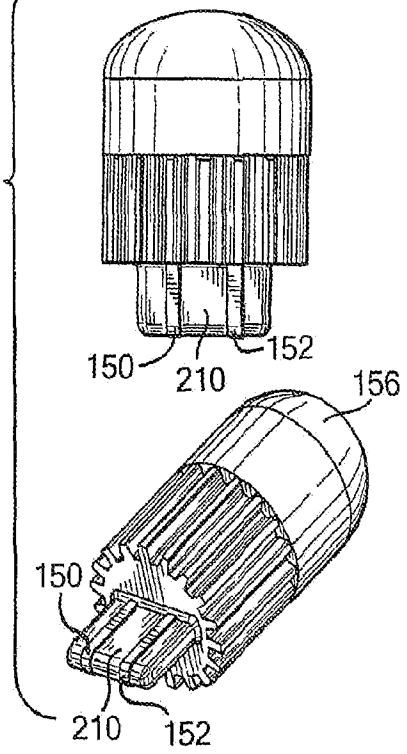


FIG. 12C

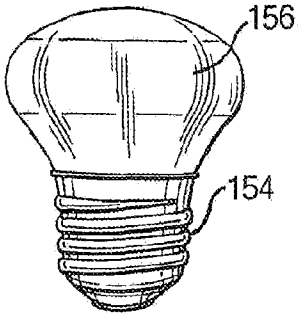
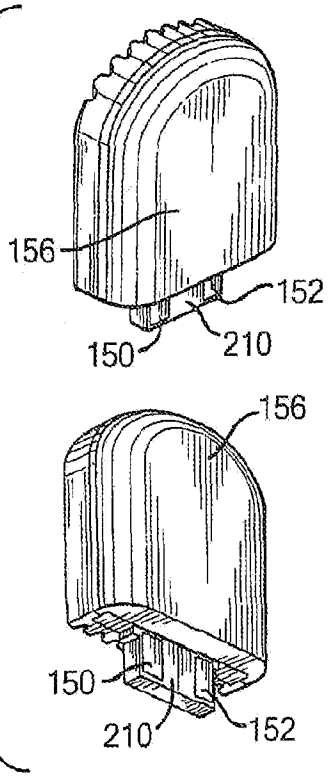
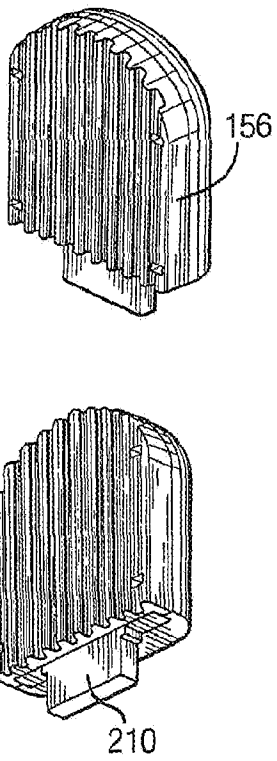


FIG. 12B





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FIG. 12D

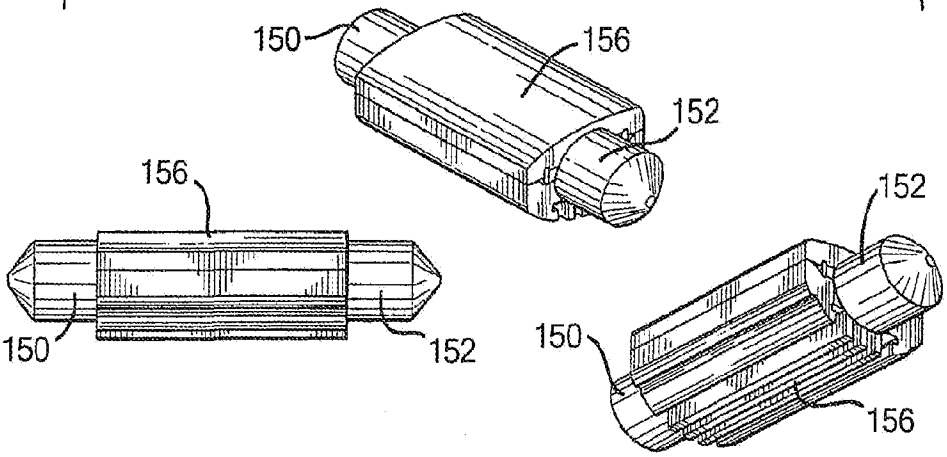


FIG. 12E

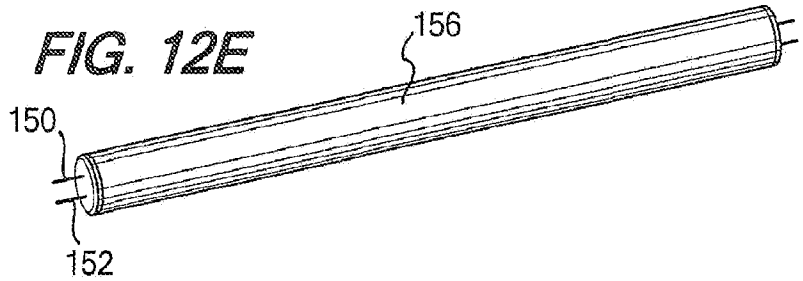


FIG. 13A

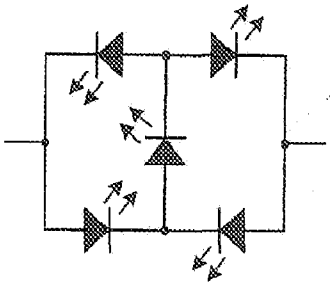


FIG. 13C

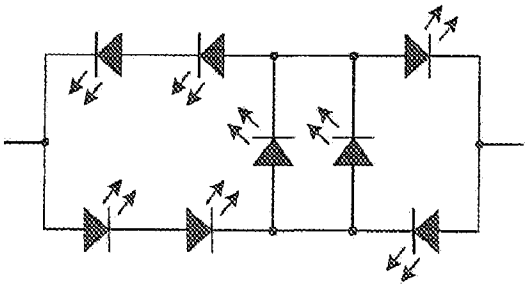


FIG. 13B

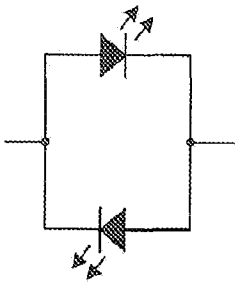
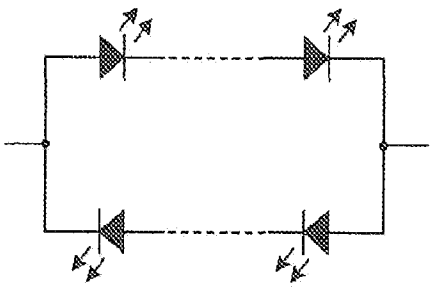


FIG. 13D



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FIG. 14

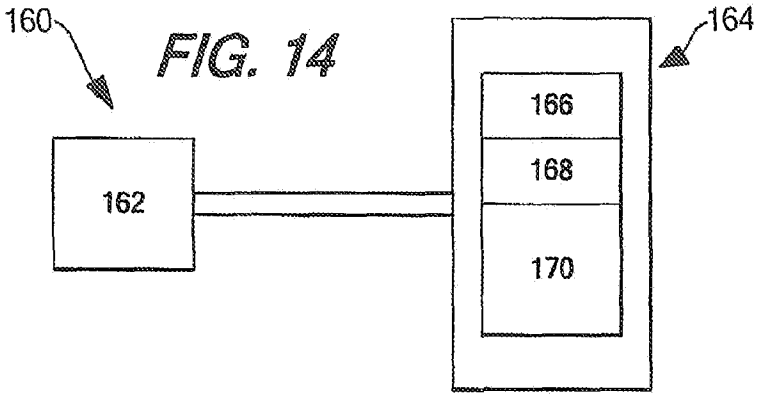


FIG. 15

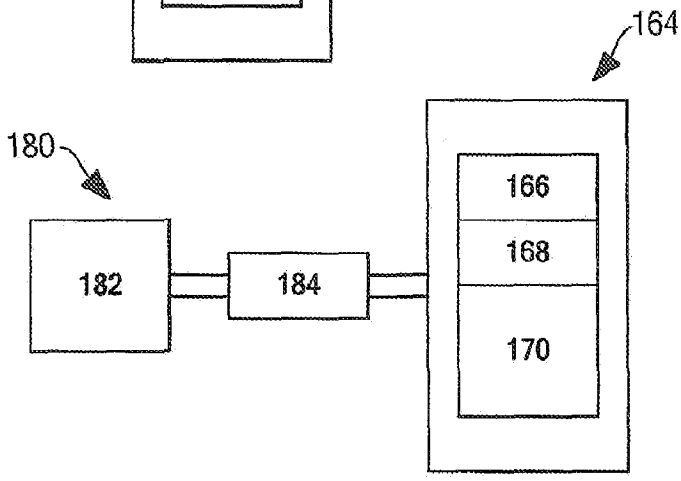


FIG. 17

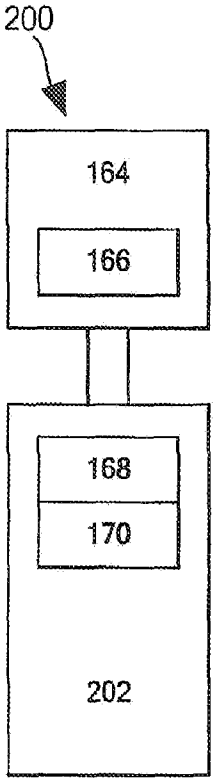
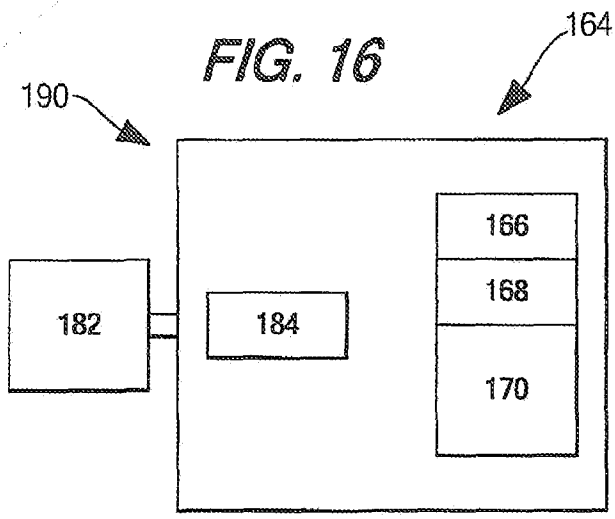


FIG. 16



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INTERNATIONAL SEARCH REPORT

International application No.
PCT/US12/51531

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - H05B 37/03, 37/00 (2012.01)
USPC - 315/250
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC (8) - H05B 37/03, 37/00 (2012.01)
USPC - 315/250

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

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
MicroPatent (US Granted, US Applications, EP-A, EP-B, WO, JP, DE-G, DE-A, DE-T, DE-U, GB-A, FR-A); DialogPro (Derwent, INSPEC, NTIS, PASCAL, Current Contents Search, Dissertation Abstracts Online, Inside Conferences); IEEE.com; Google Scholar; KEYWORDS: LED, LEDs, light*, emit*, diode*, AC, (alternating ADJ2 current*), ((current* NEAR3 limit*) NEAR3 diode*)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2009/0174337 A1 (MISKIN, M et al.) July 9, 2009; abstract; figures 1-8; paragraph [0004], [0006] and [0018]-[0026]	1-12, 43-51
Y	US 5,442,258 A (SHIBATA, Y) August 15, 1995; abstract; figure 1; column 1, lines 24-41; column 2, lines 3-9; column 2, lines 31-68	1-12, 43-51
Y	US 2005/0230600 A1 (OLSON, S et al.) October 20, 2005; abstract; figure 3; paragraphs [0065]-[0067]	11
Y	US 4,535,203 A (JENKINS, J et al.) August 13, 1985; abstract; figures 2-6; column 2, line 50 – column 3, line 51	12
P, Y	US 2011/0298393 A1 (CHEW, T) December 8, 2011; abstract; figures 1-31; paragraphs [0077]-[0093]	1-12, 43-51

☐ Further documents are listed in the continuation of Box C. ☐

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
30 November 2012 (30.11.2012)	07 JAN 2013
Name and mailing address of the ISA/US Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-3201	Authorized officer: Shane Thomas PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774

Form PCT/ISA/210 (second sheet) (July 2009)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US12/51531

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☒ Claims Nos.: 56-59
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
Because claims 56-59 are improper omnibus claims.

3. ☒ Claims Nos.: 13-22 and 52-55
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.

Electronic Acknowledgement Receipt

EFS ID:	44106743
Application Number:	17181802
International Application Number:	
Confirmation Number:	5141
Title of Invention:	MULTI-VOLTAGE AND MULTI-BRIGHTNESS LED LIGHTING DEVICES AND METHODS OF USING SAME
First Named Inventor/Applicant Name:	Michael Miskin
Customer Number:	24573
Filer:	Dennis A. Majewski/US Patent Mail
Filer Authorized By:	Dennis A. Majewski
Attorney Docket Number:	3725194.00146 14US07
Receipt Date:	25-OCT-2021
Filing Date:	22-FEB-2021
Time Stamp:	10:18:35
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Non Patent Literature	ExG06842Dowling.pdf	2005220 695cfd62c4b37e3b10adba3c60b829eb0a7171f3	no	68

Warnings:

Information:					
2	Non Patent Literature	ExH01001Dowling.pdf	3464816 2154702374 2a738581f56fe23b2b33fd5acb ba05	no	114
Warnings:					
Information:					
3	Non Patent Literature	ExH02001Lys321.pdf	4529368 7acc582a0231dc1dec88914dcf365cf7636c 6579	no	153
Warnings:					
Information:					
4	Non Patent Literature	ExH03001Miskin.pdf	381911 b2e84ca20061f9367534bd9b9ca31ad97cb b559e	no	12
Warnings:					
Information:					
5	Non Patent Literature	ExH04001Leong003.pdf	2524617 dc2716bd8a0824ca797c6aba7e01daed24c 3bbc6	no	79
Warnings:					
Information:					
6	Non Patent Literature	ExH05001Konno.pdf	3677570 02ca95fb45cc23fedd6e006f23f530baff387 e6e	no	124
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Information:					
7	Non Patent Literature	ExI01341OhishiMuthu.pdf	1134749 b0b532ab3272334bfef25e0acf14a94c2bb4 4b60	no	34
Warnings:					
Information:					
8	Non Patent Literature	ExI02341Muthu.pdf	1053123 bdca4f1dd76b4f06c7d84b3118916326975 47204	no	34
Warnings:					
Information:					

9	Non Patent Literature	ExI03341Dowling.pdf	1251383 3b6a3cad9077322a20d028e901c2da332149beb7	no	39
Warnings:					
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10	Non Patent Literature	ExI04341Konno.pdf	1165945 d96b05ebf687cd8360b7f4c6add13b046d115e77	no	40
Warnings:					
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11	Non Patent Literature	ExI05341Leong003.pdf	1757033 1b24399719b50bab6ca168f57c629426ce3e9298	no	57
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12	Non Patent Literature	ExI06341Reymond.pdf	915228 1ff307c7d4dacd5104c8bf7ebe4de9192c3b5e17	no	32
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		Total Files Size (in bytes):	23860963		

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INFORMATION DISCLOSURE STATEMENT BY APPLICANT

(Not for submission under 37 CFR 1.99)

Application Number	17181802
Filing Date	2021-02-22
First Named Inventor	Miskin
Art Unit	2844
Examiner Name	Hammond Crystal L.
Attorney Docket Number	3725194.00146 14US07

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Examiner Initial*	Cite No	Patent Number	Kind Code[1]	Issue Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear
	1	6019493		2000-02-01	Kuo	
	2	6227679	B1	2001-05-08	Zhang et al.	
	3	4271408		1981-06-02	Teshima, et al.	
	4	5847507		1998-12-08	Butterworth et al.	
	5	8362695	B2	2013-01-29	Aanegola et al.	
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	8	6016038		2000-01-18	Mueller	

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	9	4298869		1981-11-03	Okuno	
	10	7262559		2007-08-28	Tripathi et al.	
	11	8587205		2013-11-19	Ter Weeme et al.	
	12	7375476		2008-05-20	Scott et al.	
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	15	6722771		2004-04-20	Stephens	
	16	6184628		2001-02-06	Ruthenberg	
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	18	7264378		2007-09-04	Loh	
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	20	5457450		1995-10-10	Deese	
	21	5785418		1998-07-28	Hochstein	
	22	6404131		2002-06-11	Kawano et al.	
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	31	4104562		1978-08-01	DiCola	

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Examiner Initial*	Cite No	Publication Number	Kind Code[1]	Publication Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear
	1	20010005319	A1	2001-06-28	Ohishi et al.	
	2	20030038291		2003-02-27	Cao	
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	9	20090160358		2009-06-25	Slava	
	10	20100141177		2010-06-10	George	
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	20	20020167016		2002-11-14	Hoelen et al.			

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Examiner Initial*	Cite No	Foreign Document Number[3]	Country Code[2] i	Kind Code[4]	Publication Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear	T[5]
	1	2002208301	JP	A	2002-07-26	Takeo		
	2	2001004753	JP	A	2001-01-12	Takaaki et al.		
	3	9939319	WO		1999-08-05	Filipovsky et al.		
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	Attorney Docket Number	3725194.00146 14US07

	20	2264555	GB		1993-09-01	Coats		

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	1	Lynk Labs, Inc., v. Home Depot USA, Inc. The Home Dept Inc., and Home Depot Product Authority, LLC, Case No. 6:21-cv-00097-ADA, Home Depot's Preliminary Invalidity Contentions And Additional Disclosure Pursuant to Scheduling Order dated August 18, 2021 - 22 pages	
	2	U.S. Patent No. 10,492,251 ('251 Patent") - Exhibit A-01 - Takeo '301	
	3	U.S. Patent No. 10,492,251 ('251 Patent") - Exhibit A-02 - Lynam '623	
	4	U.S. Patent No. 10,492,251 ('251 Patent") - Exhibit A-03 – Filipovsky '319	
	5	U.S. Patent No. 10,492,251 ('251 Patent") - Exhibit A-04 Deese '719	
	6	U.S. Patent No. 10,492,251 ('251 Patent") - Exhibit A-05 Okuno	
	7	U.S. Patent No. 10,492,251 ('251 Patent") - Exhibit A-06 – Ohishi '319	
	8	U.S. Patent No. 10,492,251 ('251 Patent") - Exhibit A-07 Teshima	

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	Attorney Docket Number	3725194.00146 14US07

	9	U.S. Patent No. 10,349,479 ("'479 Patent") - Exhibit B-01 Dowling
	10	U.S. Patent No. 10,349,479 ("'479 Patent") - B-02 Ter Weeme
	11	U.S. Patent No. 10,349,479 ("'479 Patent") - Exhibit B-03 Lin
	12	U.S. Patent No. 10,349,479 ("'479 Patent") - Exhibit B-04 Lys '483
	13	U.S. Patent No. 10,349,479 ("'479 Patent") - Exhibit B-05 Leong '814
	14	U.S. Patent No. 10,349,479 ("'479 Patent") - Exhibit B-06 Calon
	15	U.S. Patent No. 10,349,479 ("'479 Patent") - Exhibit B-07 Nakagawara
	16	U.S. Patent No. 10,757,783 ("'783 Patent") - Exhibit C-01 Grajcar
	17	U.S. Patent No. 10,757,783 ("'783 Patent") - Exhibit C-02 Reymond
	18	U.S. Patent No. 10,757,783 ("'783 Patent") - Exhibit C-03 Walter
	19	U.S. Patent No. 10,757,783 ("'783 Patent") - Exhibit C-04 Lyos '901

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	20	U.S. Patent No. 10,757,783 ("'783 Patent") - Exhibit C-05 Hair	
	21	U.S. Patent No. 10,757,783 ("'783 Patent") - Exhibit C-06 Cho	
	22	U.S. Patent No. 10,757,783 ("'783 Patent") - Exhibit C-07 Coleman	
	23	U.S. Patent No. 10,757,783 ("'783 Patent") - Exhibit C-08 Shimizu	
	24	U.S. Patent No. 10,154,551 ("'551 Patent") - Exhibit D-01 Saito	
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	31	U.S. Patent No. 10,154,551 ("'551 Patent") - Exhibit D-08 Shimizu	
	32	U.S. Patent No. 10,517,149 ("'149 Patent") - Exhibit E-01 Takahashi	
	33	U.S. Patent No. 10,517,149 ("'149 Patent") - Exhibit E-02 Saito '590	
	34	U.S. Patent No. 10,517,149 ("'149 Patent") - Exhibit E-03 Lys '399	
	35	U.S. Patent No. 10,517,149 ("'149 Patent") - Exhibit E-04 Catalano '081	
	36	U.S. Patent No. 10,517,149 ("'149 Patent") - Exhibit E-05 Deese '719	
	37	U.S. Patent No. 10,652,979 ("'979 Patent") - Exhibit F-01 Coats '555	
	38	U.S. Patent No. 10,652,979 ("'979 Patent") - Exhibit F-02 Birrell '406	
	39	U.S. Patent No. 10,652,979 ("'979 Patent") - Exhibit F-03 Muthu '159	
	40	U.S. Patent No. 10,652,979 ("'979 Patent") - Exhibit F-04 Teshima '408	
	41	U.S. Patent No. 10,652,979 ("'979 Patent") - Exhibit F-05 Takeo	

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	42	U.S. Patent No. 10,652,979 ("'979 Patent") - Exhibit F-06 Deese '719
	43	U.S. patent application Ser. No. 60/839,453, filed on Aug. 23, 2006, entitled "LIGHTING DEVICE AND LIGHTING METHOD" to Van de Ven and Negley, ("453 Provisional")
	44	U.S. patent application Ser. No. 60/793,524, filed on Apr. 20, 2006, entitled "LIGHTING DEVICE AND LIGHTING METHOD" to Van de Ven and Negley, ("524 Provisional")
	45	U.S. patent application Ser. No. 60/844,325, filed on Sep. 13, 2006, entitled "BOOST/FLYBACK POWER SUPPLY TOPOLOGY WITH LOW SIDE MOSFET CURRENT CONTROL" to Myers ("Myers")
	46	Interim LED Purchase Specifications of the Institute of Transportation Engineers, July 1998 ("1998 Specification")
	47	"Comparison of Control Options in Private Offices in an Advanced Lighting Controls Testbed," by Judith D. Jennings et al., and published in April 1999 ("Jennings")
	48	Vehicle Detection Using a Magetic Field Sensor," by Stanely V. Marshall, and published in May 1978 ("Marshall")

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Attorney Docket Number	3725194.00146 14US07

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The fee set forth in 37 CFR 1.17 (p) has been submitted herewith.

A certification statement is not submitted herewith.

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A signature of the applicant or representative is required in accordance with CFR 1.33, 10.18. Please see CFR 1.4(d) for the form of the signature.

Signature	/Dennis A. Majewski/	Date (YYYY-MM-DD)	2021-10-25
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	2	6441558		2002-08-27	Muthu et al.	

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	2	20040212321		2006-05-02	Lys et al.	

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	1	2006023149	WO		2006-03-02	Mueller et al.	Corresponding US 8080819 is also cited	

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	1	U.S. Patent No. 10,091,842 ("'842 Patent") - Exhibit G-01 Bruning	
	2	U.S. Patent No. 10,091,842 ("'842 Patent") - Exhibit G-02 Ohishi '319	
	3	U.S. Patent No. 10,091,842 ("'842 Patent") - Exhibit G-03 Ruxton	
	4	U.S. Patent No. 10,091,842 ("'842 Patent") - Exhibit G-04 Walding	
	5	U.S. Patent No. 10,091,842 ("'842 Patent") - Exhibit G-05 Bohn	
	6	U.S. Patent No. 10,091,842 ("'842 Patent") - Exhibit G-06 Dowling	
	7	U.S. Patent No. 10,537,001 ("'001 Patent") - Exhibit H-01 Dowling	
	8	U.S. Patent No. 10,537,001 ("'001 Patent") - Exhibit H-02 Lys '321	
	9	U.S. Patent No. 10,537,001 ("'001 Patent") - Exhibit H-03 Miskin	

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	17181802
	Filing Date	2021-02-22
	First Named Inventor	Miskin
	Art Unit	2844
	Examiner Name	Hammond, Crystal L.
	Attorney Docket Number	3725194.00146 14US07

	10	U.S. Patent No. 10,537,001 ("'001 Patent") - Exhibit H-04 Leong '003
	11	U.S. Patent No. 10,537,001 ("'001 Patent") - Exhibit H-05 Konno
	12	U.S. Patent No. 10,932,341 ("'341 Patent") - Exhibit I-01 Ohishi '009
	13	U.S. Patent No. 10,932,341 ("'341 Patent") - Exhibit I-02 Muthu '558
	14	U.S. Patent No. 10,932,341 ("'341 Patent") - Exhibit I-03 Dowling
	15	U.S. Patent No. 10,932,341 ("'341 Patent") - Exhibit I-04 Konno
	16	U.S. Patent No. 10,932,341 ("'341 Patent") - Exhibit I-05 Leong '003
	17	U.S. Patent No. 10,932,341 ("'341 Patent") - Exhibit I-06 Reymond
	18	"White Light Emitting Diode Development for General Illumination Applications" to James Ibbetson, published on May 1, 2006 ("Ibbetson")

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	Application Number	17181802
	Filing Date	2021-02-22
	First Named Inventor	Miskin
	Art Unit	2844
	Examiner Name	Hammond, Crystal L.
	Attorney Docket Number	3725194.00146 14US07

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	Application Number	17181802
	Filing Date	2021-02-22
	First Named Inventor	Miskin
	Art Unit	2844
	Examiner Name	Hammond, Crystal L.
	Attorney Docket Number	3725194.00146 14US07

CERTIFICATION STATEMENT

Please see 37 CFR 1.97 and 1.98 to make the appropriate selection(s):

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See attached certification statement.

The fee set forth in 37 CFR 1.17 (p) has been submitted herewith.

A certification statement is not submitted herewith.

SIGNATURE

A signature of the applicant or representative is required in accordance with CFR 1.33, 10.18. Please see CFR 1.4(d) for the form of the signature.

Signature	/Dennis A. Majewski/	Date (YYYY-MM-DD)	2021-10-25
Name/Print	Dennis A. Majewski	Registration Number	65578

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Electronic Acknowledgement Receipt

EFS ID:	44106737
Application Number:	17181802
International Application Number:	
Confirmation Number:	5141
Title of Invention:	MULTI-VOLTAGE AND MULTI-BRIGHTNESS LED LIGHTING DEVICES AND METHODS OF USING SAME
First Named Inventor/Applicant Name:	Michael Miskin
Customer Number:	24573
Filer:	Dennis A. Majewski/US Patent Mail
Filer Authorized By:	Dennis A. Majewski
Attorney Docket Number:	3725194.00146 14US07
Receipt Date:	25-OCT-2021
Filing Date:	22-FEB-2021
Time Stamp:	10:16:02
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Foreign Reference	CN1341966-ABSTRACT-PAT.pdf	820060 fd4802428fd22df2fd4a796ead16bc18445a8fa4	no	15

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2	Foreign Reference	EP2483.pdf	5552238 15e709d39a83969a1577bd6d74d720c1c20452c5	no	39
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3	Non Patent Literature	Ex1007-1998ITESpecification.pdf	1860505 88ad7829f512b1bf3145c5b71f44ffe5ebac7cfb	no	25
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4	Foreign Reference	GB4555.pdf	1400162 a5a6ad8162f8283330d10b794a4ed150365c052a	no	22
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5	Non Patent Literature	HOME-DEPOT-INVALID-CONTENT-A.pdf	5156653 e58ee57c0e46af32ccb97f94b2a94700631e5ba3	no	22
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6	Foreign Reference	INVALEP1953825B1.pdf	317576 aa7ac3227515be6878368dad408353819d6fdd59	no	15
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7	Foreign Reference	INVALIL123123-English.pdf	65284 42b4072cd64a7fffa1fac96166d7cfea237ec2c0	no	1
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8	Foreign Reference	INVALWO9939319A3.pdf	364824 54a850c2a792ac32ae66a4053cceaf9e20d42a9b	no	7
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9	Non Patent Literature	Jennings-Comparison-of-Control-Options-April1999.pdf	4338306 c049a960263c1c32f21e16b35a08a87dbb0ae0f4	no	27
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17	Foreign Reference	WO1385.pdf	5128219 4eed5986db7a569e3c202c9e4fcb5d2f258c612c	no	49
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59	Information Disclosure Statement (IDS) Form (SB08)	00146-SB08-Invalid-Conten-Part1.pdf	615899 c700b83e645392eb3dddb73a33a052d39389e878	no	14
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Espacenet

CN1341966A Light-emitting device of high-power light-emitting diode

Applicants: GE SHICHAO [CN]

Inventors: GE SHICHAO [CN]

Classifications:

IPC ***H01L25/13; H01L33/00;*** (IPC1-7): H01L25/13; H01L33/00;

CPC **F21K9/232 (EP); F21K9/233 (EP); F21K9/64 (EP); F21V3/08 (EP,US); F21V3/12 (EP,US);** F21Y2115/10 (EP); H01L2224/48091 (EP); H01L2224/48247 (EP);

C-sets H01L2224/48091, H01L2924/00014 (EP);

Priorities: CN01135392A 2001-09-29

Application: CN1341966A·2001-09-29

Publication: CN1341966A·2002-03-27

Published as: **CN1286175C**; CN1341966A

Light-emitting device of high-power light-emitting diode

Abstract

The invention discloses a luminescence set of high-power light emitting diode. It consists of at least two chips of light emitting diode, a transparent container, at least a driving circuit and an electricity connector. The chips are installed on at least one reflector that it installed on a base plate and a radiator. The transparent container is installed above the radiator. The inner wall of the transparent container may be coated with light conversion material that convert the light emitted from the chips of light emitting diode into the light with needed color. The electricity connector is connected to outer power source and its output is connected to the chip of the light emitting diode. The invented luminescence set can be used to make bulb of light emitting diode with high power, high efficiency or light source and display in plate type.

[19]中华人民共和国国家知识产权局

[51] Int. Cl[7]
H01L 25/13
H01L 33/00

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[22]申请日 2001.9.29 [21]申请号 01135392.9

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[74]专利代理机构 杭州九州专利事务所有限公司

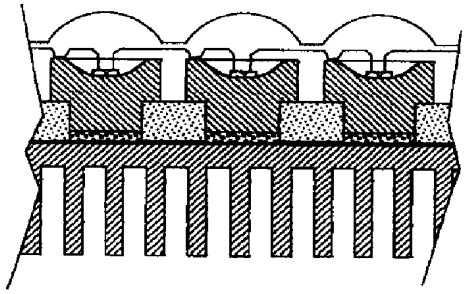
代理人 翁霁明

权利要求书 2 页 说明书 6 页 附图页数 5 页

[54]发明名称 大功率发光二极管发光装置

[57]摘要

一种大功率发光二极管发光装置，包括有至少二个发光二极管芯片，它 们被安装在至少一个反射体上，反射体被安装在一个基板和一个散热器上；一个透光容器，安装在反射体上方，透光容器内壁可有光转换材料，可将发 光二极管芯片发出的光转变成所需色的光；至少一个驱动电路和一个电连接 器，电连接器与外电源相连，其输出与发光二极管芯片相连，它可用于制造 大功率、高效率发光二极管灯泡或平板式光源和显示器。



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权 利 要 求 书

1，一种大功率发光二极管发光装置，它包括有安装在反射体上的发光二极管芯片，芯片上可有透光层，其特征在于所述的发光二极管芯片（1）至少有二个，并安装在至少一个反射体（2）上，反射体被安装在基板（8、13）上，基板安装在散热器（9）上，基板与散热器之间设置有导热胶（10）。

2、如权利要求 1 所述的大功率发光二极管发光装置，其特征在于安装有发光二极管芯片的反射体为由银、铜、铝、合金或镀银金属等高热导率的金属制成，该反射体被安装在如陶瓷、玻璃、电路板、云母、人造云母等构成的高热导率的基板（8、13）及散热器（9）上，反射体、基板和散热器之间设置有导热胶（10）。

3，一种大功率发光二极管发光装置，它包括有安装在反射体上的发光二极管芯片，芯片上可有透光层，其特征在于所述的发光二极管芯片至少有二个，并安装在至少一个反射体上，反射体被安装在散热器（9）上，反射体与散热器之间设置有导热胶（10）,导热胶（10）层内有如小玻璃珠的绝缘支柱（24）。

4、如权利要求 1 和 3 所述的大功率发光二极管发光装置，其特征在于所述的反射体上制成有一较深的反射碗（12a），其深度大于反射碗口径的半径，反射碗的形状可设计成有利于光输出的如抛物面等形状。

5、如权利要求 1 和 3 所述的大功率发光二极管发光装置，其特征在于所述的发光二极管芯片可按需要串联、并联或串并联连接，并被安装在平面或曲面反射体上。

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6、如权利要求 1 和 3 所述的大功率发光二极管发光装置，其特征在于所述发光二极管芯片（1、1a、1b.....）和反射体（7、12、12a）上可有光转换材料（15）。

7、一种大功率发光二极管灯泡，它包括一个如前所述的发光二极管发光装置（101、102、103），其特征在于发光二极管芯片前方有泡壳（14），该泡壳（14）固定在散热器（9）上，散热器（9）被设计成与灯泡相似并有利散热的如叶片、通孔或其他几何形状等形状,；一个绝缘外壳（18）用于连接散热器（9）和下部灯头（17），灯头（17）与外壳（18）内有驱动器（19），其输入端经引线（20）与灯头相连；其输出经引线（22）与发光二极管芯片相连。

8、如权利要求 7 所述的大功率发光二极管灯泡或显示单元，其特征在于所述的泡壳（14）的内壁上有光转换材料（15），并可有保护层（16）。

9、如权利要求 7 或 8 所述的大功率发光二极管灯泡或显示单元，其特征在于所述的泡壳（14）为透光泡壳，并被设计成如球形、蘑菇形等不同形状。

10、如权利要求 7 所述的大功率发光二极管灯泡，其特征在于所述的泡壳（14）可为一开口泡壳并可有反射层（21），基板（12、13）散热器（9）上设置有至少一个通孔（23），空气可经通孔（23）和散热器（9）流通。

11，一种大功率发光二极管显示单元，它包括一个如前所述的发光二极管发光装置（101、102、103），其特征在于发光二极管芯片前方有泡壳（14），该泡壳（14）固定在散热器（9）上，散热器（9）安装于显示系统的基板上。

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说　　明　　书

大功率发光二极管发光装置

技术领域

本发明涉及一种大功率发光二极管照明和显示装置，用于照明和信息显示。

背景技术

现有技术的发光二极管均以 1 或 2 个芯片安装于一个反射碗内，后用透光环氧树脂密封为一基本单元，此种结构芯片散热难，芯片安装密度低，难于制成大功率的发光二极管器件。发光二极管是一种对温度很敏感的器件，输入功率增加时，芯片温度上升将导致发光效率明显下降。对于大功率发光二极管，如何改进散热，特别是大电流和高芯片安装密度的情况下，散热更是一个关键的问题。

发明内容

本发明的目的是要克服上述存在的不足，而提供一种大功率发光二极管发光器件，它是通过如下技术方案来实现的，它包括有安装在反射体上的发光二极管芯片，芯片上可有透光层，所述的发光二极管芯片至少有二个，并安装在至少一个反射体上，反射体被安装在基板上，基板安装在散热器上，基板与散热器之间设置有导热胶。

所述的安装有发光二极管芯片的反射体为由银、铜、铝、合金或镀银金属等高热导率的金属制成，该反射体被安装在如陶瓷、玻璃或电路板等构成的高热导率的基板及散热器上，反射体、基板和散热器之间设置有导热胶。

它还包括有安装在反射体上的发光二极管芯片，芯片上可有透光层，所

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述的发光二极管芯片至少有二个，并安装在至少一个反射体上，反射体被安装在散热器上，反射体与散热器之间设置有导热胶，导热胶层内有如小玻璃珠等绝缘支柱。

前述的反射体上设置有较深的反射碗，其深度大于反射碗口径的半径，反射碗的形状可设计成有利于光输出的如抛物面等形状。

所述的大功率发光二极管发光装置，其特征在于所述的发光二极管芯片可按需串联或并联、串并联连接，并被安装在平面或曲面反射体上。

所述的大功率发光二极管发光装置，其特征在于所述发光二极管芯片和反射体上可有光转换材料。

一种大功率发光二极管灯泡，它包括一个如前所述的发光二极管发光装置，所述发光二极管芯片前方有泡壳，该泡壳固定在散热器上，散热器被设计成与灯泡相似并有利散热的如叶片、通孔或其他几何形状等形状，一个绝缘外壳用于连接散热器和下部灯头，灯头与外壳内有驱动器，其输入端经引线与灯头相连；其输出经引线与发光二极管芯片相连。

所述的泡壳的内壁上可有光转换材料，并可有保护层。

所述的泡壳为透光泡壳，被设计成如球形、蘑菇形等不同形状。

所述的泡壳可为一开口泡壳并可有反射层，基板上设置有至少一个通孔，使空气可经通孔和散热器流通。

所述导热胶内也可有绝缘支柱，如小玻璃珠，这时反射体可直接安装于散热器上。

一种大功率发光二极管显示单元，它包括一个如前所述的发光二极管发光装置，所述的发光二极管芯片前方可有泡壳，该泡壳固定在散热器上，散

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热器安装于显示系统的基板上。

本发明的大功率发光二极管发光装置与现有技术的发光二极管相比，具有功率大、效率高等优点，可用于制造大功率发光二极管灯和显示器。

附图说明

图 1 为现有技术的发光二极管的结构示意图。

图 2 为本发明的大功率发光二极管发光装置的一个实施例的局部剖面结构示意图。

图 3 为本发明的大功率发光二极管发光装置的又一个实施例的局部结构示意图。

图 4 为图 3 的等效电路图。

图 5 为图 3 的 A-A 剖面结构示意图。

图 6 为本发明的大功率发光二极管发光装置的又一个实施例的局部结构示意图。

图 7 为本发明的大功率发光二极管灯泡的一个实施例的剖面结构示意图。

图 8 为本发明的大功率发光二极管灯泡的又一个实施例的剖面结构示意图。

具体实施方式

下面将结合附图对本发明作详细的介绍：图 1 所示为有一个发光二极管芯片 1 的例子。芯片被安装在一个反射碗 2 内，芯片经连接线 4 和阳极引线 3 相连，并通过发光二极管芯片的引出线 6 外连，芯片上还有透光环氧树脂层 5。

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在此种结构，芯片和反射碗均被环氧树脂密封包围，散热困难，芯片温度容易升高而导致发光效率下降，工作电流一般限于 20mA 以下，且芯片安装密度低，难于制成大功率的发光二极管发光装置。

图 2 为本发明的大功率发光二极管发光装置的一个实施例的局部剖面结构示意图 101。图 2 所示为一串相互串联的大功率发光二极管发光装置的例子。图中有发光二极管芯片 1，它固定在反射体 7 上，例如金属反射碗内，所述反射碗固定在基板 8 上。基板 8 与一散热器 9 紧密接触，其间有导热胶 10，反射碗与散热器 9 之间有一间隙，其中也有导热胶 10，用于绝缘和导热。散热器 9 可为一平板或有多个槽的有利于散热的形状的板。芯片上有透光密封胶 11，例如环氧树脂。所述绝缘基板 7 例如由陶瓷、玻璃或电路板等热导率高的材料制成。所述散热器由热导率高的材料例如铝、银、铜或合金等制成。为防止绝缘基板 8 因膨胀系数与散热器 9 不同而断裂，导热胶 10 可为软性胶。芯片 1 的排列可按需要串联、并联或串并联。绝缘基板 8 和散热器 9 可以是平面的或曲面的。为避免透光密封胶 11 因热膨胀而断裂，所述透光密封胶 11 可分成若干小块。

图 2 所述的结构，芯片 1 与散热器 9 之间热阻很小，可使芯片产生的热量很快散掉；同时芯片的安装密度可很高；从而可制成大功率、高效率的发光二极管发光装置。

为确保发光二极管芯片中有个别损坏时器件仍能正常工作，芯片的排列可先将若干个芯片并联后串联，如图 3 所示。图中 1a、1b、1c...和 1A、1B、1C...为芯片，另图中所示有连接线 4a、4b，导电反射基板 12。所述芯片可安装在平面或曲面的反射体上。

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图 4 为图 3 的等效电路图，其中 1a、1b、1c.....并联，1A、1B、1C..... 并联，若干组并联的芯片相互串联。

图 5 为图 3 的 A-A 剖面结构示意图 102，其中芯片阵列 1a、1b、1c...，导电反射基板 12，散热板 9，二者之间有薄绝缘导热层 13，如云母、人造云母等；另有导热胶层 10，芯片上可有透光密封胶 11。芯片和反射基板 12 上可有光转换材料 15，可将由芯片发出的光转变成所需色的光。

以上图 1 和图 5 所示为本发明的发光二极管发光装置的结构的二个实施例的示意图。它们可用于制成平面或曲面光源，也可用于制成灯泡式的照明灯或显示单元。

图 5 中导热胶层 10 内也可有绝缘支柱，如小玻璃珠，如图 6 中 24 所示。这时反射体可直接安装于散热器上，而不用绝缘导热层 13。

为得到效率更高、聚焦的出射光 25，反射体上的反射碗 12a 可较深，例如深度大于反射碗口径的半径，如图 6 所示；反射碗 12a 的形状可设计成有利于光输出的形状、如抛物面等。图 6 中其它数字的意义与图 5 中相同。

图 7 为本发明的大功率发光二极管灯泡的一个实施例的结构剖面示意图。其中发光二极管发光可用图 2（101）、图 5（102）或图 6（103）的结构，图 6 中所示为用图 5 所示结构的例子。图中数字 1a、1b.....，9，10，11，12，和 13 所代表的意义与图 5 相同；其中散热器 9 被设计成与灯泡相似并有利散热的形状，如叶片、通孔或其他几何形状。芯片阵列 1a、1b.....上有一透光泡壳 14，由玻璃或塑料制成，固定在散热器 9 上，其内壁上可有光转换材料 15，可将由芯片发出的光转变成所需色的光。光转换材料 15 上可有保护层 16 以保护光转换材料。图中有灯头 17，绝缘外壳 18 由塑料或陶

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瓷制成，用于连接散热器与灯头。驱动电路 19，其输入端经引线 20 与灯头 17 相连；其输出经引线 21 与发光二极管芯片相连，当外电源经灯头接通时，驱动器的输出即可点亮发光二极管芯片，使灯泡发光。

泡壳 14 内壁上也可不用光转换材料，泡壳为透明或乳白色。

芯片 1a、1b.....可为相同发光色或不同发光色的，以得到所需色的光输出。可用于制造照明灯泡或显示器。

图 7 所示的整灯的形状，可设计成其它几何形状，如球形、蘑菇形等。泡壳 14 也可以是开口的，其内壁上可有反射层 22，如图 8 所示。图 7 中所示为用图 6 所示结构的例子。图 7 中其他数字的意义与图 5 中相同。这时散热器 9 上和反射基板 12 上可有至少一个通孔 23，使空气经散热器流通，以增加散热效果。

图 6 和图 7 所示的装置也可用于制造显示单元，这时灯头 17 和外壳 18 可不用，直接把散热器 9 安装于显示系统基板上，散热器 9 也可以是显示系统基板本身。

本发明要求保护的范围不限于本文中介绍的各实施例，涉及的专门技术是本专业一般人员所熟悉的，因此只要了解本发明的内容，可以做各种形式的变换和代换。

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说 明 书 附 图

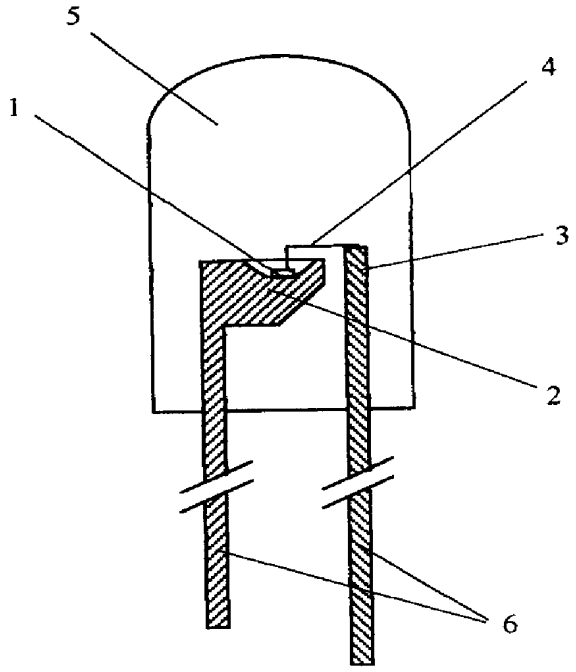


图 1

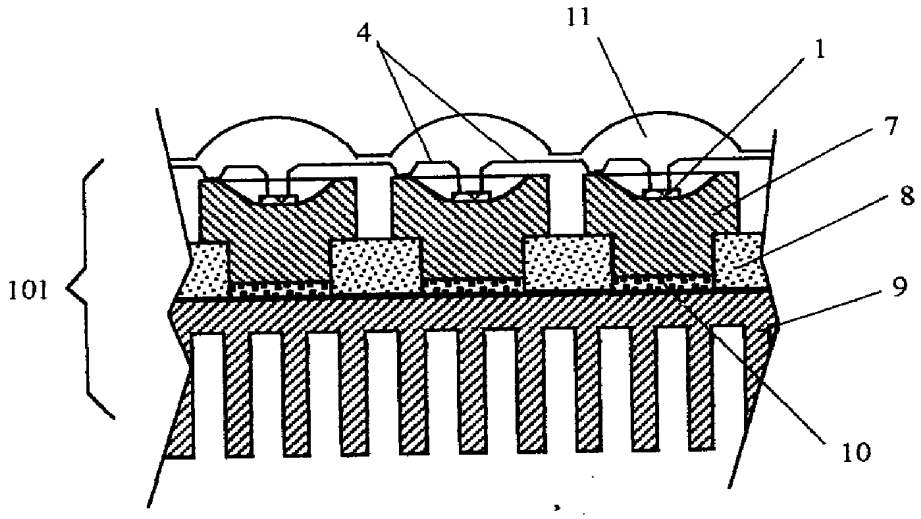


图 2

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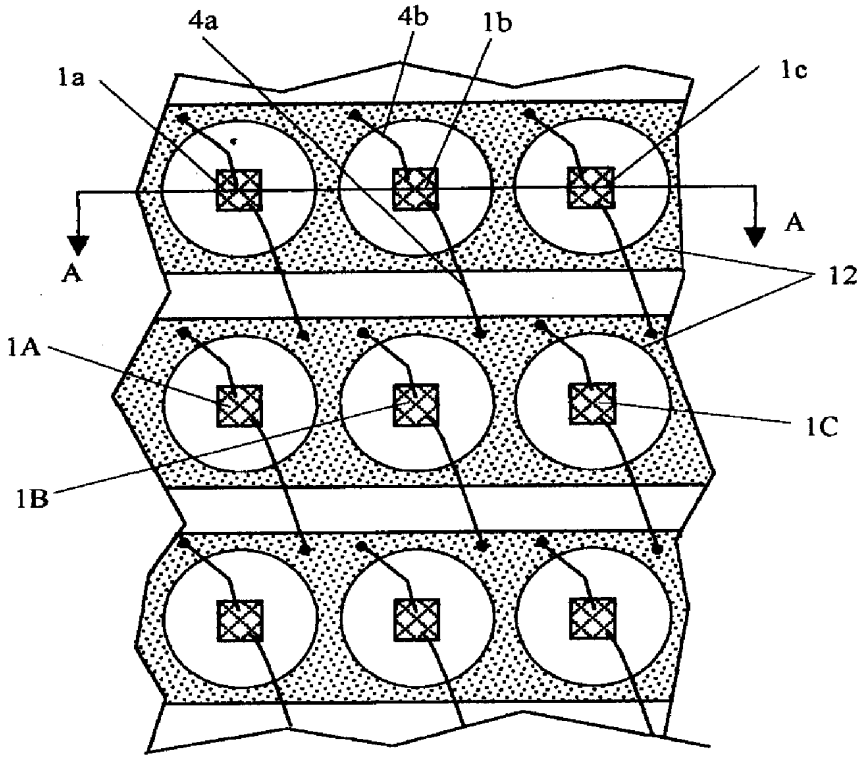


图 3

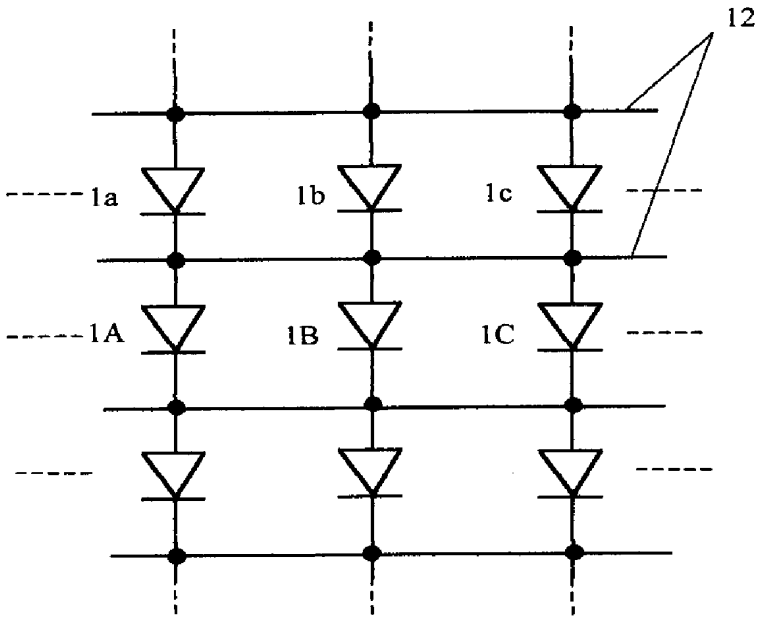


图 4

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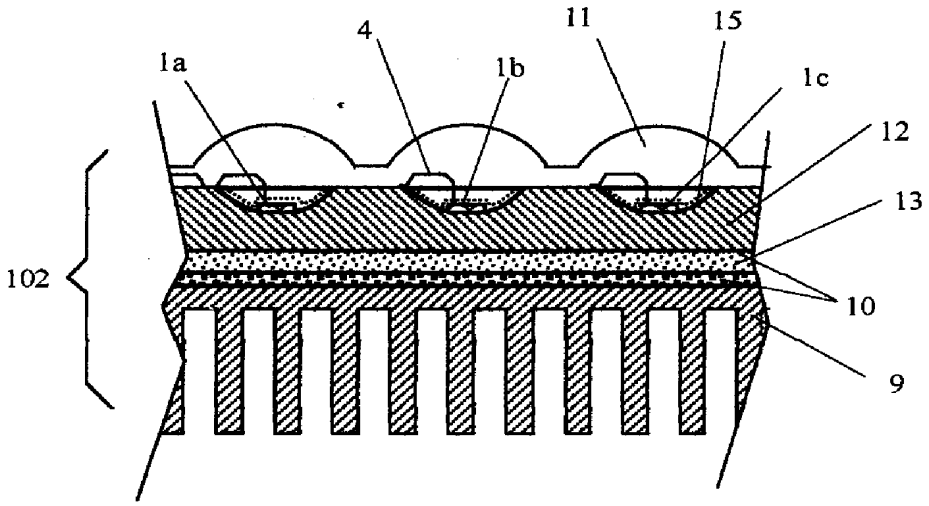


图 5

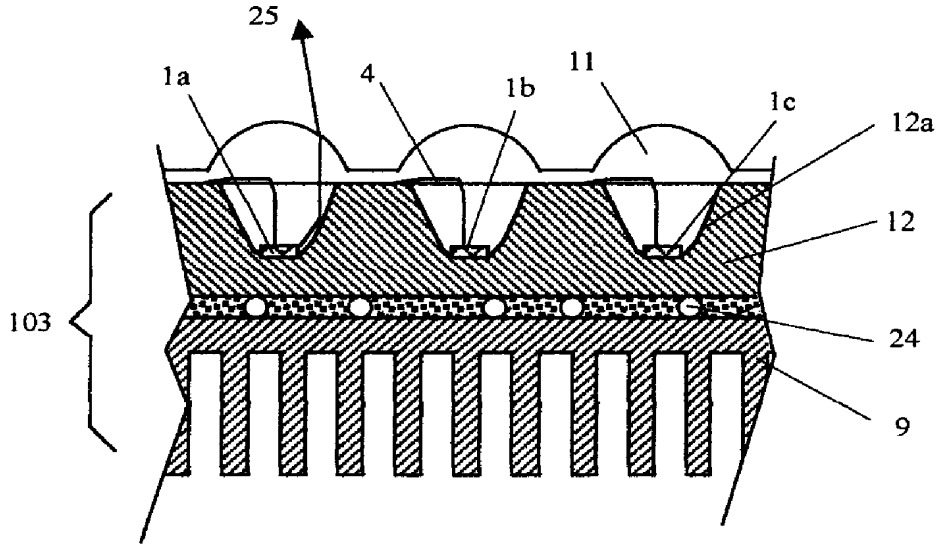


图 6

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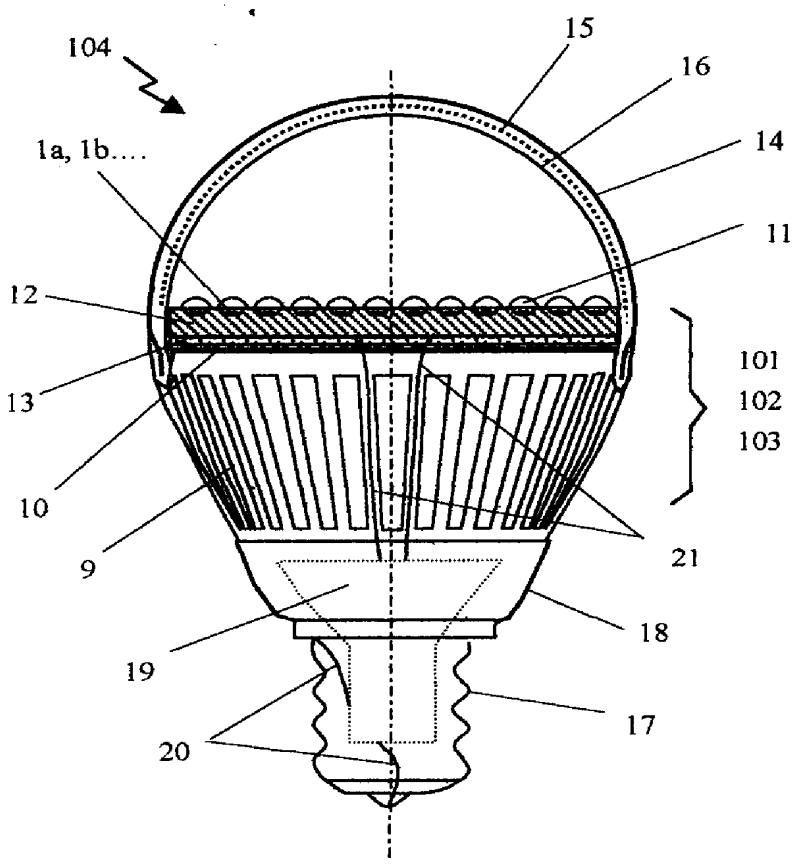


图 7

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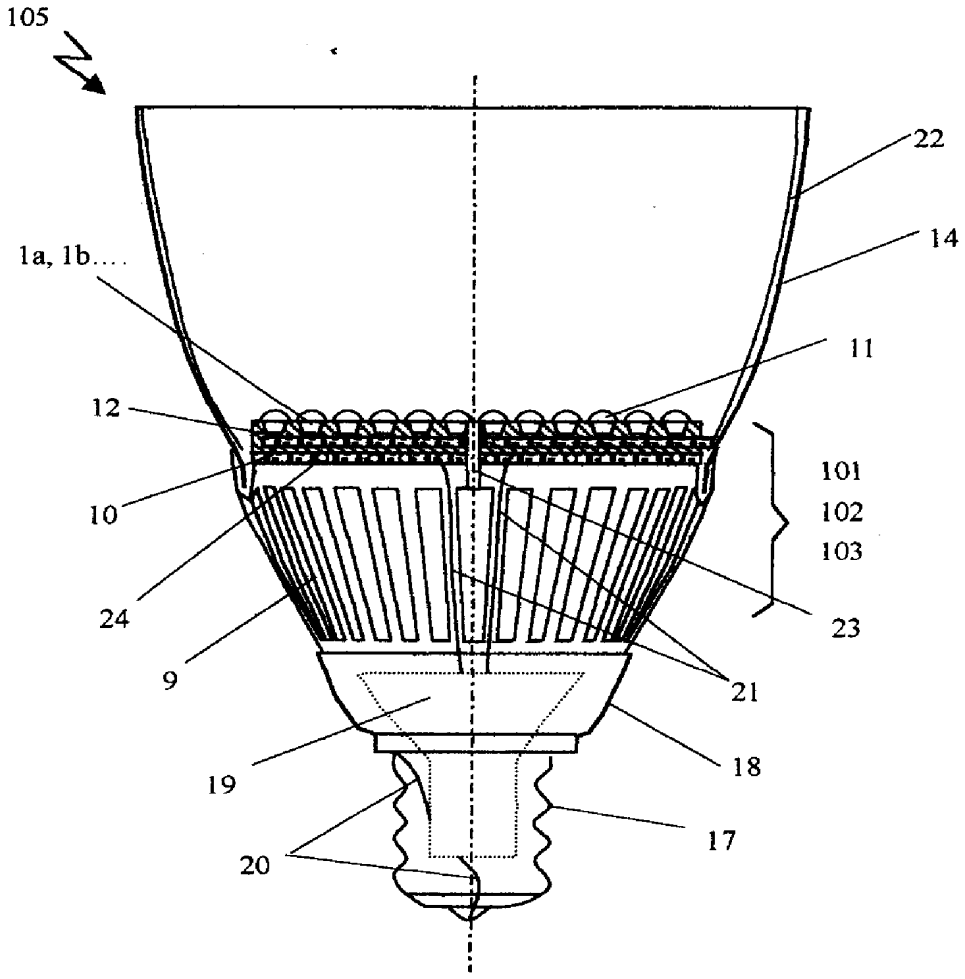


图 8

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(54) **LED DIMMING CONTROLLER**

LED DIMMERSTEUERUNG

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EP 1 502 483 B1

Description

Field of the Invention

[0001] The present invention is directed generally to methods and apparatus for providing power to devices on A.C. power circuits. More particularly, the invention relates to methods and apparatus for providing power to light emitting diode (LED) based devices, primarily for illumination purposes.

Background

[0002] In various lighting applications (e.g., home, commercial, industrial, etc.), there are instances in which it is desirable to adjust the amount of light generated by one or more conventional light sources (e.g., incandescent light bulbs, fluorescent light fixtures, etc.). In many cases, this is accomplished via a user-operated device, commonly referred to as a "dimmer," that adjusts the power delivered to the light source(s). Many types of conventional dimmers are known that allow a user to adjust the light output of one or more light sources via some type of user interface (e.g., by turning a knob, moving a slider, etc., often mounted on a wall in proximity to an area in which it is desirable to adjust the light level). The user interface of some dimmers also may be equipped with a switching/adjustment mechanism that allows one or more light sources to be switched off and on instantaneously, and also have their light output gradually varied when switched on.

[0003] Many lighting systems for general interior or exterior illumination often are powered by an A.C. source, commonly referred to as a "line voltage" (e.g., 120 Volts RMS at 60 Hz, 220 Volts RMS at 50 Hz). A conventional A.C. dimmer typically receives the A.C. line voltage as an input, and provides an A.C. signal output having one or more variable parameters that have the effect of adjusting the average voltage of the output signal (and hence the capability of the A.C. output signal to deliver power) in response to user operation of the dimmer. This dimmer output signal generally is applied, for example, to one or more light sources that are mounted in conventional sockets or fixtures coupled to the dimmer output (such sockets or fixtures sometimes are referred to as being on a "dimmer circuit").

[0004] Conventional A.C. dimmers may be configured to control power delivered to one or more light sources in one of a few different ways. For example, in one implementation, the adjustment of the user interface causes the dimmer to increase or decrease a voltage amplitude of the A.C. dimmer output signal. More commonly, however, in other implementations, the adjustment of the user interface causes the dimmer to adjust the duty cycle of the A.C. dimmer output signal (e.g., by "chopping-out" portions of A.C. voltage cycles). This technique sometimes is referred to as "angle modulation" (based on the adjustable phase angle of the output signal). Perhaps the most commonly used dimmers of this type employ a triac that is selectively operated to adjust the duty cycle (i.e., modulate the phase angle) of the dimmer output signal by chopping-off rising portions of A.C. voltage half-cycles (i.e., after zero-crossings and before peaks). Other types of dimmers that adjust duty cycles may employ gate turn-off (GTO) thyristors that are selectively operated to chop-off falling portions of A.C. voltage half-cycles (i.e., after peaks and before zero-crossings).

[0005] Fig. 1 generally illustrates some conventional A.C. dimmer implementations. In particular, Fig. 1 shows an example of an A.C. voltage waveform 302 (e.g., representing a standard line voltage) that may provide power to one or more conventional light sources. Fig. 1 also shows a generalized A.C. dimmer 304 responsive to a user interface 305. In the first implementation discussed above, the dimmer 304 is configured to output the waveform 308, in which the amplitude 307 of the dimmer output signal may be adjusted via the user interface 305. In the second implementation discussed above, the dimmer 304 is configured to output the waveform 309, in which the duty cycle 306 of the waveform 309 may be adjusted via the user interface 305.

[0006] As discussed above, both of the foregoing techniques have the effect of adjusting the average voltage applied to the light source(s), which in turn adjusts the intensity of light generated by the source(s). Incandescent sources are particularly well-suited for this type of operation, as they produce light when there is current flowing through a filament in either direction; as the average voltage of an A.C. signal applied to the source(s) is adjusted (e.g., either by an adjustment of voltage amplitude or duty cycle), the current (and hence the power) delivered to the light source also is changed and the corresponding light output changes. With respect to the duty cycle technique, the filament of an incandescent source has thermal inertia and does not stop emitting light completely during short periods of voltage interruption. Accordingly, the generated light as perceived by the human eye does not appear to flicker when the voltage is "chopped," but rather appears to gradually change.

[0007] US-6,127,783 discloses a white light emitting luminaire including a plurality of LEDs in each of the colors red, green, and blue have a separate current regulator which receives current outputs from an A.C. converter.

[0008] US-6,369,525 discloses a white LED array driver circuit with a multiple output flyback converter with output current mode control. The circuit comprises a power supply source, a transformer, and a controller arranged to control the flow of current to the primary winding of the transformer.

[0009] US-A-2002/0048169 discloses the general concept of converting A.C. power signals from a dimmer circuit into D.C. power for an LED. However, it does not disclose that higher frequency components present in a chopped signal from a dimmer circuit can cause fatal damage to LED light sources in certain circumstances.

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It is an aim of the present invention to address this problem.

Summary

[0010] There is provided according to the present invention an illumination apparatus, comprising: at least one LED; and at least one controller coupled to the at least one LED and configured to provide D.C. power to the at least one LED, wherein the controller is configured to receive from an A.C. power source an A.C. power-related signal having higher frequency components than a standard A.C. line voltage and to provide said D.C. power based on the A.C. power-related signal, characterized in that the at least one controller is configured to filter out the higher frequency components. According to a second aspect of the present invention there is provided an illumination method, comprising an act of: A) providing D.C. power to at least one LED based on a power-related signal provided by an A.C. power source having higher frequency components than a standard A.C. line voltage, characterized in that the higher frequency components are filtered out of the power-related signal prior to providing D.C. power to the at least one LED.

[0011] In one embodiment, methods and apparatus of the invention particularly facilitate the use of LED-based light sources on A.C. power circuits that are controlled by conventional dimmers (i.e. "A.C. dimmer circuits"). In one aspect, methods and apparatus of the present invention facilitate convenient substitution of LED-based light sources in lighting environments employing A.C. dimming devices and conventional light sources. In yet other aspects, methods and apparatus according to the present invention facilitate the control of one or more parameters relating to the light generated by LED-based light sources (e.g., intensity, color, color temperature, temporal characteristics, etc.) via operation of a conventional A.C. dimmer and/or other signals present on the A.C. power circuit.

[0012] More generally, one embodiment of the invention is directed to an illumination apparatus, comprising at least one LED and at least one controller coupled to the at least one LED. The controller is configured to receive a power-related signal from an A.C. power source that provides signals other than a standard A.C, line voltage. The controller further is configured to provide power to the at least one LED based on the power-related signal.

[0013] Another embodiment of the invention is directed to an illumination method, comprising an act of providing power to at least one LED based on a power-related signal from an A.C. power source that provides signals other than a standard A.C. line voltage.

[0014] Another embodiment of the invention is directed to an illumination apparatus, comprising at least one LED, and at least one controller coupled to the at least one LED and configured to receive a power-related signal from an alternating current (A.C.) dimmer circuit and provide power to the at least one LED based on the power-related signal.

[0015] Another embodiment of the invention is directed to an illumination method, comprising an act of providing power to at least one LED based on a power-related signal from an alternating current (A.C.) dimmer circuit.

[0016] Another embodiment of the invention is directed to an illumination apparatus, comprising at least one LED adapted to generate an essentially white light, and at least one controller coupled to the at least one LED and configured to receive a power-related signal from an alternating current (A.C.) dimmer circuit and provide power to the at least one LED based on the power-related signal. The A.C. dimmer circuit is controller by a user interface to vary the power-related signal. The controller is configured to variably control at least one parameter of the essentially white light in response to operation of the user interface so as to approximate light generation characteristics of an incandescent light source.

[0017] Another embodiment of the invention is directed to a lighting system, comprising at least one LED, a power connector, and a power converter associated with the power connector and adapted to convert A.C. dimmer circuit power received by the power connector to form a converted power. The system also includes an adjustment circuit associated with the power converter adapted to adjust power delivered to the at least one LED.

[0018] Another embodiment of the invention is directed to a method of providing illumination, comprising the steps of providing an AC dimmer circuit, connecting an LED lighting system to the AC dimmer circuit, generating light from the LED lighting system by energizing the AC dimmer circuit, and adjusting the light generated by the LED lighting system by adjusting the AC dimmer circuit.

[0019] Another embodiment of the invention is directed to method for controlling at least one device powered via an A.C. line voltage. The method comprises an act of generating a power signal based on the A.C. line voltage, wherein the power signal provides an essentially constant power to the at least one device and includes at least one communication channel carrying control information for the at least one device, the at least one communication channel occupying a portion of a duty cycle over a period of cycles of the A.C. line voltage.

[0020] Another embodiment of the invention is directed to an apparatus for controlling at least one device powered via an A.C. line voltage. The apparatus comprises a supply voltage controller configured to generate a power signal based on the A.C. line voltage, wherein the power signal provides an essentially constant power to the at least one device and includes at least one communication channel carrying control information for the at least one device, the at least one communication channel occupying a portion of a duty cycle over a period of cycles of the A.C. line voltage. In one aspect of this embodiment, the supply voltage controller includes at least one user interface to provide variable control information in the at least one communication channel.

[0021] As used herein for purposes of the present dis-

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closure, the term "LED" should be understood to include any electroluminescent diode or other type of carrier injection / junction-based system that is capable of generating radiation in response to an electric signal. Thus, the term LED includes, but is not limited to, various semiconductor-based structures that emit light in response to current, light emitting polymers, electroluminescent strips, and the like.

[0022] In particular, the term LED refers to light emitting diodes of all types (including semi-conductor and organic light emitting diodes) that may be configured to generate radiation in one or more of the infrared spectrum, ultraviolet spectrum, and various portions of the visible spectrum (generally including radiation wavelengths from approximately 400 nanometers to approximately 700 nanometers). Some examples of LEDs include, but are not limited to, various types of infrared LEDs, ultraviolet LEDs, red LEDs, blue LEDs, green LEDs, yellow LEDs, amber LEDs, orange LEDs, and white LEDs (discussed further below). It also should be appreciated that LEDs may be configured to generate radiation having various bandwidths for a given spectrum (e.g., narrow bandwidth, broad bandwidth).

[0023] For example, one implementation of an LED configured to generate essentially white light (e.g., a white LED) may include a number of dies which respectively emit different spectra of electroluminescence that, in combination, mix to form essentially white light. In another implementation, a white light LED may be associated with a phosphor material that converts electroluminescence having a first spectrum to a different second spectrum. In one example of this implementation, electroluminescence having a relatively short wavelength and narrow bandwidth spectrum "pumps" the phosphor material, which in turn radiates longer wavelength radiation having a somewhat broader spectrum.

[0024] It should also be understood that the term LED does not limit the physical and/or electrical package type of an LED. For example, as discussed above, an LED may refer to a single light emitting device having multiple dies that are configured to respectively emit different spectra of radiation (e.g., that may or may not be individually controllable). Also, an LED may be associated with a phosphor that is considered as an integral part of the LED (e.g., some types of white LEDs). In general, the term LED may refer to packaged LEDs, non-packaged LEDs, surface mount LEDs, chip-on-board LEDs, T-package mount LEDs, radial package LEDs, power package LEDs, LEDs including some type of encasement and/or optical element (e.g., a diffusing lens), etc.

[0025] The term "light source" should be understood to refer to any one or more of a variety of radiation sources, including, but not limited to, LED-based sources (employing one or more LEDs as defined above), incandescent sources (e.g., filament lamps, halogen lamps), fluorescent sources, phosphorescent sources, high-intensity discharge sources (e.g., sodium vapor, mercury vapor, and metal halide lamps), lasers, other types of electroluminescent sources, pyro-luminescent sources (e.g., flames), candle-luminescent sources (e.g., gas mantles, carbon arc radiation sources), photo-luminescent sources (e.g., gaseous discharge sources), cathode luminescent sources using electronic satiation, galvano-luminescent sources, crystallo-luminescent sources, kine-luminescent sources, thermo-luminescent sources, triboluminescent sources , sonoluminescent sources, radioluminescent sources, and luminescent polymers.

[0026] A given light source may be configured to generate electromagnetic radiation within the visible spectrum, outside the visible spectrum, or a combination of both. Hence, the terms "light" and "radiation" are used interchangeably herein. Additionally, a light source may include as an integral component one or more filters (e.g., color filters), lenses, or other optical components. Also, it should be understood that light sources may be configured for a variety of applications, including, but not limited to, indication and/or illumination. An "illumination source" is a light source that is particularly configured to generate radiation having a sufficient intensity to effectively illuminate an interior or exterior space.

[0027] The term "spectrum" should be understood to refer to any one or more frequencies (or wavelengths) of radiation produced by one or more light sources. Accordingly, the term "spectrum" refers to frequencies (or wavelengths) not only in the visible range, but also frequencies (or wavelengths) in the infrared, ultraviolet, and other areas of the overall electromagnetic spectrum. Also, a given spectrum may have a relatively narrow bandwidth (essentially few frequency or wavelength components) or a relatively wide bandwidth (several frequency or wavelength components having various relative strengths). It should also be appreciated that a given spectrum may be the result of a mixing of two or more other spectra (e.g., mixing radiation respectively emitted from multiple light sources).

[0028] For purposes of this disclosure, the term "color" is used interchangeably with the term "spectrum." However, the term "color" generally is used to refer primarily to a property of radiation that is perceivable by an observer (although this usage is not intended to limit the scope of this term). Accordingly, the terms "different colors" implicitly refer to multiple spectra having different wavelength components and/or bandwidths. It also should be appreciated that the term "color" may be used in connection with both white and non-white light.

[0029] The term "color temperature" generally is used herein in connection with white light, although this usage is not intended to limit the scope of this term. Color temperature essentially refers to a particular color content or shade (e.g., reddish, bluish) of white light. The color temperature of a given radiation sample conventionally is characterized according to the temperature in degrees Kelvin (K) of a black body radiator that radiates essentially the same spectrum as the radiation sample in question. The color temperature of white light generally falls within a range of from approximately 700 degrees K (gen-

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erally considered the first visible to the human eye) to over 10,000 degrees K.

[0030] Lower color temperatures generally indicate white light having a more significant red component or a "warmer feel," while higher color temperatures generally indicate white light having a more significant blue component or a "cooler feel." By way of example, fire has a color temperature of approximately 1,800 degrees K, a conventional incandescent bulb has a color temperature of approximately 2848 degrees K, early morning daylight has a color temperature of approximately 3,000 degrees K, and overcast midday skies have a color temperature of approximately 10,000 degrees K. A color image viewed under white light having a color temperature of approximately 3,000 degree K has a relatively reddish tone, whereas the same color image viewed under white light having a color temperature of approximately 10,000 degrees K has a relatively bluish tone.

[0031] The terms "lighting unit" and "lighting fixture" are used interchangeably herein to refer to an apparatus including one or more light sources of same or different types. A given lighting unit may have any one of a variety of mounting arrangements for the light source(s), enclosure/housing arrangements and shapes, and/or electrical and mechanical connection configurations. Additionally, a given lighting unit optionally may be associated with (e.g., include, be coupled to and/or packaged together with) various other components (e.g., control circuitry) relating to the operation of the light source(s). An "LED-based lighting unit" refers to a lighting unit that includes one or more LED-based light sources as discussed above, alone or in combination with other non LED-based light sources.

[0032] The terms "processor" or "controller" are used herein interchangeably to describe various apparatus relating to the operation of one or more light sources. A processor or controller can be implemented in numerous ways, such as with dedicated hardware, using one or more microprocessors that are programmed using software (e.g., microcode) to perform the various functions discussed herein, or as a combination of dedicated hardware to perform some functions and programmed microprocessors and associated circuitry to perform other functions.

[0033] In various implementations, a processor or controller may be associated with one or more storage media (generically referred to herein as "memory," e.g., volatile and non-volatile computer memory such as RAM, PROM, EPROM, and EEPROM, floppy disks, compact disks, optical disks, magnetic tape, etc.). In some implementations, the storage media may be encoded with one or more programs that, when executed on one or more processors and/or controllers, perform at least some of the functions discussed herein. Various storage media may be fixed within a processor or controller or may be transportable, such that the one or more programs stored thereon can be loaded into a processor or controller so as to implement various aspects of the present invention discussed herein. The terms "program" or "computer program" are used herein in a generic sense to refer to any type of computer code (e.g., software or microcode) that can be employed to program one or more processors or controllers.

[0034] The term "addressable" is used herein to refer to a device (e.g., a light source in general, a lighting unit or fixture, a controller or processor associated with one or more light sources or lighting units, other non-lighting related devices, etc.) that is configured to receive information (e.g., data) intended for multiple devices, including itself, and to selectively respond to particular information intended for it. The term "addressable" often is used in connection with a networked environment (or a "network," discussed further below), in which multiple devices are coupled together via some communications medium or media.

[0035] In one network implementation, one or more devices coupled to a network may serve as a controller for one or more other devices coupled to the network (e.g., in a master / slave relationship). In another implementation, a networked environment may include one or more dedicated controllers that are configured to control one or more of the devices coupled to the network. Generally, multiple devices coupled to the network each may have access to data that is present on the communications medium or media; however, a given device may be "addressable" in that it is configured to selectively exchange data with (i.e., receive data from and/or transmit data to) the network, based, for example, on one or more particular identifiers (e.g., "addresses") assigned to it.

[0036] The term "network" as used herein refers to any interconnection of two or more devices (including controllers or processors) that facilitates the transport of information (e.g. for device control, data storage, data exchange, etc.) between any two or more devices and/or among multiple devices coupled to the network. As should be readily appreciated, various implementations of networks suitable for interconnecting multiple devices may include any of a variety of network topologies and employ any of a variety of communication protocols. Additionally, in various networks according to the present invention, any one connection between two devices may represent a dedicated connection between the two systems, or alternatively a non-dedicated connection. In addition to carrying information intended for the two devices, such a non-dedicated connection may carry information not necessarily intended for either of the two devices (e.g., an open network connection). Furthermore, it should be readily appreciated that various networks of devices as discussed herein may employ one or more wireless, wire/cable, and/or fiber optic links to facilitate information transport throughout the network.

[0037] The term "user interface" as used herein refers to an interface between a human user or operator and one or more devices that enables communication between the user and the device(s). Examples of user interfaces that may be employed in various implementa-

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tions of the present invention include, but are not limited to, switches, potentiometers, buttons, dials, sliders, a mouse, keyboard, keypad, various types of game controllers (e.g., joysticks), track balls, display screens, various types of graphical user interfaces (GUIs), touch screens, microphones and other types of sensors that may receive some form of human-generated stimulus and generate a signal in response thereto.

[0038] It should be appreciated the all combinations of the foregoing concepts and additional concepts discussed in greater detail below are contemplated as being part of the inventive subject matter disclosed herein. In particular, all combinations of claimed subject matter appearing at the end of this disclosure are contemplated as being part of the inventive subject matter.

Brief Description of the Figures

[0039] The following figures depict certain illustrative embodiments of the invention in which like reference numerals refer to like elements. These depicted embodiments are to be understood as illustrative of the invention and not as limiting in any way.

Fig. 1 illustrates exemplary operation of conventional A.C. dimming devices;

Fig. 2 illustrates a conventional implementation for providing power to an LED-based light source from an A.C. line voltage;

Fig. 3 illustrates a lighting unit including an LED-based light source according to one embodiment of the invention;

Fig. 4 is a circuit diagram illustrating various components of the lighting unit of Fig. 3, according to one embodiment of the invention;

Fig. 5 illustrates a lighting unit including an LED-based light source according to another embodiment of the invention;

Fig. 6 is a circuit diagram illustrating various components of the lighting unit of Fig. 5, according to one embodiment of the invention;

Fig. 7 is a block diagram of a processor-based lighting unit including an LED-based light source according to another embodiment of the invention;

Fig. 8 is a circuit diagram illustrating various components of the power circuitry for the lighting unit of Fig. 7;

Fig. 9 is a circuit diagram illustrating a conventional current sink employed in driving circuitry for an LED-based light source, according to one embodiment of the invention;

Fig. 10 is a circuit diagram illustrating an improved current sink, according to one embodiment of the invention; and

Fig. 11 is a circuit diagram illustrating an improved current sink, according to another embodiment of the invention.

Detailed Description

1. *Overview*

[0040] Light Emitting Diode (LED) based illumination sources are becoming more popular in applications where general, task, accent, or other lighting is desired. LED efficiencies, high intensities, low cost, and high level of controllability are driving demand for LED-based light sources as replacements for conventional non LED-based light sources.

[0041] While conventional A.C. dimming devices as discussed above often are employed to control conventional light sources such as incandescent lights using an A.C. power source, Applicants have recognized and appreciated that generally such dimmers are not acceptable for use with solid-state light sources such as LED-based light sources. Stated differently, Applicants have identified that LED-based light sources, which operate based on substantially D.C. power sources, generally are incompatible with dimmer circuits that provide A.C. output signals. This situation impedes convenient substitution of LED-based light sources into pre-existing lighting systems in which conventional light sources are operated via A.C. dimmer circuits.

[0042] There are some solutions currently for providing power to LED-based lighting systems via an A.C. line voltage, but these solutions suffer from significant drawbacks if applied to A.C. dimmer circuits. Fig. 2 illustrates one such generalized scenario, in which a standard A.C. line voltage 302 (e.g., 120 Vrms, 220 Vrms, etc.) is used to power an LED-based lighting system, such as a traffic light 808 (the traffic light includes three modules of LED arrays, one red, one yellow and one green, with associated circuitry). In the arrangement of Fig. 2, a full-wave rectifier 802, together with capacitors 800 and 806 and resistor 804, filter the applied A.C. line voltage so as to supply a substantially D.C. source of power for the traffic light 808. In particular, the capacitor 800 may be specifically selected, depending on the impedance of other circuit components, such that energy is passed to the traffic light based primarily on the expected frequency of the A.C. line voltage (e.g., 60 Hz).

[0043] One problem with the arrangement shown in Fig. 2 if the applied A.C. signal is provided by a dimmer circuit rather than as a line voltage is that the applied signal may include frequency components that are significantly different from the frequency of the line voltage for which the circuit was designed. For example, consider a dimmer circuit that provides a duty cycle-controlled (i.e., angle modulated) A.C. signal 309 such as that shown in Fig. 1; by virtue of the abrupt signal excursions due to the "chopping-off' of portions of voltage cycles, signals of this type include significantly higher frequency components than a typical line voltage. Were such an angle modulated A.C. signal to be applied to the arrangement of Fig. 2, the capacitor 800 would allow excess energy associated with these higher frequency components to

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pass through to the traffic light, in most cases causing fatal damage to the light sources.

[0044] In view of the foregoing, one embodiment of the present invention is directed generally to methods and apparatus for facilitating the use of LED-based light sources on A.C. power circuits that provide either a standard line voltage or that are controlled by conventional dimmers (i.e, "A.C. dimmer circuits"). In one aspect, methods and apparatus of the present invention facilitate convenient substitution of LED-based light sources in lighting environments employing conventional dimming devices and conventional light sources. In yet other aspects, methods and apparatus according to the present invention facilitate the control of one or more parameters relating to the light generated by LED-based light sources (e.g., intensity, color, color temperature, temporal characteristics, etc.) via operation of a conventional dimmer and/or other control signals that may be present in connection with an A.C. line voltage.

[0045] Lighting units and systems employing various concepts according to the principles of the present invention may be used in a residential setting, commercial setting, industrial setting or any other setting where conventional A.C. dimmers are found or are desirable. Furthermore, the various concepts disclosed herein may be applied in lighting units according to the present invention to ensure compatibility of the lighting units with a variety of lighting control protocols that provide various control signals via an A.C. power circuit.

[0046] One example of such a control protocol is given by the X10 communications language, which allows X10-compatible products to communicate with each other via existing electrical wiring in a home (i.e., wiring that supplies a standard A.C. line voltage). In a typical X10 implementation, an appliance to be controlled (e.g., lights, thermostats, jacuzzi/hot tub, etc.) is plugged into an X10 receiver, which in turn plugs into a conventional wall socket coupled to the A.C. line voltage. The appliance to be controlled can be assigned with a particular address. An X10 transmitter/controller is plugged into another wall socket coupled to the line voltage, and communicates control commands (e.g., on, off, dim, bright, etc.), via the same wiring providing the line voltage, to one or more X10 receivers based at least in part on the assigned address(es) (further information regarding X10 implementations may be found at the website "www.smarthome.com"). According to one embodiment, methods and apparatus of the present invention facilitate compatibility of various LED-based light sources and lighting units with X10 and other communication protocols that communicate control information in connection with an A.C. line voltage.

[0047] In general, methods and apparatus according to the present invention allow a substantially complete retrofitting of a lighting environment with solid state LED-based light sources; in particular, pursuant to the present invention, the use of LED-based light sources as substitutes for incandescent light sources is not limited to only those A.C. power circuits that are supplied directly from a line voltage (e.g., via a switch); rather, methods and apparatus of the present invention allow LED-based light sources to be used in most any conventional (e.g., incandescent) socket, including those coupled to an A.C. dimmer circuit and/or receiving signals other than a standard line voltage.

[0048] In various embodiments, an LED-based lighting unit or fixture according to the invention may include a controller to appropriately condition an A.C. signal provided by a dimmer circuit so as to provide power to (i.e., "drive") one or more LEDs of the lighting unit. The controller may drive the LED(s) using any of a variety of techniques, including analog control techniques, pulse width modulation (PWM) techniques or other power regulation techniques. Although not an essential feature of the present invention, in some embodiments the circuitry of the LED-based lighting unit may include one or more microprocessors that are programmed to carry out various signal conditioning and/or light control functions. In various implementations of both processor and non-processor based embodiments, an LED-based lighting unit according to the invention may be configured for operation on an A.C. dimmer circuit with or without provisions for allowing one or more parameters of generated light to be adjusted via user operation of the dimmer.

[0049] More specifically, in one embodiment, an LED-based lighting unit may include a controller wherein at least a portion of the power delivered to the controller, as derived from an A.C. dimmer circuit, is regulated at a substantially constant value over a significant range of dimmer operation so as to provide an essentially stable power source for the controller and other circuitry associated with the lighting unit. In one aspect of this embodiment, the controller also may be configured to monitor the adjustable power provided by the dimmer circuit so as to permit adjustment of one or more parameters of the light generated by the lighting unit in response to operation of the dimmer.

[0050] In particular, there are several parameters of light generated by an LED-based light source (other than, or in addition to, intensity or brightness, for example) that may be controlled in response to dimmer operation according to the present invention. For example, in various embodiments, an LED-based lighting unit may be configured such that one or more properties of the generated light such as color (e.g., hue, saturation or brightness), or the correlated color temperature of white light, as well as temporal parameters (e.g., rate of color variation or strobing of one or more colors) are adjustable via dimmer operation.

[0051] As discussed above, in one embodiment, an LED-based lighting unit may include one or more processor-based controllers, including one or more memory storage devices, to facilitate the foregoing and other examples of adjustable light generation via dimmer operation. In particular, in one embodiment, such a lighting unit may be configured to selectively execute, via dimmer op-

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eration, one or more lighting programs stored in controller memory. Such lighting programs may represent various static or time-varying lighting effects involving multiple colors, color temperatures, and intensities of generated light, for example. In one aspect of this embodiment, the processor-based controller of the lighting unit may be configured to monitor the A.C. signal provided by the dimmer circuit so as to select different programs and/or program parameters based on one or more changes in the monitored dimmer signal having a particular characteristic (e.g., a particular instantaneous value relating to the dimmer signal, a particular time averaged value relating to the dimmer signal, an interruption of power provided by the dimmer for a predetermined duration, a particular rate of change of the dimmer signal, etc). Upon the selection of a new program or parameter, further operation of the dimmer may adjust the selected parameter or program.

[0052] In another exemplary embodiment, an LED-based lighting unit according to the present invention may be configured to be coupled to an A.C. dimmer circuit and essentially recreate the lighting characteristics of a conventional incandescent light as a dimmer is operated to increase or decrease the intensity of the generated light. In one aspect of this embodiment, this simulation may be accomplished by simultaneously varying the intensity and the color of the light generated by the LED-based source in response to dimmer operation, so as to approximate the variable lighting characteristics of an incandescent source whose intensity is varied. In another aspect of this embodiment, such a simulation is facilitated by a processor-based controller particularly programmed to monitor an A.C. signal provided by the dimmer circuit and respectively control differently colored LEDs of the lighting unit in response to dimmer operation so as to simultaneously vary both the overall color and intensity of the light generated by the lighting unit.

[0053] While many of the lighting effects discussed herein are associated with dimmer compatible control, several effects may be generated according to the present invention using other control systems as well. For example, the color temperature of an LED-based light source may be programmed to reduce as the intensity is reduced and these lighting changes may be controlled by a system other than a dimmer system (e.g. wireless communication, wired communication and the like) according to various embodiments of the invention.

[0054] Another embodiment of the present invention is directed to a method for selling, marketing, and advertising of LED-based light sources and lighting systems. The method may include advertising an LED lighting system compatible with conventional A.C. dimmers or dimming systems. The method may also include advertising an LED light that is compatible with both dimmable and non-dimmable lighting control systems.

[0055] Following below are more detailed descriptions of various concepts related to, and embodiments of, methods and apparatus for providing power to LED-based lighting according to the present invention. It should be appreciated that various aspects of the invention, as discussed above and outlined further below, may be implemented in any of numerous ways, as the invention is not limited to any particular manner of implementation. Examples of specific implementations are provided for illustrative purposes only.

2. *Non-processor based Exemplary Embodiments*

[0056] As discussed above, according to various embodiments, LED-based light sources capable of operation via A.C. dimmer circuits may be implemented with or without microprocessor-based circuitry. In this section, some examples are given of lighting units that include circuitry configured to appropriately condition A.C. signals provided by a dimmer circuit without the aid of a microprocessor or microcontroller. In the sections that follow, a number of processor-based examples are discussed.

[0057] Fig. 3 illustrates an LED-based lighting unit 200 according to one embodiment of the present invention. For purposes of illustration, the lighting unit 200 is depicted generally to resemble a conventional incandescent light bulb having a screw-type base connector 202 to engage mechanically and electrically with a conventional light socket. It should be appreciated, however, that the invention is not limited in this respect, as a number of other configurations including other housing shapes and/or connector types are possible according to other embodiments. Various examples of power connector configurations include, but are not limited to, screw-type connectors, wedge-type connectors, multi-pin type connectors, and the like, to facilitate engagement with conventional incandescent, halogen, fluorescent or high intensity discharge (HID) type sockets. Such sockets, in turn, may be connected directly to a source of A.C. power (e.g., line voltage), or via a switch and/or dimmer to the source of A.C. power.

[0058] The lighting unit 200 of Fig. 3 includes an LED-based light source 104 having one or more LEDs. The lighting unit also includes a controller 204 that is configured to receive an A.C. signal 500 via the connector 202 and provide operating power to the LED-based light source 104. According to one aspect of this embodiment, the controller 204 includes various components to ensure proper operation of the lighting unit for A.C. signals 500 that are provided by a dimmer circuit and, more specifically, by a dimmer circuit that outputs duty cycle-controlled (i.e., angle modulated) A.C. signals as discussed above.

[0059] To this end, according to the embodiment of Fig. 3, the controller 204 includes a rectifier 404, a low pass (i.e., high frequency) filter 408 and a DC converter 402. In one aspect of this embodiment, the output of the DC converter 402 provides an essentially stable DC voltage as a power supply for the LED-based light source 104, regardless of user adjustments of the dimmer that

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provides the A.C. signal 500. More specifically, in this embodiment, the various components of the controller 204 facilitate operation of the lighting unit 200 on a dimmer circuit without providing for adjustment of the generated light based on dimmer operation; rather, the primary function of the controller 204 in the embodiment of Fig. 3 is to ensure that no damage is done to the LED-based light source based on deriving power from an A.C. dimmer circuit.

[0060] In particular, according to one aspect of this embodiment, an essentially constant DC power is provided to the LED-based light source as long as the dimmer circuit outputs an A.C. signal 500 that provides sufficient power to operate the controller 204. In one implementation, the dimmer circuit may output an A.C. signal 500 having a duty cycle of as low as 50% "on" (i.e., conducting) that provides sufficient power to cause light to be generated by the LED-based light source 104. In yet another implementation, the dimmer circuit may provide an A.C. signal 500 having a duty cycle of as low as 25% or less "on" that provides sufficient power to the light source 104. In this manner, user adjustment of the dimmer over a significantly wide range does not substantially affect the light output of the lighting unit 200. Again, the foregoing examples are provided primarily for purposes of illustration, as the invention is not necessarily limited in these respects.

[0061] Fig. 4 is an exemplary circuit diagram that illustrates some of the details of the various components shown in Fig. 3, according to one embodiment of the invention. Again, one of the primary functions of the circuitry depicted in Fig. 4 is to ensure safe operation of the LED-based light source 104 based on an A.C. signal 500 provided to the lighting unit 200 via a conventional A.C. dimmer circuit. As shown in Fig. 4, the rectifier 404 may be realized by a diode bridge (D47, D48, D49 and D50), while the low pass filter is realized from the various passive components (capacitors C2 and C3, inductor L2, and resistors R4 and R6) shown in the figure. In this embodiment, the DC converter 402 is realized in part using the integrated circuit model number TNY264/266 manufactured by Power Integrations, Inc., 5245 Hellyer Avenue, San Jose, California 95138 (www.powerint.com), and is configured to provide a 16 VDC supply voltage to power the LED-based light source 104.

[0062] It should be appreciated that filter parameters (e.g., of the low pass filter shown in Fig. 4) are significantly important to ensure proper operation of the controller 204. In particular, the cutoff frequencies of the filter must be substantially less than a switching frequency of the DC converter, but substantially greater than the typical several cycle cutoff frequency employed in ordinary switch-mode power supplies. According to one implementation, the total input capacitance of the controller circuit is such that little energy remains in the capacitors at the conclusion of each half cycle of the AC waveform. The inductance similarly should be chosen to provide adequate isolation of the high frequency components created by the DC converter to meet regulatory requirements (under certain conditions this value may be zero). In yet other implementations, it may be advantageous to place all or part of the filter components ahead of the bridge rectifier 404.

[0063] The light source 104 of Fig. 4 may include one or more LEDs (as shown for example as the LEDs D52 and D53 in Fig. 4) having any of a variety of colors, and multiple LEDs may be configured in a variety of serial or parallel arrangements. Additionally, based on the particular configuration of the LED source 104, one or more resistors or other components may be used in serial and/or parallel arrangements with the LED source 104 to appropriately couple the source to the DC supply voltage.

[0064] According to another embodiment of the invention, an LED-based light source not only may be safely powered by an A.C. dimmer circuit, but additionally the intensity of light generated by the light source may be adjusted via user operation of a dimmer that controls the A.C. signal provided by the dimmer circuit. Fig. 5 shows another example of a lighting unit 200A, similar to the lighting unit shown in Fig. 3, that is suitable for operation via a dimmer circuit. Unlike the lighting unit shown in Fig. 3, however, the lighting unit 200A of Fig. 5 is configured to have an adjustable light output that may be controlled via a dimmer. To this end, the controller 204A shown in Fig. 5 includes an additional adjustment circuit 208 that further conditions a signal output from the DC converter 402. The adjustment circuit 208 in turn provides a variable drive signal to the LED-based light source 104, based on variations in the A.C. signal 500 (e.g., variations in the average voltage of the signal) in response to user operation of the dimmer.

[0065] Fig. 6 is an exemplary circuit diagram that illustrates some of the details of the various components shown in Fig. 5, according to one embodiment of the invention. Many of the circuit elements shown in Fig. 6 are similar or identical to those shown in Fig. 4. The additional adjustment circuit 208 is implemented in Fig. 6 in part by the resistors R2 and R6 which form a voltage divider in the feedback loop of the integrated circuit U1. A control voltage 410 is derived at the junction of the resistors R2 and R6, which control voltage varies in response to variations in the A.C. signal 500 due to dimmer operation. The control voltage 410 is applied via diode D5 to a voltage-to-current converter implemented by resistor R1 and transistor Q1, which provide a variable drive current to the LED-based light source 104 that tracks adjustments of the dimmer's user interface. In this manner, the intensity of the light generated by the light source 104 may be varied via the dimmer over a significant range of dimmer operation. Of course, it should be appreciated that if the dimmer is adjusted such that the A.C. signal 500 is no longer capable of providing adequate power to the associated circuitry, the light source 104 merely ceases to produce light.

[0066] It should be appreciated that in the circuit of Fig.

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6, the control voltage 410 is essentially a filtered, scaled, maximum limited version of average DC voltage fed to the DC converter. This circuit relies on the DC converter to substantially discharge the input capacitors each half cycle. In practice this is easily achieved because input current to the controller stays fairly constant or increases as the duty cycle of the signal 500 is reduced, so long as device output does not decrease faster than the control voltage.

3. *Processor-based Exemplary Embodiments*

[0067] According to other embodiments of the invention, an LED-based lighting unit suitable for operation via an A.C. dimmer circuit may be implemented using a processor-based controller. Below, an embodiment of an LED-based lighting unit including a processor is presented, including a discussion of how such a lighting unit may be particularly configured for operation via an A.C. dimmer circuit. For example, in addition to a microprocessor, such a processor-based lighting unit also may include, and/or receive signal(s) from, one or more other components associated with the microprocessor to facilitate the control of the generated light based at least in part on user adjustment of a conventional A.C. dimmer. Once a processor-based control scheme is implemented in a lighting unit according to the present invention, a virtually limitless number of configurations are possible for controlling the generated light.

[0068] Fig. 7 shows a portion of an LED-based lighting unit 200B that includes a processor-based controller 204B according to one embodiment of the invention. Various examples of processor controlled LED-based lighting units similar to that described below in connection with Fig. 7 may be found, for example, in U.S. Patent No. 6,016,038, issued January 18, 2000 to Mueller et al., entitled "Multicolored LED Lighting Method and Apparatus," and U.S. Patent No. 6,211,626, issued April 3, 2001 to Lys et al, entitled "Illumination Components," which patents are both hereby incorporated herein by reference.

[0069] In one aspect, while not shown explicitly in Fig. 7, the lighting unit 200B may include a housing structure that is configured similarly to the other lighting units shown in Figs. 3 and 5 (i.e., as a replacement for an incandescent bulb having a conventional screw-type connector). Again, however, it should be appreciated that the invention is not limited in this respect; more generally, the lighting unit 200B may be implemented using any one of a variety of mounting arrangements for the light source (s), enclosure/housing arrangements and shapes to partially or fully enclose the light sources, and/or electrical and mechanical connection configurations.

[0070] As shown in Fig. 7, the lighting unit 200B includes one or more light sources 104A, 104B, and 104C (shown collectively as 104), wherein one or more of the light sources may be an LED-based light source that includes one or more light emitting diodes (LEDs). In one aspect of this embodiment, any two or more of the light sources 104A, 104B, and 104C may be adapted to generate radiation of different colors (e.g. red, green, and blue, respectively). Although Fig. 7 shows three light sources 104A, 104B, and 104C, it should be appreciated that the lighting unit is not limited in this respect, as different numbers and various types of light sources (all LED-based light sources, LED-based and non-LED-based light sources in combination, etc.) adapted to generate radiation of a variety of different colors, including essentially white light, may be employed in the lighting unit 200B, as discussed further below.

[0071] As shown in Fig. 7, the lighting unit 200B also may include a processor 102 that is configured to control drive circuitry 109 to drive the light sources 104A, 104B, and 104C so as to generate various intensities of light from the light sources. For example, in one implementation, the processor 102 may be configured to output via the drive circuitry 109 at least one control signal for each light source so as to independently control the intensity of light generated by each light source. Some examples of control signals that may be generated by the processor and drive circuitry to control the light sources include, but are not limited to, pulse modulated signals, pulse width modulated signals (PWM), pulse amplitude modulated signals (PAM), pulse code modulated signals (PCM) analog control signals (e.g., current control signals, voltage control signals), combinations and/or modulations of the foregoing signals, or other control signals.

[0072] In one implementation of the lighting unit 200B, one or more of the light sources 104A, 104B, and 104C shown in Fig. 7 may include a group of multiple LEDs or other types of light sources (e.g., various parallel and/or serial connections of LEDs or other types of light sources) that are controlled together by the processor 102. Additionally, it should be appreciated that one or more of the light sources 104A, 104B, and 104C may include one or more LEDs that are adapted to generate radiation having any of a variety of spectra (i.e., wavelengths or wavelength bands), including, but not limited to, various visible colors (including essentially white light), various color temperatures of white light, ultraviolet, or infrared. LEDs having a variety of spectral bandwidths (e.g., narrow band, broader band) may be employed in various implementations of the lighting unit 200B.

[0073] In another aspect of the lighting unit 200B shown in Fig. 7, the lighting unit may be constructed and arranged to produce a wide range of variable color radiation. For example, the lighting unit 200B may be particularly arranged such that the processor-controlled variable intensity light generated by two or more of the light sources combines to produce a mixed colored light (including essentially white light having a variety of color temperatures). In particular, the color (or color temperature) of the mixed colored light may be varied by varying one or more of the respective intensities of the light sources (e.g., in response to one or more control signals output by the processor and drive circuitry). Furthermore, the processor 102 may be particularly configured (e.g., pro-

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grammed) to provide control signals to one or more of the light sources so as to generate a variety of static or time-varying (dynamic) multi-color (or multi-color temperature) lighting effects.

[0074] Thus, the lighting unit 200B may include a wide variety of colors of LEDs in various combinations, including two or more of red, green, and blue LEDs to produce a color mix, as well as one or more other LEDs to create varying colors and color temperatures of white light. For example, red, green and blue can be mixed with amber, white, UV, orange, IR or other colors of LEDs. Such combinations of differently colored LEDs in the lighting unit 200B can facilitate accurate reproduction of a host of desirable spectrums of lighting conditions, examples of which includes, but are not limited to, a variety of outside daylight equivalents at different times of the day, various interior lighting conditions, lighting conditions to simulate a complex multicolored background, and the like. Other desirable lighting conditions can be created by removing particular pieces of spectrum that may be specifically absorbed, attenuated or reflected in certain environments.

[0075] As shown in Fig. 7, the lighting unit 200B also may include a memory 114 to store various information. For example, the memory 114 may be employed to store one or more lighting programs for execution by the processor 102 (e.g., to generate one or more control signals for the light sources), as well as various types of data useful for generating variable color radiation (e.g., calibration information). The memory 114 also may store one or more particular identifiers (e.g., a serial number, an address, etc.) that may be used either locally or on a system level to identify the lighting unit 200B. In various embodiments, such identifiers may be pre-programmed by a manufacturer, for example, and may be either alterable or non-alterable thereafter (e.g., via some type of user interface located on the lighting unit, via one or more data or control signals received by the lighting unit, etc.). Alternatively, such identifiers may be determined at the time of initial use of the lighting unit in the field, and again may be alterable or non-alterable thereafter.

[0076] In another aspect, as also shown in Fig. 7, the lighting unit 200B optionally may be configured to receive a user interface signal 118 that is provided to facilitate any of a number of user-selectable settings or functions (e.g., generally controlling the light output of the lighting unit 200B, changing and/or selecting various pre-programmed lighting effects to be generated by the lighting unit, changing and/or selecting various parameters of selected lighting effects, setting particular identifiers such as addresses or serial numbers for the lighting unit, etc.). In one embodiment of the invention discussed further below, the user interface signal 118 may be derived from an A.C. signal provided by a dimmer circuit and/or other control signal(s) on an A.C. power circuit, so that the light generated by the light source 104 may be controlled in response to dimmer operation and/or the other control signal(s).

[0077] More generally, in one aspect of the embodiment shown in Fig. 7, the processor 102 of the lighting unit 200B is configured to monitor the user interface signal 118 and control one or more of the light sources 104A, 104B, and 104C based at least in part on the user interface signal. For example, the processor 102 may be configured to respond to the user interface signal by originating one or more control signals (e.g., via the drive circuitry 109) for controlling one or more of the light sources. Alternatively, the processor 102 may be configured to respond by selecting one or more pre-programmed control signals stored in memory, modifying control signals generated by executing a lighting program, selecting and executing a new lighting program from memory, or otherwise affecting the radiation generated by one or more of the light sources.

[0078] To this end, the processor 102 may be configured to use any one or more of several criteria to "evaluate" the user interface signal 118 and perform one or more functions in response to the user interface signal. For example, the processor 102 may be configured to take some action based on a particular instantaneous value of the user interface signal, a change of some characteristic of the user interface signal, a rate of change of some characteristic of the user interface signal, a time averaged value of some characteristic of the user interface signal, periodic patterns or interruptions of the user interface signal having particular durations, zero-crossings of an A.C. user interface signal, etc.

[0079] In one embodiment, the processor is configured to digitally sample the user interface signal 118 and process the samples according to some predetermined criteria to determine if one or more functions need to be performed. In yet another embodiment, the memory 114 associated with the processor 102 may include one or more tables or, more generally, a database, that provides a mapping of values relating to the user interface signal to values for various control signals used to control the LED-based light source 104 (e.g., a particular value or condition associated with the user interface signal may correspond to particular duty cycles of PWM signals respectively applied to differently colored LEDs of the light source). In this manner, a wide variety of lighting control functions may be performed based on the user interface signal.

[0080] Fig. 7 also illustrates that the lighting unit 200B may be configured to receive one or more signals 122 from one or more other signal sources 124. In one implementation, the processor 102 of the lighting unit may use the signal(s) 122, either alone or in combination with other control signals (e.g., signals generated by executing a lighting program, user interface signals, etc.), so as to control one or more of the light sources 104A, 104B and 104C in a manner similar to that discussed above in connection with the user interface. Some examples of a signal source 124 that may be employed in, or used in connection with, the lighting unit 200B of Fig. 7 include any of a variety of sensors or transducers that generate one or more signals 122 in response to some stimulus.

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Examples of such sensors include, but are not limited to, various types of environmental condition sensors, such as thermally sensitive (e.g., temperature, infrared) sensors, humidity sensors, motion sensors, photosensors/light sensors (e.g., sensors that are sensitive to one or more particular spectra of electromagnetic radiation), various types of cameras, sound or vibration sensors or other pressure/force transducers (e.g., microphones, piezoelectric devices), and the like.

[0081] As also shown in Fig. 7, the lighting unit 200B may include one or more communication ports 120 to facilitate coupling of the lighting unit to any of a variety of other devices. For example, one or more communication ports 120 may facilitate coupling multiple lighting units together as a networked lighting system, in which at least some of the lighting units are addressable (e.g., have particular identifiers or addresses) and are responsive to particular data transported across the network.

[0082] In particular, in a networked lighting system environment, as data is communicated via the network, the processor 102 of each lighting unit coupled to the network may be configured to be responsive to particular data (e.g., lighting control commands) that pertain to it (e.g., in some cases, as dictated by the respective identifiers of the networked lighting units). Once a given processor identifies particular data intended for it, it may read the data and, for example, change the lighting conditions produced by its light sources according to the received data (e.g., by generating appropriate control signals to the light sources). In one aspect, the memory 114 of each lighting unit coupled to the network may be loaded, for example, with a table of lighting control signals that correspond with data the processor 102 receives. Once the processor 102 receives data from the network, the processor may consult the table to select the control signals that correspond to the received data, and control the light sources of the lighting unit accordingly.

[0083] In one aspect of this embodiment, the processor 102 of a given lighting unit, whether or not coupled to a network, may be configured to interpret lighting instructions/data that are received in a DMX protocol (as discussed, for example, in U.S. Patents 6,016,038 and 6,211,626), which is a lighting command protocol conventionally employed in the lighting industry for some programmable lighting applications. However, it should be appreciated that lighting units suitable for purposes of the present invention are not limited in this respect, as lighting units according to various embodiments may be configured to be responsive to other types of communication protocols so as to control their respective light sources.

[0084] The lighting unit 200B of Fig. 7 also includes power circuitry 108 that is configured to derive power for the lighting unit based on an A.C. signal 500 (e.g., a line voltage, a signal provided by a dimmer circuit, etc.). In one implementation of the lighting unit 200B, the power circuitry 108 may be configured similarly to portions of the circuits shown in Figs. 4 and 6, for example. In particular, Fig. 8 illustrates one exemplary circuit arrangement for the power circuitry 108, based on several of the elements shown in Figs. 4 and 6, that may be employed in one implementation of the lighting unit 200B. In the circuit shown in Fig. 8, a 5 Volt DC output 900 is provided for at least the processor 102, whereas a 16 Volt DC output 902 is provided for the drive circuitry 109, which ultimately provides power to the LED-based light source 104. Like the circuits shown in Figs. 4 and 6, it should be appreciated that as the overall power provided by the A.C. signal 500 is reduced due to operation of a dimmer, for example, at some point the power circuitry 108 will be unable to provide sufficient power to the various components of the lighting unit 200B and it will cease to generate light. Nonetheless, in one aspect, the power circuitry 108 is configured to provide sufficient power to the lighting unit over a significant range of dimmer operation.

[0085] According to another embodiment of the invention, the power circuitry 108 shown in Fig. 8 may be modified to also provide a control signal that reflects variations in the A.C. signal 500 (e.g., changes in the average voltage) in response to dimmer operation. For example, the circuit of Fig. 8 may be modified to include additional components similar to those shown in connection with the adjustment circuit 208 of Fig. 6 which provide the control voltage 410 (e.g., a resistor divider network in the opto-isolator feedback loop). A control signal similarly derived from the circuit of Fig. 8 may serve as the user interface signal 118 applied to the processor 102, as indicated by the dashed line 410B shown in Fig. 7. In other embodiments, the circuit of Fig. 8 may be modified so as to derive a control/user interface signal from other portions of the circuitry, such as an output of the rectifier or low pass filter, for example.

[0086] In yet another embodiment, the user interface signal 118 provided to the processor 102 may be the A.C. signal 500 itself, as indicated in Fig. 7 by the connections 500B. In this embodiment, the processor 102 may be particularly programmed to digitally sample the A.C. signal 500 and detect changes in one or more characteristics of the A.C. signal (e.g., amplitude variations, degree of angle modulation, etc.). In this manner, rather than respond to a control signal that is derived based on variations of an average voltage of the A.C. signal 500 due to dimmer operation, the processor may respond to dimmer operation by "more directly" monitoring some characteristic (e.g., the degree of angle modulation) of the A.C. dimmer output signal. A number of techniques readily apparent to those skilled in the art, some of which were discussed above in connection with the user interface signal 118, may be similarly implemented by the processor to sample and process the A.C. signal 500.

[0087] Once a user interface signal 118 that represents dimmer operation is derived using any of the techniques discussed above (or other techniques), the processor 102 may be programmed to implement any of a virtually limitless variety of light control functions based on user adjustment of the dimmer. For example, user adjustment

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of a dimmer may cause the processor to change one or more of the intensity, color, correlated color temperature, or temporal qualities of the light generated by the lighting unit 200B.

[0088] To more specifically illustrate the foregoing, consider the lighting unit 200B configured with two lighting programs stored in the memory 114; the first lighting program is configured to allow adjustment of the overall color of the generated light in response to dimmer operation, and the second lighting program is configured to allow adjustment of the overall intensity of the generated light, at a given color, in response to dimmer operation. Moreover, the processor is programmed such that a particular type of dimmer operation toggles between the two programs, and such that on initial power-up, one of the two programs (e.g., the first program) is automatically executed as a default.

[0089] In this example, on power up, the first program (e.g., adjustable color) begins executing, and a user may change the overall color of the generated light by operating the dimmer user interface in a "normal" fashion over some range of adjustment (e.g., the color may be varied through a rainbow of colors from red to blue with gradual adjustment of the dimmer's user interface).

[0090] Once arriving at a desirable color, the user may then select the second program (e.g., adjustable intensity) for execution by operating the dimmer user interface in some particular predetermined manner (e.g., instantaneously interrupting the power for a predetermined period via an on/off switch incorporated with the dimmer, adjusting the dimmer's user interface at a quick rate, etc.). As discussed above in connection with user interface signal concepts, any number of criteria may be used to evaluate dimmer operation and determine if a new program selection is desired, or if adjustment of a currently executing program is desired. Various examples of program or mode selection via a user interface, as well as parameter adjustment within a selected program or mode, are discussed in U.S. Non-provisional Application Serial No. 09/805,368 and U.S. Non-provisional Application Serial No. 10/045,629, incorporated herein by reference.

[0091] In this example, once the second program begins to execute, the user may change the intensity of the generated light (at the previously adjusted color) by subsequent "normal" operation (e.g., gradual adjustment) of the dimmer's user interface. Using the foregoing exemplary procedure, the user may adjust both the intensity and the color of the light emitted from the lighting unit via a conventional A.C. dimmer.

[0092] It should be appreciated that the foregoing example is provided primarily for purposes of illustration, and that the invention is not limited in these respects. In general, according to various embodiments of the invention, multiple parameters relating to the generated light may be changed in sequence, or simultaneously in combination. Also, via selection and execution of a lighting program, temporal characteristics of the generated light also may be adjusted (e.g., rate of strobing of a given color, rate of change of a rainbow wash of colors, etc.).

[0093] For example, in one embodiment, an LED-based light source coupled to an A.C. dimmer circuit may be configured to essentially recreate the lighting characteristics of a conventional incandescent light as a dimmer is operated to increase or decrease the intensity of the generated light. In one aspect of this embodiment, this simulation may be accomplished by simultaneously varying the intensity and the color of the light generated by the LED-based source via dimmer operation.

[0094] More specifically, in conventional incandescent light sources, the color temperature of the light emitted generally reduces as the power dissipated by the light source is reduced (e.g., at lower intensity levels, the correlated color temperature of the light produced may be near 2000K, while the correlated color temperature of the light at higher intensities may be near 3200K). This is why an incandescent light tends to appear redder as the power to the light source is reduced. Accordingly, in one embodiment, an LED-based lighting unit may be configured such that a single dimmer adjustment may be used to simultaneously change both the intensity and color of the light source so as to produce a relatively high correlated color temperature at higher intensities (e.g. when the dimmer provides essentially "full" power) and produce lower correlated color temperatures at lower intensities, so as to mimic an incandescent source.

[0095] Another embodiment of the present invention is directed to a flame simulation control system, or other simulation control system. The system may include an LED-based light source or lighting unit arranged to produce flame effects or simulations. Such a flame simulation system may be used to replace more conventional flame simulation systems (e.g. incandescent or neon). The flame simulation lighting device may be configured (e.g., include a lighting program) for altering the appearance of the generated light to simulate wind blowing through the flame or random flickering effects to make the simulation more realistic. Such a simulation system may be associated with a user interface to control the effects, and also may be configured to be adapted for use and/or controlled via an A.C. dimmer circuit (e.g., a dimmer control system may be used to change the effects of the simulation system). In other implementations, the user interface may communicate to the simulation device through wired or wireless communication and a user may be able to alter the effects of the device through the user interface. The simulation device may include an effect that can be modified for rate of change, intensity, color, flicker rate, to simulate windy conditions, still conditions, moderate conditions or any other desirable modification.

[0096] Many lighting control systems do not include dimmer circuits where dimming and other alterable lighting effects would be desirable. Accordingly, yet another embodiment of the present invention is directed to a lighting effect control system including a wireless control system. According to this embodiment, an LED-based light source or lighting unit may be adapted to receive wireless

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communications to effect lighting changes in the lighting system (e.g., see Fig. 7 in connection with communication link 120). A wireless transmitter may be used by a user to change the lighting effects generated by the lighting system. In one implementation, the transmitter is associated with a power switch for the control system. For example, the power switch may be a wall mounted power switch and a user interface may be associated with the wall-mounted switch. The user interface may be used to generate wireless communication signals that are communicated to the lighting system to cause a change in the light emitted. In another embodiment, the signals are communicated to the lighting system over the power wires in a multiplexed fashion where the light decodes the data from the power.

[0097] Yet another embodiment of the invention is directed to methods and apparatus for communicating control information to one or more lighting devices, as well as other devices that typically are powered via a standard A.C. line voltage, by using a portion of the duty cycle of the line voltage to communicate the control information. For example, according to one embodiment, a supply voltage controller is configured to receive a standard A.C. line voltage as an input, and provide as an output a power signal including control information. The power signal provides an essentially constant A.C. power source; however, according to one aspect of this embodiment, the signal periodically is "interrupted" (e.g., a portion of the AC duty cycle over a period of cycles is removed) to provide one or more communication channels over which control information (e.g., digitally encoded information) may be transmitted to one or more devices coupled to the power signal. The device(s) coupled to the power signal may be particularly configured to be responsive in some way to such control information.

[0098] For example, it should be appreciated that the various LED-based lighting units disclosed herein, having the capability to provide power to LED-based light sources from a standard A.C. line voltage, an A.C. dimmer circuit (e.g., providing an angle modulated power source), or from a power source in which other control signals may be present in connection with an A.C. line voltage, may be particularly configured to be compatible with the power signal described above and responsive to the control information transmitted over the communication channel.

[0099] According to one aspect of this embodiment, a supply voltage controller to provide a power signal as discussed above may be implemented as a processor-based user interface, including any number of features (e.g., buttons, dials, sliders, etc.) to facilitate user operation of the controller. In particular, in one implementation, the supply voltage controller may be implemented to resemble a conventional dimmer (e.g., having a knob or a slider as a user interface), in which an associated processor is particularly programmed to monitor operation of the user interface and generate control information in response to such operation. The processor also is programmed to transmit the control information via one or more communication channels of the power signal, as discussed above.

[0100] In other aspects of this embodiment, unlike currently available home control networks/systems such as X10, the device(s) being controlled by the power signal essentially are defined by the electrical wiring that provides the power signal, rather than by programming or addresses assigned to the device(s). Additionally, other "non-controllable" devices (i.e., not configured to be responsive to the control information transported on the power signal) may be coupled to the power signal without any detrimental effect, and allow for a mix of controllable and non-controllable devices on the same power circuit (i.e., delivering the same power signal to all devices on the circuit). Moreover, devices in different wiring domains (i.e., on different power circuits) are guaranteed through topology not to interfere with, or be responsive to, the power signal on a particular power circuit. In yet another aspect, the power signal of this embodiment is essentially "transparent" to (i.e., does not interfere with) other protocols such as X10.

[0101] In one exemplary implementation based on a supply voltage controller providing a power signal as discussed above on a given power circuit, a number of lighting devices (e.g., conventional lighting devices, LED-based lighting units, etc) may be coupled to the power circuit and configured such that they are essentially non-responsive to any control information transmitted on the power circuit. For example, the "non-responsive" lighting devices may be conventional incandescent light sources or other devices that receive power via the portion of the power signal that does not include the communication channel. These lighting devices may serve in a given environment to provide general illumination in the environment.

[0102] In addition to the non-responsive lighting devices in this example, one or more other controllable lighting devices (e.g., particularly configured LED-based lighting units) also may be coupled to the same power circuit and configured to be responsive to the control information in the communication channel of the power signal (i.e., responsive to user operation of the supply voltage controller). In this manner, the controllable lighting device(s) may provide various types of accent/special effects lighting to complement the general illumination provided by the other "non-responsive" devices on the same power circuit.

4. *Exemplary Drive Circuit Embodiments*

[0103] With reference again to Fig. 7, the drive circuitry 109 of the lighting unit 200B may be implemented in numerous ways, one of which employs one or more current drivers respectively corresponding to the one or more light sources 104A, 104B and 104C (collectively 104). In particular, according to one embodiment, the drive circuitry 109 is configured such that each differently colored

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light source is associated with a voltage to current converter that receives a voltage control signal (e.g., a digital PWM signal) from the processor 102 and provides a corresponding current to energize the light source. Such a driver circuit is not limited to implementations of lighting units that are particularly configured for operation via an A.C. dimmer circuit; more generally, lighting units similar to the lighting unit 200B and configured for use with various types of power sources (e.g, A.C. line voltages, A.C. dimmer circuits, D.C. power sources) may employ driver circuitry including one or more voltage to current converters.

[0104] Fig. 9 illustrates one example of a portion of the driver circuitry 109 employing a conventional voltage to current converter, also referred to as a "current sink" 910. As shown in Fig. 9, the current sink 910 receives a digital input control signal from the processor 102 and provides a current I_A to drive the light source 104A. It should be appreciated that, according to one embodiment, multiple light sources are included in the lighting unit, and that the driver circuitry 109 includes circuitry similar to that shown in Fig. 9 for each light source (wherein the processor provides one control signal for each current sink).

[0105] The current sink 910 illustrated in Fig. 9 is widely used for control of current in various applications, and is discussed in many popular textbooks (e.g., see Intuitive IC OPAMPS, Thomas M. Frederiksen, 1984, pages 186-189). The operational amplifier based current sink of Fig. 9 functions to maintain the voltage at the node "A" (i.e., across the resistor R6) and the "reference" voltage at the node "C" (at the non-inverting input of the operational amplifier U1A) at the same value. In this manner, the light source current I_A is related to (i.e., tracks) the digital control signal provided by the processor 102.

[0106] The reference voltage at the point "C" in Fig. 9 may be developed in a variety of ways, and the Frederiksen text referenced above suggests that a resistor divider (e.g., R2 and R5) is a good method of creating this voltage. Generally, the reference voltage is chosen by a designer of the circuit as a compromise; on one hand, the voltage should be as low as possible, to reduce the burden voltage (i.e. the lowest voltage at which the current I_A is maintained) of the current sink. On the other hand, lowering the reference voltage increases the circuit error, due to various sources, including: 1) the offset voltage of the op-amp; 2) differences in the input bias currents of the op-amp; 3) poor tolerances of low value resistors; and 4) errors in sensing small voltages due to voltage drops across component interconnections. Lowering the reference voltage also decreases the speed of the circuit, because feedback to the op-amp is reduced. This situation can also lead to instabilities in the circuit.

[0107] The reference voltage at the point "C" in Fig. 9 need not be constant, and it may be switched between any desired voltages to generate different currents. In particular, a pulse width modulated (PWM) digital control voltage may be applied to the circuit from the processor 102, to generate a switched current I_A. Through careful selection of resistor values for the voltage divider formed by resistors R2 and R5, various circuit goals may be achieved, including the matching of op-amp bias currents.

[0108] One issue with the circuit shown in Fig. 9 is that when the digital control signal from the processor is not present or off (e.g., at zero volts), the operational amplifier U1A may not turn the transistor M1 fully off. As a result, some current I_A may still flow through the light source 104A, even though the light source is intended to be off. In view of the foregoing, one embodiment of the present invention is directed to drive circuitry for LED-based light sources that incorporates an improved current sink design to ensure more accurate control of the light sources.

[0109] Fig. 10 illustrates one example of such an improved current sink 910A according to one embodiment of the invention. The current sink 910A is configured such that there is a known "error voltage" at the node "B" (e.g., the inverting input of the operational amplifier U1A), through the use of resistors R4 and R1. In particular, the values of resistors R4 and R1 are selected so as to slightly increase the voltage at the node "B" as compared to the arrangement shown in Fig. 9. As a result, when the reference voltage at the node "C" is zero (i.e., when the digital control signal is such that the light source 104A is intended to be off), the voltage at the node "B" is slightly above that at the node "C". This voltage difference forces the op-amp to drive its output low, which hence drives transistor M1 well into its "off" region and avoids any inadvertent flow of the current I_A.

[0110] The small known error voltage introduced at the node "B" does not necessarily result in any increase in current error. In one embodiment, the values of resistors R2 and R5 may be adjusted to compensate for the effects of the error voltage. For example, resistors R4 and R1 may be selected to result in 20mV at the node "B" when the node "C" is at zero volts (such that the OP AMP is in the "off" state). In the "on" state, the circuit may be configured such that there is approximately 5mV of sense voltage at the node "A" (across the resistor R6). The error voltage is added to the desired sense resistor voltage, and the values of resistors R2 and R5 are appropriately selected to result in a 25mV reference voltage at the node "C" in the presence of a digital control signal indicating an "on" state. In one embodiment, the circuit may be configured such that the output current I_A and sense voltage at node "A" may be much greater than the minimums, for various reasons, but most notably because lower cost op-amps may be used to achieve 1% accuracy if the sense voltage is increased to the 300-700mV range.

[0111] Fig. 11 shows yet another embodiment of a current sink 910B, in which several optional components are added to the circuit of Fig. 10, which increase the speed and current capability of the circuit. In particular, as the size of transistor M1 is increased towards larger currents, capacitor C1 and resistor R3 may be added to compensate for the larger capacitance of M1. This capacitance presents a large load to the op-amp, and for many op-

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amp designs, this can cause instability. Resistor R3 lowers the apparent load presented by M1, and C1 provides a high frequency feedback path for the op-amp, which bypasses M1. In one aspect of this embodiment, the circuit impedance at nodes "B" and "C" may be matched, to reduce the effects of op-amp bias current. In another embodiment this matching may be avoided by using modem FET input op-amps.

[0112] Having thus described several illustrative embodiments of the invention, various alterations, modifications, and improvements will readily occur to those skilled in the art. Such alterations, modifications, and improvements are intended to be within the spirit and scope of the invention. While some examples presented herein involve specific combinations of functions or structural elements, it should be understood that those functions and elements may be combined in other ways according to the present invention to accomplish the same or different objectives. In particular, acts, elements and features discussed in connection with one embodiment are not intended to be excluded from a similar or other roles in other embodiments. Accordingly, the foregoing description is by way of example only, and is not intended as limiting.

Claims

1. An illumination apparatus (200), comprising:

   at least one LED (104); and
   at least one controller (204) coupled to the at least one LED (104) and configured to provide D.C. power to the at least one LED (104), wherein the controller is configured to receive from an A.C. power source an A.C. power-related signal having higher frequency components than a standard A.C. line voltage and to provide said D.C. power based on the A.C. power-related signal, **characterized in that** the at least one controller (204) is configured to filter out the higher frequency components.

2. The apparatus of claim 1, wherein the A.C. power source is an (A.C.) dimmer circuit.

3. The apparatus of claim 2, wherein the A.C. dimmer circuit is controlled by a user interface to vary the power-related signal, and wherein the at least one controller is configured to provide an essentially non-varying power to the at least one LED (104) over a significant range of operation of the user interface.

4. The apparatus of claim 3, wherein the operation of the user interface varies a duty cycle of the power-related signal, and wherein the at least one controller (204) is configured to provide the essentially non-varying power to the at least one LED (104) over a significant range of operation of the user interface notwithstanding variations in the duty cycle of the power-related signal.

5. The apparatus of claim 3, wherein the at least one controller (204) comprises:

   a rectifier (404) to receive the power-related signal and provide a rectified power-related signal;
   a low pass filter (408) to filter the rectified power-related signal; and
   a DC converter (402) to provide the essentially non-varying power based on the filtered rectified power-related signal.

6. The apparatus of claim 3, further comprising:

   a screw-type power connector configured to engage mechanically and electrically with a conventional incandescent light socket so as to couple the apparatus to the A.C. dimmer circuit.

7. The apparatus of claim 6, further comprising:

   a housing, coupled to the screw-type power connector, to enclose the at least one LED and the at least one controller, the housing being structurally configured to resemble an incandescent light bulb.

8. The apparatus of claim 7, wherein the at least one LED (104) includes a plurality of differently colored LEDs.

9. The apparatus of claim 2, wherein the A. C. dimmer circuit is controlled by a user interface to vary the power-related signal, and wherein the at least one controller is configured to variably control at least one parameter of generated by the at least one LED (104) in response to operation of the user interface.

10. The apparatus of claim 9, wherein the operation of the user interface varies a duty cycle of the power-related signal, and wherein the at least one controller (204) is configured to variably control the at least one parameter of the light based at least on the variable duty cycle of the power-related signal.

11. The apparatus of claim 9, wherein the at least one parameter of the light that is variably controlled by the at least one controller (204) in response to operation of the user interface includes at least one of an intensity of the light, a color of the light, a color temperature of the light, and a temporal characteristic of the light.

12. The apparatus of claim 9, wherein the at least one controller (204) is configured to variably control at

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least two different parameters of the light generated by the at least one LED (104) in response to operation of the user interface.

13. The apparatus of claim 12, wherein the at least one controller (204) is configured to variably control at least an intensity and a color of the light simultaneously in response to operation of the user interface.

14. The apparatus of claim 12, wherein the at least one LED (204) is configured to generate an essentially white light, and wherein the at least one controller (204) is configured to variably control at least an intensity and a color temperature of the white light simultaneously in response to operation of the user interface.

15. The apparatus of claim 14, wherein the at least one controller (204) is configured to variably control at least the intensity and the color temperature of the essentially white light in response to operation of the user interface so as to approximate light generation characteristics of an incandescent light source.

16. The apparatus of claim 15, wherein the at least one controller (204) is configured to variably control the color temperature of the essentially white light over a range from approximately 2000 degrees K at a minimum intensity to 3200 degrees K at a maximum intensity.

17. The apparatus of claim 15, further comprising:

a screw-type power connector (202) configured to engage mechanically and electrically with a conventional incandescent light socket so as to couple the apparatus to the A.C. dimmer circuit.

18. The apparatus of claim 17, further comprising:

a housing, coupled to the screw-type power connector, to enclose the at least one LED (104) and the at least one controller (204), the housing being structurally configured to resemble an incandescent light bulb.

19. The apparatus of claim 15, wherein the at least one LED includes a plurality of differently colored LEDs.

20. The apparatus of claim 9, wherein the at least one controller includes:

an adjustment circuit (208) to variably control the at least one parameter of light based on the varying power-related signal; and
power circuitry to provide at least the power to the at least one LED (104) based on the varying power-related signal.

21. The apparatus of claim 20, wherein the power circuitry includes:

a rectifier (404) to receive the power-related signal and provide a rectified power related signal;
a low pass filter to filter (408) the rectified power-related signal; and
a DC converter (404) to provide the power to at least the at least one LED (104) based on the filtered rectified power-related signal.

22. The apparatus of claim 21, wherein the adjustment circuit is coupled to the DC converter and is configured to variably control the at least one LED (104) based on the filtered rectified power-related signal.

23. The apparatus of claim 21, wherein the adjustment circuit includes at least one processor (102) configured to monitor at least one of the power-related signal, the rectified power-related signal, and the filtered rectified power-related signal so as to variably control the at least one LED (104).

24. The apparatus of claim 21, wherein the power circuitry is configured to provide at least the power to the at least one LED (104) and power to the at least one processor (102) based on the varying power-related signal.

25. The apparatus of claim 21, wherein the at least one processor (102) is configured to sample the varying power-related signal and determine at least one varying characteristic of the varying power-related signal.

26. The apparatus of claim 21, wherein the operation of the user interface varies a duty cycle of the power-related signal, and wherein the at least one processor (102) is configured to variably control the at least one parameter of the light based at least on the varying duty cycle of the power-related signal.

27. The apparatus of claim 26, wherein the at least one LED (104) includes a plurality of differently colored LEDs.

28. The apparatus of claim 27, wherein:

the plurality of differently colored LEDs includes:
at least one first LED (104A,104B,104C) adapted to output at least first radiation having a first spectrum; and
at least one second LED (104A,104B,104C) adapted to output second radiation having a second spectrum different than the first spectrum; and
the at least one processor (102) is configured to independently control at least a first intensity of

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the first radiation and a second intensity of the second radiation in response to operation of the user interface.

29. The apparatus of claim 28, wherein the at least one processor (102) is programmed to implement a pulse width modulation (PWM) technique to control at least the first intensity of the first radiation and the second intensity of the second radiation.

30. The apparatus of claim 29, wherein the at least one processor (102) further is programmed to:

generate at least a first PWM signal to control the first intensity of the first radiation and a second PWM signal to control the second intensity of the second radiation; and
determine duty cycles of the respective first and second PWM signals based at least in part on variations in the power-related signal due to operation of the user interface.

31. The apparatus of claim 20, wherein the adjustment circuit includes drive circuitry (109) including at least one voltage-to-current converter to provide at least one drive current to the at least one LED so as to control the at least one parameter of the generated light.

32. The apparatus of claim 31, wherein the at least one voltage-to-current converter includes an operational amplifier (UIA) configured so as to have a predetermined error voltage applied across its non-inverting and inverting inputs during operation to essentially reduce to zero a current output of the at least one voltage-to-current converter when a voltage applied to the at least one voltage-to-current converter is essentially zero.

33. An illumination method, comprising an act of:

A) providing D.C. power to at least one LED (104) based on a power-related signal provided by an A.C. power source having higher frequency components than a standard A.C. line voltage, **characterized in that** the higher frequency components are filtered out of the power-related signal prior to providing D.C. power to the at least one LED (104).

34. The illumination method of claim 33, wherein the act A) includes an act of:

providing the D.C. power to the at least one LED (104) based on a power-related signal from an alternating current (A.C.) dimmer circuit.

35. The method of claim 34, wherein the A.C. dimmer circuit is controlled by a user interface to vary the power-related signal, and wherein the act A) comprises an act of:

B) providing an essentially non-varying power to the at least one LED (104) over a significant range of operation of the user interface.

36. The method of claim 35, wherein the operation of the user interface duty cycle of the power-related signal, and wherein the act B) includes an act of providing the essentially non-varying power to the at least one LED (104) over a significant range of operation of the user interface notwithstanding variations in the duty cycle of the power-related signal.

37. The method of claim 35, wherein the act B) includes acts of:

rectifying the power-related signal to provide a rectified power-related signal;
filtering the rectified power-related signal; and
providing the essentially non-varying power based on the filtered rectified power related signal.

38. The method of claim 35, wherein the at least one LED includes a plurality of differently colored LEDs.

39. The method of claim 34, wherein the A.C. dimmer circuit is controlled by a user interface to vary the power-related signal, and wherein the act A) includes an act of:

C) variably controlling at least one parameter of light generated by the at least one LED (104) in response to operation of the user interface.

40. The method of claim 39, wherein the operation of the user interface varies a duty cycle of the power-related signal, and wherein the act C) includes an act of:

D) variably controlling the at least one parameter of the light based at least on the variable duty cycle of the power-related signal.

41. The method of claim 39, wherein the act D) includes an act of:

variably controlling at least one of an intensity of the light, a color of the light, a color temperature of the light, and a temporal characteristic of the light in response to operation of the user interface.

42. The method of claim 39, wherein the act D) includes an act of:

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E) variably controlling at least two different parameters of the light generated by the at least one LED in response to operation of the user interface.

43. The method of claim 42, wherein the act E) includes an act of:

variably controlling at least an intensity and a color of the light simultaneously in response to operation of the user interface.

44. The method of claim 42, wherein the at least one LED (104) is configured to generate an essentially white light, and wherein the act E) includes an act of:

F) variably controlling at least an intensity and a color temperature of the white light simultaneously in response to operation of the user interface.

45. The method of claim 44, wherein the act F) includes an act of:

G) variably controlling at least the intensity and the color temperature of the essentially white light in response to operation of the user interface so as to approximate light generation characteristics of an incandescent light source.

46. The method of claim 45, wherein the act G) includes an act of:

variably controlling the color temperature of the essentially white light over a range from approximately 2000 degrees K at a minimum intensity to 3200 degrees K at a maximum intensity.

47. The method of claim 46, wherein the at least one LED includes a plurality of differently colored LEDs.

48. The method of claim 39, wherein the act C) includes an act of

H) digitally sampling the varying power-related signal and determine at least one varying characteristic of the varying power-related signal.

49. The method of claim 48, wherein the operation of the user interface varies a duty cycle of the power-related signal, and wherein the act H) includes an act of variably controlling the at least one parameter of the light based at least on the varying duty cycle of the sampled power-related signal.

50. The method of claim 39, wherein:

the at least one LED (104) includes;

at least one first LED (104A,104B,104C) adapted to output at least first radiation having a first spectrum; and

at least one second LED (104A,104B,104C) adapted to output second radiation having a second spectrum different than the first spectrum; and

the act C) includes an act of:

I) independently controlling at least a first intensity of the first radiation and a second intensity of the second radiation in response to operation of the user interface.

51. The method of claim 50, wherein the act 1) includes an act of:

J) implementing a pulse width modulation (PWM) technique to control at least the first intensity of the first radiation and the second intensilty of the second radiation.

52. The method of claim 51, wherein the act J) includes acts of:

generating at least a first PWM signal to control the first intensity of the first radiation and a second PWM signal to control the second intensity of the second radiation; and

determining duty cycles of the respective first and second PWM signals based at least in part on variations in the power-related signal due to operation of the user interface.

Patentansprüche

1. Beleuchtungsvorrichtung (200) mit:

mindestens einer LED (104) sowie

mindestens einer Steuereinrichtung (204), die an die mindestens eine LED (104) gekoppelt und so konfiguriert ist, dass sie der mindestens einen LED (104) Gleichstromleistung zuführt, wobei die Steuereinrichtung so konfiguriert ist, dass sie von einer Wechselstromquelle ein wechselstromleistungsbezogenes Signal mit höheren Frequenzkomponenten als eine normale Netzwechselspannung empfängt und die auf dem wechselstromleistungsbezogenen Signal basierende Gleichstromleistung abgibt, **dadurch gekennzeichnet, dass** die mindestens eine Steuereinrichtung (204) so konfiguriert ist, dass sie die höheren Frequenzkomponenten ausfiltert.

2. Vorrichtung nach Anspruch 1, wobei die Wechselstromquelle eine (Wechselstrom-) Dimmerschal-

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tung ist.

3. Vorrichtung nach Anspruch 2, wobei die Wechselstrom-Dimmerschaltung von einer Anwenderschnittstelle gesteuert wird, um das leistungsbezogene Signal zu variieren, und wobei die mindestens eine Steuereinrichtung so konfiguriert ist, dass sie der mindestens einen LED (104) über einen signifikanten Bereich des Betriebs der Anwenderschnittstelle eine im Wesentlichen nicht variierende Leistung zuführt.

4. Vorrichtung nach Anspruch 3, wobei der Betrieb der Anwenderschnittstelle ein Tastverhältnis des leistungsbezogenen Signals variiert, und wobei die mindestens eine Steuereinrichtung (204) so konfiguriert ist, dass sie, ungeachtet Variationen in dem Tastverhältnis des leistungsbezogenen Signals, der mindestens einen LED (104) über einen signifikanten Bereich des Betriebs der Anwenderschnittstelle die im Wesentlichen nicht variierende Leistung zuführt.

5. Vorrichtung nach Anspruch 3, wobei die mindestens eine Steuereinrichtung (204) umfasst:

einen Gleichrichter (404), um das leistungsbezogene Signal zu empfangen und ein gleichgerichtetes, leistungsbezogenes Signal vorzusehen,
ein Tiefpassfilter (408), um das gleichgerichtete, leistungsbezogene Signal zu filtern, sowie
einen Gleichstromwandler (402), um die im Wesentlichen nicht variierende Leistung aufgrund des gefilterten, gleichgerichteten, leistungsbezogenen Signals vorzusehen.

6. Vorrichtung nach Anspruch 3, welche weiterhin umfasst:

einen Leistungsstecker mit Schraubanschluss, der so konfiguriert ist, dass er mechanisch und elektrisch in eine konventionelle Glühlampenfassung greift, um die Vorrichtung an die Wechselstrom-Dimmerschaltung zu koppeln.

7. Vorrichtung nach Anspruch 6, welche weiterhin umfasst:

ein an den Leistungsstecker mit Schraubanschluss gekoppeltes Gehäuse, um die mindestens eine LED und die mindestens eine Steuereinrichtung zu umschließen, wobei das Gehäuse strukturell so konfiguriert ist, dass es einer Glühlampe gleicht.

8. Vorrichtung nach Anspruch 7, wobei die mindestens eine LED (104) mehrere verschiedenfarbige LEDs enthält.

9. Vorrichtung nach Anspruch 2, wobei die Wechselstrom-Dimmerschaltung von einer Anwenderschnittstelle gesteuert wird, um das leistungsbezogene Signal zu variieren, und wobei mindestens eine Steuereinrichtung so konfiguriert ist, dass sie mindestens einen Parameter des von der mindestens einen LED (104) in Reaktion auf den Betrieb der Anwenderschnittstelle erzeugten Lichts variabel steuert.

10. Vorrichtung nach Anspruch 9, wobei der Betrieb der Anwenderschnittstelle ein Tastverhältnis des leistungsbezogenen Signals variiert, und wobei die mindestens eine Steuereinrichtung (204) so konfiguriert ist, dass sie den mindestens einen Parameter des Lichts zumindest aufgrund des variablen Tastverhältnisses des leistungsbezogenen Signals variabel steuert.

11. Vorrichtung nach Anspruch 9, wobei der mindestens eine Parameter des Lichts, welches von der mindestens einen Steuereinrichtung (204) in Reaktion auf den Betrieb der Anwenderschnittstelle variabel gesteuert wird, mindestens eine Intensität des Lichts, eine Farbe des Lichts, eine Farbtemperatur des Lichts sowie eine temporale Charakteristik des Lichts enthält.

12. Vorrichtung nach Anspruch 9, wobei die mindestens eine Steuereinrichtung (204) so konfiguriert ist, dass sie mindestens zwei unterschiedliche Parameter des von der mindestens einen LED (104) in Reaktion auf den Betrieb der Anwenderschnittstelle erzeugten Lichts variabel steuert.

13. Vorrichtung nach Anspruch 12, wobei die mindestens eine Steuereinrichtung (204) so konfiguriert ist, dass sie zumindest eine Intensität und eine Farbe des Lichts in Reaktion auf den Betrieb der Anwenderschnittstelle gleichzeitig variabel steuert.

14. Vorrichtung nach Anspruch 12, wobei die mindestens eine LED (204) so konfiguriert ist, dass sie ein im Wesentlichen weißes Licht erzeugt, und wobei die mindestens eine Steuereinrichtung (204) so konfiguriert ist, dass sie zumindest eine Intensität und eine Farbtemperatur des weißen Lichts in Reaktion auf den Betrieb der Anwenderschnittstelle gleichzeitig variabel steuert.

15. Vorrichtung nach Anspruch 14, wobei die mindestens eine Steuereinrichtung (204) so konfiguriert ist, dass sie zumindest die Intensität und die Farbtemperatur des im Wesentlichen weißen Lichts in Reaktion auf den Betrieb der Anwenderschnittstelle variabel steuert, um sich der Lichterzeugungscha-

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rakteristik einer Glühlichtquelle zu nähern.

16. Vorrichtung nach Anspruch 15, wobei die mindestens eine Steuereinrichtung (204) so konfiguriert ist, dass sie die Farbtemperatur des im Wesentlichen weißen Lichts über einen Bereich von ungefähr 2000 Grad K bei einer minimalen Intensität bis 3200 Grad K bei einer maximalen Intensität variabel steuert.

17. Vorrichtung nach Anspruch 15, welche weiterhin umfasst:

einen Leistungsstecker mit Schraubanschluss, welcher so konfiguriert ist, dass er mechanisch und elektrisch in eine konventionelle Glühlampenfassung greift, um die Vorrichtung an die Wechselstrom-Dimmerschaltung zu koppeln.

18. Vorrichtung nach Anspruch 17, welche weiterhin umfasst:

ein an den Leistungsstecker mit Schraubanschluss gekoppeltes Gehäuse, um die mindestens eine LED (104) und die mindestens eine Steuereinrichtung (204) zu umschließen, wobei das Gehäuse strukturell so konfiguriert ist, dass es einer Glühlampe gleicht.

19. Vorrichtung nach Anspruch 15, wobei die mindestens eine LED mehrere verschiedenfarbige LEDs enthält.

20. Vorrichtung nach Anspruch 9, wobei die mindestens eine Steuereinrichtung enthält:

eine Einstellschaltung (208), um den mindestens einen Lichtparameter aufgrund des variierenden, leistungsbezogenen Signals variabel zu steuern, sowie
einen Leistungsschaltkreis, um der mindestens einen LED (104) die Leistung aufgrund des variierenden, leistungsbezogenen Signals zuzuführen.

21. Vorrichtung nach Anspruch 20, wobei der Leistungsschaltkreis enthält:

einen Gleichrichter (404), um das leistungsbezogene Signal zu empfangen und ein gleichgerichtetes, leistungsbezogenes Signal vorzusehen,
ein Tiefpassfilter (408), um das gleichgerichtete, leistungsbezogene Signal zu filtern, sowie
einen Gleichstromwandler (404), um der mindestens einen LED (104) die Leistung aufgrund des gefilterten, gleichgerichteten, leistungsbezogenen Signals zuzuführen.

22. Vorrichtung nach Anspruch 21, wobei die Einstellschaltung an den Gleichstromwandler gekoppelt und so konfiguriert ist, dass sie die mindestens eine LED (104) aufgrund des gefilterten, gleichgerichteten, leistungsbezogenen Signals variabel steuert.

23. Vorrichtung nach Anspruch 21, wobei die Einstellschaltung mindestens einen Prozessor (102) enthält, der so konfiguriert ist, dass er zumindest das leistungsbezogene Signal, das gleichgerichtete, leistungsbezogene Signal oder das gefilterte, gleichgerichtete, leistungsbezogene Signal überwacht, um die mindestens eine LED (104) variabel zu steuern.

24. Vorrichtung nach Anspruch 21, wobei der Leistungsschaltkreis so konfiguriert ist, dass er zumindest der mindestens einen LED (104) und dem mindestens einen Prozessor (102) Leistung aufgrund des variierenden, leistungsbezogenen Signals zuführt.

25. Vorrichtung nach Anspruch 21, wobei der mindestens eine Prozessor (102) so konfiguriert ist, dass er das variierende, leistungsbezogene Signal abtastet und mindestens eine variierende Charakteristik des variierenden, leistungsbezogenen Signals bestimmt.

26. Vorrichtung nach Anspruch 21, wobei der Betrieb der Anwenderschnittstelle ein Tastverhältnis des leistungsbezogenen Signals variiert, und wobei der mindestens eine Prozessor (102) so konfiguriert ist, dass er den mindestens einen Parameter des Lichts aufgrund des variierenden Tastverhältnisses des leistungsbezogenen Signals variabel steuert.

27. Vorrichtung nach Anspruch 26, wobei die mindestens eine LED (104) mehrere verschiedenfarbige LEDs enthält.

28. Vorrichtung nach Anspruch 27, wobei die mehreren verschiedenfarbigen LEDs enthalten:

mindestens eine erste LED (104A,104B,104C), die zumindest eine erste Strahlung mit einem ersten Spektrum abgeben kann, sowie
mindestens eine zweite LED (104A,104B, 104C), die eine zweite Strahlung mit einem sich von dem ersten Spektrum unterscheidenden, zweiten Spektrum abgeben kann, und wobei
der mindestens eine Prozessor (102) so konfiguriert ist, dass er zumindest eine erste Intensität der ersten Strahlung und eine zweite Intensität der zweiten Strahlung in Reaktion auf den Betrieb der Anwenderschnittstelle unabhängig steuern kann.

29. Vorrichtung nach Anspruch 28, wobei der minde-

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stens eine Prozessor (102) so programmiert ist, dass er eine Pulsbreitenmodulations-(PWM)-Technik realisiert, um zumindest die erste Intensität der ersten Strahlung und die zweite Intensität der zweiten Strahlung zu steuern.

30. Vorrichtung nach Anspruch 29, wobei der mindestens eine Prozessor (102) weiterhin so programmiert ist, dass er
zumindest ein erstes PWM-Signal zur Steuerung der ersten Intensität der ersten Strahlung und ein zweites PWM-Signal zur Steuerung der zweiten Intensität der zweiten Strahlung erzeugt und
Tastverhältnisse des jeweiligen ersten und zweiten PWM-Signals, die infolge des Betriebs der Anwenderschnittstelle zumindest zum Teil auf Variationen in dem leistungsbezogenen Signal basieren, bestimmt.

31. Vorrichtung nach Anspruch 20, wobei die Einstellschaltung eine Treiberschaltung (109) mit mindestens einem Spannungs-Strom-Wandler enthält, um der mindestens einen LED mindestens einen Ansteuerungsstrom zur Steuerung des mindestens einen Parameters des erzeugten Lichts zuzuführen.

32. Vorrichtung nach Anspruch 31, wobei der mindestens eine Spannungs-Strom-Wandler einen Operationsverstärker (U1A) enthält, der so konfiguriert ist, dass er eine vorgegebene, bei Betrieb über seinen nicht invertierenden und invertierenden Eingang angelegte Fehlerspannung aufweist, um eine Stromabgabe des mindestens einen Spannungs-Strom-Wandlers im Grunde genommen auf Null zu reduzieren, wenn eine an den mindestens einen Spannungs-Strom-Wandler angelegte Spannung im Grunde genommen Null ist.

33. Beleuchtungsverfahren, welches den Schritt des

A) Zuführens von Gleichstromleistung zu mindestens einer LED (104) aufgrund eines von einer Wechselstromquelle vorgesehenen, leistungsbezogenen Signals mit höheren Frequenzkomponenten als eine normale Netzwechselspannung umfasst, **dadurch gekennzeichnet, dass** die höheren Frequenzkomponenten aus dem leistungsbezogenen Signal ausgefiltert werden, bevor der mindestens einen LED (104) Gleichstromleistung zugeführt wird.

34. Beleuchtungsverfahren nach Anspruch 33, wobei der Schritt A) einen Schritt des
Zuführens der Gleichstromleistung zu der mindestens einen LED (104) aufgrund eines leistungsbezogenen Signals von einer Wechselstrom-(AC)-Dimmerschaltung enthält.

35. Verfahren nach Anspruch 34, wobei die Wechselstrom-Dimmerschaltung von einer Anwenderschnittstelle gesteuert wird, um das leistungsbezogene Signal zu variieren, und wobei der Schritt A) einen Schritt des

B) Zuführens einer im Wesentlichen nicht variierenden Leistung zu der mindestens einen LED (104) über einen signifikanten Bereich des Betriebs der Anwenderschnittstelle umfasst.

36. Verfahren nach Anspruch 35, wobei der Betrieb der Anwenderschnittstelle ein Tastverhältnis des leistungsbezogenen Signals variiert, und wobei der Schritt B), ungeachtet Variationen in dem Tastverhältnis des leistungsbezogenen Signals, einen Schritt des Zuführens der im Wesentlichen nicht variierenden Leistung zu der mindestens einen LED (104) über einen signifikanten Bereich des Betriebs der Anwenderschnittstelle enthält.

37. Verfahren nach Anspruch 35, wobei der Schritt B) die folgenden Schritte enthält:

Gleichrichten des leistungsbezogenen Signals, um ein gleichgerichtetes, leistungsbezogenes Signal vorzusehen,
Filtern des gleichgerichteten, leistungsbezogenen Signals sowie
Vorsehen der im Wesentlichen nicht variierenden Leistung aufgrund des gefilterten, gleichgerichteten, leistungsbezogenen Signals.

38. Verfahren nach Anspruch 35, wobei die mindestens eine LED mehrere verschiedenfarbige LEDs enthält.

39. Verfahren nach Anspruch 34, wobei die Wechselstrom-Dimmerschaltung von einer Anwenderschnittstelle gesteuert wird, um das leistungsbezogene Signal zu variieren, und wobei der Schritt A) einen Schritt der

C) variablen Steuerung von mindestens einem Parameter des von der mindestens einen LED (104) erzeugten Lichts in Reaktion auf den Betrieb der Anwenderschnittstelle enthält.

40. Verfahren nach Anspruch 39, wobei der Betrieb der Anwenderschnittstelle ein Tastverhältnis des leistungsbezogenen Signals variiert, und wobei der Schritt C) einen Schritt der

D) variablen Steuerung des mindestens einen Parameters des Lichts zumindest aufgrund des variablen Tastverhältnisses des leistungsbezogenen Signals enthält.

41. Verfahren nach Anspruch 39, wobei der Schritt D)

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einen Schritt der
variablen Steuerung von zumindest einer Intensität des Lichts, einer Farbe des Lichts, einer Farbtemperatur des Lichts oder einer temporalen Charakteristik des Lichts in Reaktion auf den Betrieb der Anwenderschnittstelle enthält.

42. Verfahren nach Anspruch 39, wobei der Schritt D) einen Schritt der

E) variablen Steuerung von mindestens zwei unterschiedlichen Parametern des von der mindestens einen LED erzeugten Lichts in Reaktion auf den Betrieb der Anwenderschnittstelle enthält.

43. Verfahren nach Anspruch 42, wobei der Schritt E) einen Schritt der
variablen, gleichzeitigen Steuerung von zumindest einer Intensität und einer Farbe des Lichts in Reaktion auf den Betrieb der Anwenderschnittstelle enthält.

44. Verfahren nach Anspruch 42, wobei die mindestens eine LED (104) so konfiguriert ist, dass sie ein im Wesentlichen weißes Licht erzeugt, und wobei der Schritt E) einen Schritt der

F) variablen, gleichzeitigen Steuerung von zumindest einer Intensität und einer Farbtemperatur des weißen Lichts in Reaktion auf den Betrieb der Anwenderschnittstelle enthält.

45. Verfahren nach Anspruch 44, wobei der Schritt F) einen Schritt der

G) variablen Steuerung von zumindest der Intensität und Farbtemperatur des im Wesentlichen weißen Lichts in Reaktion auf den Betrieb der Anwenderschnittstelle enthält, um sich den Lichterzeugungscharakteristiken einer Glühlichtquelle zu nähern.

46. Verfahren nach Anspruch 45, wobei der Schritt G) einen Schritt der
variablen Steuerung der Farbtemperatur des im Wesentlichen weißen Lichts über einen Bereich von ungefähr 2000 Grad K bei einer minimalen Intensität bis 3200 Grad K bei einer maximalen Intensität enthält.

47. Verfahren nach Anspruch 46, wobei die mindestens eine LED mehrere verschiedenfarbige LEDs enthält.

48. Verfahren nach Anspruch 39, wobei der Schritt C) einen Schritt des

H) digitalen Abtastens des variierenden, leistungsbezogenen Signals und Bestimmens von mindestens einer variierenden Charakteristik des variierenden, leistungsbezogenen Signals enthält.

49. Verfahren nach Anspruch 48, wobei der Betrieb der Anwenderschnittstelle ein Tastverhältnis des leistungsbezogenen Signals variiert, und wobei der Schritt H) einen Schritt der variablen Steuerung des mindestens einen Parameters des Lichts zumindest aufgrund des variierenden Tastverhältnisses des abgetasteten, leistungsbezogenen Signals enthält.

50. Verfahren nach Anspruch 39, wobei die mindestens eine LED (104) enthält:

mindestens eine erste LED (104A,104B,104C), die zumindest eine erste Strahlung mit einem ersten Spektrum abgeben kann, sowie
mindestens eine zweite LED (104A,104B, 104C), die eine zweite Strahlung mit einem sich von dem ersten Spektrum unterscheidenden, zweiten Spektrum abgeben kann, und wobei der Schritt C) einen Schritt der

I) unabhängigen Steuerung von zumindest einer ersten Intensität der ersten Strahlung sowie einer zweiten Intensität der zweiten Strahlung in Reaktion auf den Betrieb der Anwenderschnittstelle enthält.

51. Verfahren nach Anspruch 50, wobei der Schritt I) einen Schritt des

J) Realisierens einer Pulsbreitenmodulations-(PWM)-Technik enthält, um zumindest die erste Intensität der ersten Strahlung und die zweite Intensität der zweiten Strahlung zu steuern.

52. Verfahren nach Anspruch 51, wobei der Schritt J) einen Schritt des
Erzeugens von mindestens einem ersten PWM-Signal zur Steuerung der ersten Intensität der ersten Strahlung und einem zweiten PWM-Signal zur Steuerung der zweiten Intensität der zweiten Strahlung, sowie
Bestimmens von Tastverhältnissen des jeweiligen ersten und zweiten PWM-Signals zumindest zum Teil aufgrund von Variationen des leistungsbezogenen Signals infolge des Betriebs der Anwenderschnittstelle enthält.

Revendications

1. Appareil d'illumination (200), comprenant :

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au moins une DEL (104) ; et
au moins un contrôleur (204) couplé à l'au moins une DEL (104) et configuré pour fournir du courant continu à l'au moins une DEL (104), dans lequel le contrôleur est configuré pour recevoir d'une source de courant alternatif un signal se rapportant au courant alternatif ayant des composants de fréquence supérieure à une tension de ligne de courant alternatif standard et pour fournir ledit courant continu sur la base du signal se rapportant au courant alternatif, **caractérisé en ce que** l'au moins un contrôleur (204) est configuré pour filtrer les composants de fréquence supérieure.

2. Appareil selon la revendication 1, dans lequel la source de courant alternatif est un circuit de gradateur (de courant alternatif).

3. Appareil selon la revendication 2, dans lequel le circuit de gradateur de courant alternatif est commandé par une interface utilisateur pour faire varier le signal se rapportant au courant, et dans lequel l'au moins un contrôleur est configuré pour fournir un courant essentiellement non variable à l'au moins une DEL (104) sur une plage significative de fonctionnement de l'interface utilisateur.

4. Appareil selon la revendication 3, dans lequel le fonctionnement de l'interface utilisateur fait varier un cycle d'usage du signal se rapportant au courant, et dans lequel l'au moins un contrôleur (204) est configuré pour fournir le courant essentiellement non variable à l'au moins une DEL (104) sur une plage significative de fonctionnement de l'interface utilisateur indépendamment des variations du cycle d'usage du signal se rapportant au courant.

5. Appareil selon la revendication 3, dans lequel l'au moins un contrôleur (104) comprend :

un redresseur (404) pour recevoir le signal se rapportant au courant et fournir un signal se rapportant au courant redressé ;
un filtre passe-bas (408) pour filtrer le signal se rapportant au courant redressé ; et
un convertisseur de courant continu (402) pour fournir le courant essentiellement non variable sur la base du signal se rapportant au courant redressé filtré.

6. Appareil selon la revendication 3, comprenant en outre :

un connecteur de courant de type vissé configuré pour se mettre en prise mécaniquement et électriquement avec une douille de lumière incandescente conventionnelle de manière à coupler l'appareil au circuit de gradateur de courant alternatif.

7. Appareil selon la revendication 6, comprenant en outre :

un boîtier, couplé au connecteur de courant de type vissé, pour enfermer l'au moins une DEL et l'au moins un contrôleur, le boîtier étant structurellement configuré pour ressembler à une ampoule de lumière incandescente.

8. Appareil selon la revendication 7, dans lequel l'au moins une DEL (104) comprend une pluralité de DEL de couleurs différentes.

9. Appareil selon la revendication 2, dans lequel le circuit de gradateur de courant alternatif est commandé par une interface utilisateur pour faire varier le signal se rapportant au courant, et dans lequel l'au moins un contrôleur est configuré pour commander de manière variable au moins un paramètre de la lumière générée par l'au moins une DEL (104) en réponse au fonctionnement de l'interface utilisateur.

10. Appareil selon la revendication 9, dans lequel le fonctionnement de l'interface utilisateur fait varier un cycle d'usage du signal se rapportant au courant, et dans lequel l'au moins un contrôleur (204) est configuré pour commander de manière variable l'au moins un paramètre de la lumière sur la base au moins du cycle d'usage variable du signal se rapportant au courant.

11. Appareil selon la revendication 9, dans lequel l'au moins un paramètre de la lumière qui est commandée de manière variable par l'au moins un paramètre (204) en réponse au fonctionnement de l'interface utilisateur comprend au moins l'une d'une intensité de la lumière, d'une couleur de la lumière, d'une température de couleur de la lumière et d'une caractéristique temporale de la lumière.

12. Appareil selon la revendication 9, dans lequel l'au moins un contrôleur (204) est configuré pour commander de manière variable au moins deux paramètres différents de la lumière générée par l'au moins une DEL (104) en réponse au fonctionnement de l'interface utilisateur.

13. Appareil selon la revendication 12, dans lequel l'au moins un contrôleur (204) est configuré pour commander de manière variable au moins une intensité et une couleur de la lumière simultanément en réponse au fonctionnement de l'interface utilisateur.

14. Appareil selon la revendication 12, dans lequel l'au moins une DEL (104) est configurée pour générer

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une lumière essentiellement blanche, et dans lequel l'au moins un contrôleur (204) est configuré pour commander de manière variable au moins une intensité et une température de couleur de la lumière blanche simultanément en réponse au fonctionnement de l'interface utilisateur.

15. Appareil selon la revendication 14, dans lequel l'au moins un contrôleur (204) est configuré pour commander de manière variable au moins l'intensité et la température de couleur de la lumière essentiellement blanche en réponse au fonctionnement de l'interface utilisateur de manière à approximer les caractéristiques de génération de lumière d'une source de lumière incandescente.

16. Appareil selon la revendication 15, dans lequel l'au moins un contrôleur (204) est configuré pour commander de manière variable la température de couleur de la lumière essentiellement blanche sur une plage d'une intensité minimale d'environ 2000 degrés K à une intensité maximale d'environ 3200 degrés K.

17. Appareil selon la revendication 15, comprenant en outre :

un connecteur de courant de type vissé (202) configuré pour se mettre en prise mécaniquement et électriquement avec une douille de lumière incandescente conventionnelle de manière à coupler l'appareil au circuit de gradateur de courant alternatif.

18. Appareil selon la revendication 17, comprenant en outre :

un boîtier, couplé au connecteur de courant de type vissé, pour enfermer l'au moins une DEL (104) et l'au moins un contrôleur (204), le boîtier étant structurellement configuré pour ressembler à une ampoule de lumière incandescente.

19. Appareil selon la revendication 15, dans lequel l'au moins une DEL comprend une pluralité de DEL de couleurs différentes.

20. Appareil selon la revendication 9, dans lequel l'au moins un contrôleur comprend :

un circuit d'ajustement (208) pour commander de manière variable l'au moins un paramètre de la lumière sur la base du signal se rapportant au courant variable ; et
un circuit de courant pour fournir au moins le courant à l'au moins une DEL (104) sur la base du signal se rapportant au courant variable.

21. Appareil selon la revendication 20, dans lequel le circuit de courant comprend :

un redresseur (404) pour recevoir le signal se rapportant au courant et fournir un signal se rapportant au courant redressé ;
un filtre passe-bas (408) pour filtrer le signal se rapportant au courant redressé ; et
un convertisseur de courant continu (402) pour fournir le courant au moins à l'au moins une DEL (104) sur la base du signal se rapportant au courant redressé filtré.

22. Appareil selon la revendication 21, dans lequel le circuit d'ajustement est couplé au convertisseur de courant continu et est configuré pour commander de manière variable l'au moins une DEL (104) sur la base du signal se rapportant au courant redressé filtré.

23. Appareil selon la revendication 21, dans lequel le circuit d'ajustement comprend au moins un processeur (102) configuré pour surveiller au moins l'un du signal se rapportant au courant, du signal se rapportant au courant redressé, et du signal se rapportant au courant redressé filtré de façon à commander de manière variable l'au moins une DEL (104).

24. Appareil selon la revendication 21, dans lequel le circuit de courant est configuré pour fournir au moins le courant à l'au moins une DEL (104) et du courant à l'au moins un processeur (102) sur la base du signal se rapportant au courant variable.

25. Appareil selon la revendication 21, dans lequel l'au moins un processeur (102) est configuré pour échantillonner le signal se rapportant au courant variable et déterminer au moins une caractéristique variable du signal se rapportant au courant variable.

26. Appareil selon la revendication 21, dans lequel le fonctionnement de l'interface utilisateur fait varier un cycle d'usage du signal se rapportant au courant, et dans lequel l'au moins un processeur (102) est configuré pour commander de manière variable l'au moins un paramètre de la lumière sur la base au moins du cycle d'usage variable du signal se rapportant au courant.

27. Appareil selon la revendication 26, dans lequel l'au moins une DEL (104) comprend une pluralité de DEL de couleurs différentes.

28. Appareil selon la revendication 27, dans lequel la pluralité de DEL de couleurs différentes comprend :

au moins une première DEL (104A, 104B, 104C)

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apte à délivrer au moins un premier rayonnement ayant un premier spectre ; et
au moins une seconde DEL (104A, 104B, 104C) apte à délivrer un second rayonnement ayant un second spectre différent du premier spectre ; et
l'au moins un processeur (102) est configuré pour commander de manière indépendante au moins une première intensité du premier rayonnement et une seconde intensité du second rayonnement en réponse au fonctionnement de l'interface utilisateur.

29. Appareil selon la revendication 28, dans lequel l'au moins un processeur (102) est programmé pour mettre en oeuvre une technique de modulation de largeur d'impulsion (PWM) pour commander au moins la première intensité du premier rayonnement et la seconde intensité du second rayonnement.

30. Appareil selon la revendication 29, dans lequel l'au moins un processeur (102) est en outre programmé pour :

générer au moins un premier signal PWM pour commander la première intensité du premier rayonnement et un second signal PWM pour commander la seconde intensité du second rayonnement ; et
déterminer des cycles d'usage des premier et second signaux PWM respectifs sur la base au moins en partie des variations du signal se rapportant au courant en raison du fonctionnement de l'interface utilisateur.

31. Appareil selon la revendication 20, dans lequel le circuit d'ajustement comprend un circuit d'entraînement (109) comprenant au moins un convertisseur de tension en intensité pour fournir au moins une intensité d'entraînement à l'au moins une DEL de manière à commander l'au moins un paramètre de la lumière générée.

32. Appareil selon la revendication 31, dans lequel l'au moins un convertisseur de tension en intensité comprend un amplificateur opérationnel (UIA) configuré de manière à avoir une tension d'erreur prédéterminée appliquée à travers ses entrées sans inversion et avec inversion pendant le fonctionnement pour essentiellement réduire à zéro une sortie d'intensité de l'au moins un convertisseur de tension en intensité lorsqu'une tension appliquée à l'au moins un convertisseur de tension en intensité est essentiellement nulle.

33. Procédé d'illumination, comprenant un acte consistant à :

A) fournir du courant continu à l'au moins une DEL (104) sur la base d'un signal se rapportant au courant fourni par une source de courant alternatif ayant des composants de fréquence supérieure à une tension de ligne de courant alternatif standard,

caractérisé en ce que les composants de fréquence supérieure sont filtrés du signal se rapportant au courant avant de fournir du courant continu à l'au moins une DEL (104).

34. Procédé d'illumination selon la revendication 33, dans lequel l'acte A) comprend un acte consistant à :

fournir le courant continu à l'au moins une DEL (104) sur la base d'un signal se rapportant au courant émanant du circuit de gradateur de courant alternatif.

35. Procédé selon la revendication 34, dans lequel le circuit de gradateur de courant alternatif est commandé par une interface utilisateur pour faire varier le signal se rapportant au courant, et dans lequel l'acte A) comprend un acte consistant à :

B) fournir un courant essentiellement non variable à l'au moins une DEL (104) sur une plage significative de fonctionnement de l'interface utilisateur.

36. Procédé selon la revendication 35, dans lequel le fonctionnement de l'interface utilisateur fait varier un cycle d'usage du signal se rapportant au courant, et dans lequel l'acte B) comprend un acte consistant à fournir le courant essentiellement non variable à l'au moins une DEL (104) sur une plage significative de fonctionnement de l'interface utilisateur indépendamment des variations du cycle d'usage du signal se rapportant au courant.

37. Procédé selon la revendication 35, dans lequel l'acte B) comprend les actes consistant à :

redresser le signal se rapportant au courant pour fournir un signal se rapportant au courant redressé ;
filtrer le signal se rapportant au courant redressé ; et fournir le courant essentiellement non variable sur la base du signal se rapportant au courant redressé filtré.

38. Procédé selon la revendication 35, dans lequel l'au moins une DEL comprend une pluralité de DEL de couleurs différentes.

39. Procédé selon la revendication 34, dans lequel le circuit de gradateur de courant alternatif est com-

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mandé par une interface utilisateur pour faire varier le signal se rapportant au courant, et dans lequel l'acte A) comprend un acte consistant à :

C) commander de manière variable au moins un paramètre de la lumière générée par l'au moins une DEL (104) en réponse au fonctionnement de l'interface utilisateur.

40. Procédé selon la revendication 39, dans lequel le fonctionnement de l'interface utilisateur fait varier un cycle d'usage du signal se rapportant au courant, et dans lequel l'acte C) comprend un acte consistant à :

D) commander de manière variable l'au moins un paramètre de la lumière sur la base au moins du cycle d'usage variable du signal se rapportant au courant.

41. Procédé selon la revendication 39, dans lequel l'acte D) comprend un acte consistant à : commander de manière variable au moins l'une d'une intensité de la lumière, d'une couleur de la lumière, d'une température de couleur de la lumière et d'une caractéristique temporale de la lumière en réponse au fonctionnement de l'interface utilisateur.

42. Procédé selon la revendication 39, dans lequel l'acte D) comprend un acte consistant à :

E) commander de manière variable au moins deux paramètres différents de la lumière générée par l'au moins une DEL (104) en réponse au fonctionnement de l'interface utilisateur.

43. Procédé selon la revendication 42, dans lequel l'acte E) comprend un acte consistant à :

commander de manière variable au moins une intensité et une couleur de la lumière simultanément en réponse au fonctionnement de l'interface utilisateur.

44. Procédé selon la revendication 42, dans lequel l'au moins une DEL (104) est configurée pour générer une lumière essentiellement blanche, et dans lequel l'acte E) comprend un acte consistant à :

F) commander de manière variable au moins une intensité et une température de couleur de la lumière blanche simultanément en réponse au fonctionnement de l'interface utilisateur.

45. Procédé selon la revendication 44, dans lequel l'acte F) comprend un acte consistant à :

G) commander de manière variable au moins l'intensité et la température de couleur de la lumière essentiellement blanche en réponse au fonctionnement de l'interface utilisateur de manière à approximer les caractéristiques de génération de lumière d'une source de lumière incandescente.

46. Procédé selon la revendication 45, dans lequel l'acte G) comprend un acte consistant à :

commander de manière variable la température de couleur de la lumière essentiellement blanche sur une plage d'une intensité minimale d'environ 2000 degrés K à une intensité maximale d'environ 3200 degrés K.

47. Procédé selon la revendication 46, dans lequel l'au moins une DEL comprend une pluralité de DEL de couleurs différentes.

48. Procédé selon la revendication 39, dans lequel l'acte C) comprend un acte consistant à :

H) échantillonner numériquement le signal se rapportant au courant variable et déterminer au moins une caractéristique variable du signal se rapportant au courant variable.

49. Procédé selon la revendication 48, dans lequel le fonctionnement de l'interface utilisateur fait varier un cycle d'usage du signal se rapportant au courant, et dans lequel l'acte H) comprend un acte consistant à :

commander de manière variable l'au moins un paramètre de la lumière sur la base au moins du cycle d'usage variable du signal se rapportant au courant échantillonné.

50. Procédé selon la revendication 39, dans lequel :

l'au moins une DEL (104) comprend :
au moins une première DEL (104A, 104B, 104C) apte à délivrer au moins un premier rayonnement ayant un premier spectre ; et
au moins une seconde DEL (104A, 104B, 104C) apte à délivrer un second rayonnement ayant un second spectre différent du premier spectre ; et
l'acte C) comprend un acte consistant à :

I) commander de manière indépendante au moins une première intensité du premier rayonnement et une seconde intensité du second rayonnement en réponse au fonctionnement de l'interface utilisateur.

51. Procédé selon la revendication 50, dans lequel l'acte I) comprend un acte consistant à :

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J) mettre en oeuvre une technique de modulation de largeur d'impulsion (PWM) pour commander au moins la première intensité du premier rayonnement et la seconde intensité du second rayonnement.

52. Procédé selon la revendication 51, dans lequel l'acte J) comprend les actes consistant à :

générer au moins un premier signal PWM pour commander la première intensité du premier rayonnement et un second signal PWM pour commander la seconde intensité du second rayonnement ; et
déterminer des cycles d'usage des premier et second signaux PWM respectifs sur la base au moins en partie des variations du signal se rapportant au courant en raison du fonctionnement de l'interface utilisateur.

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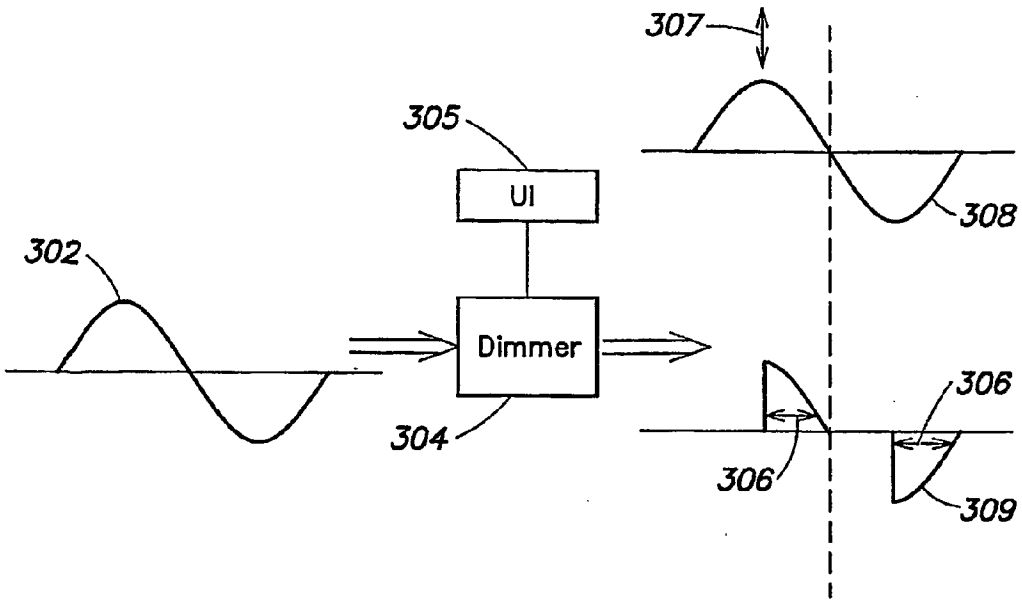


FIG. 1
(PRIOR ART)

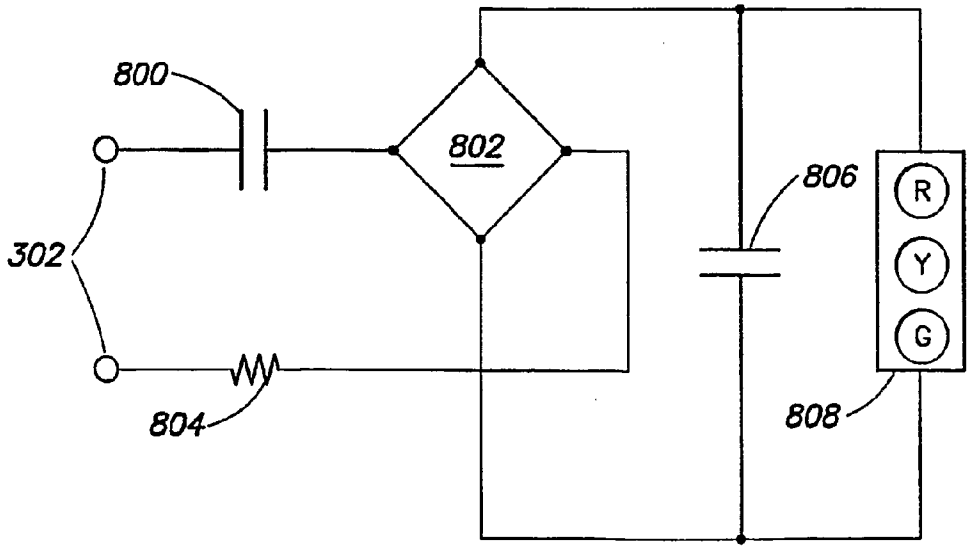


FIG. 2
(PRIOR ART)

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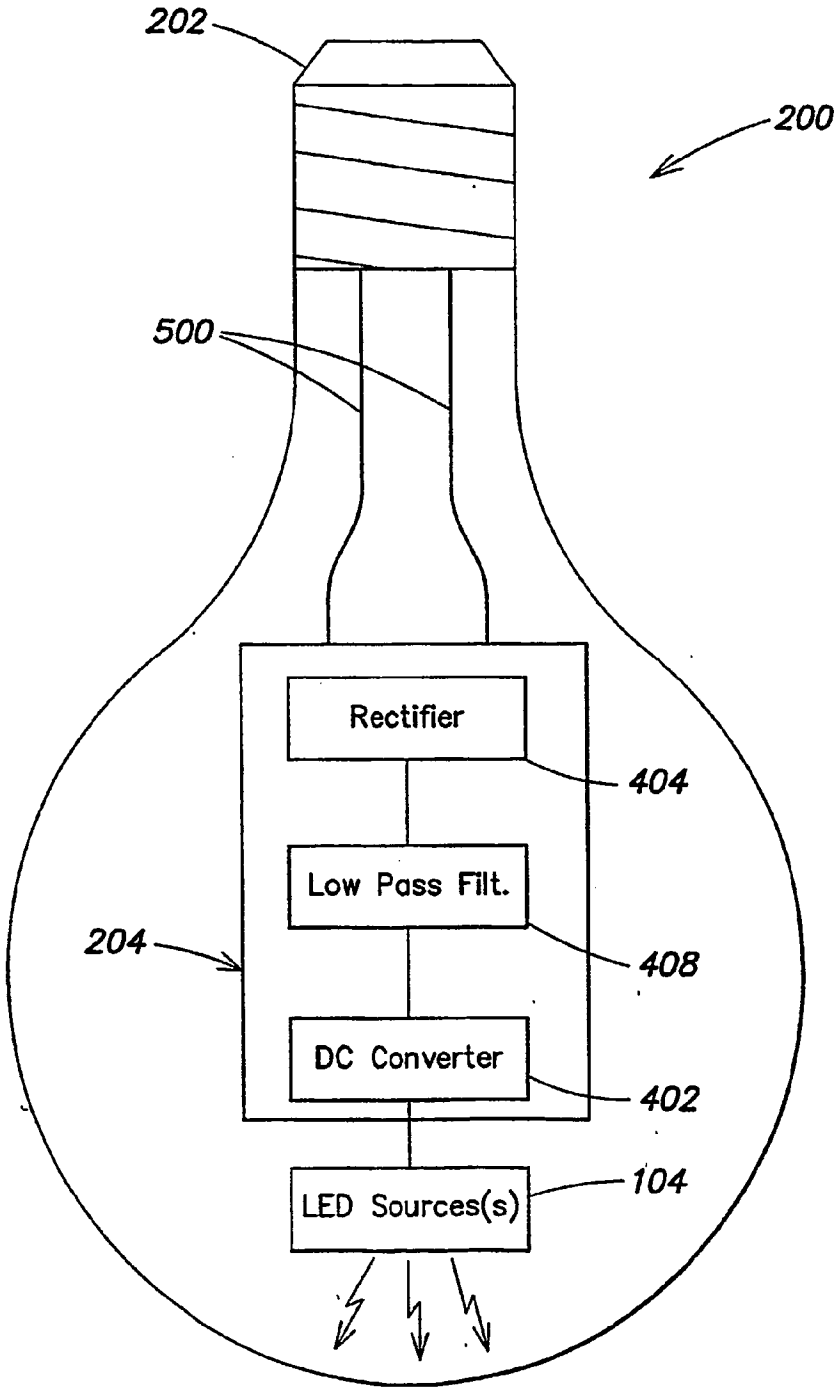


FIG. 3

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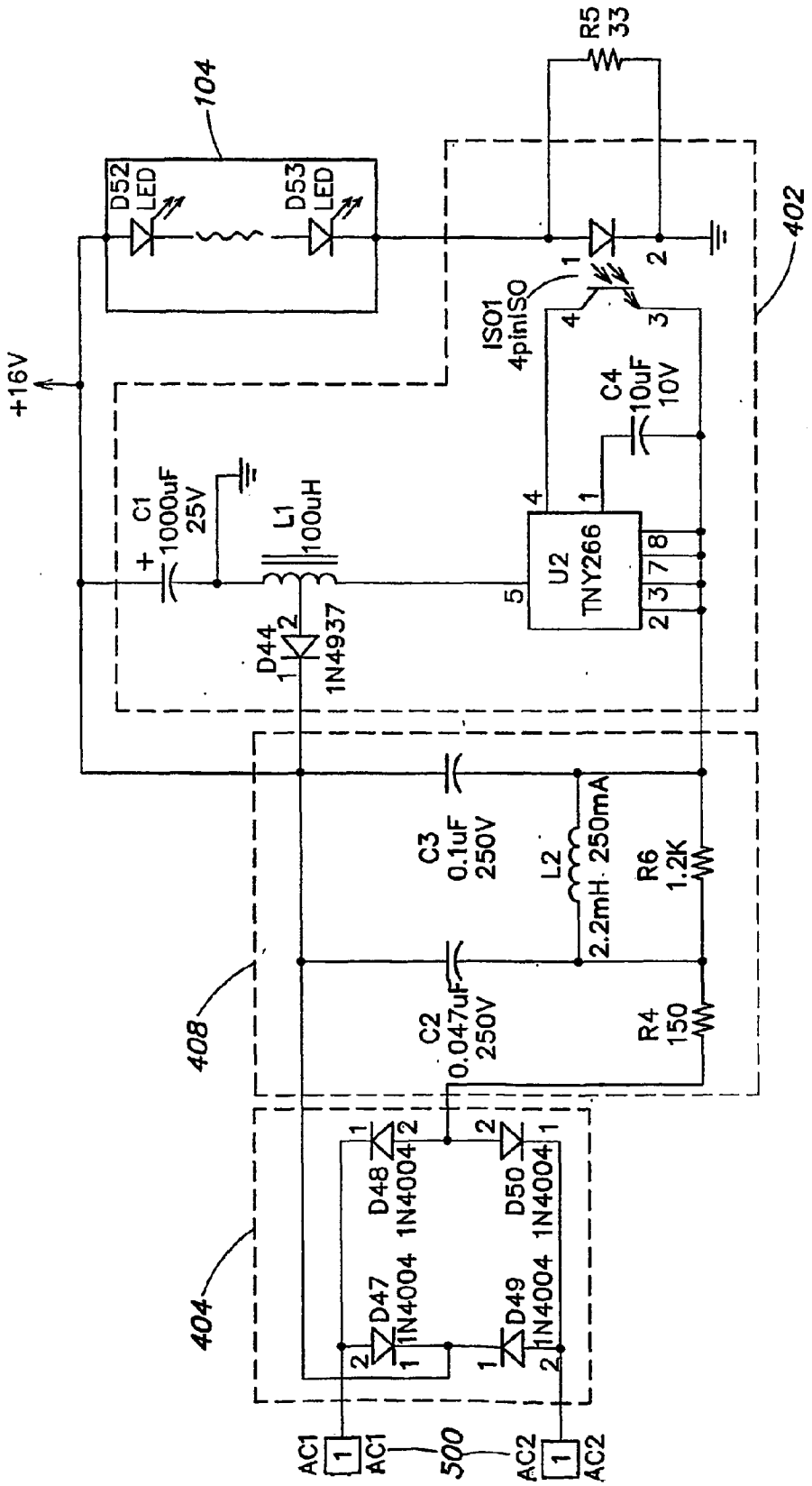


FIG. 4

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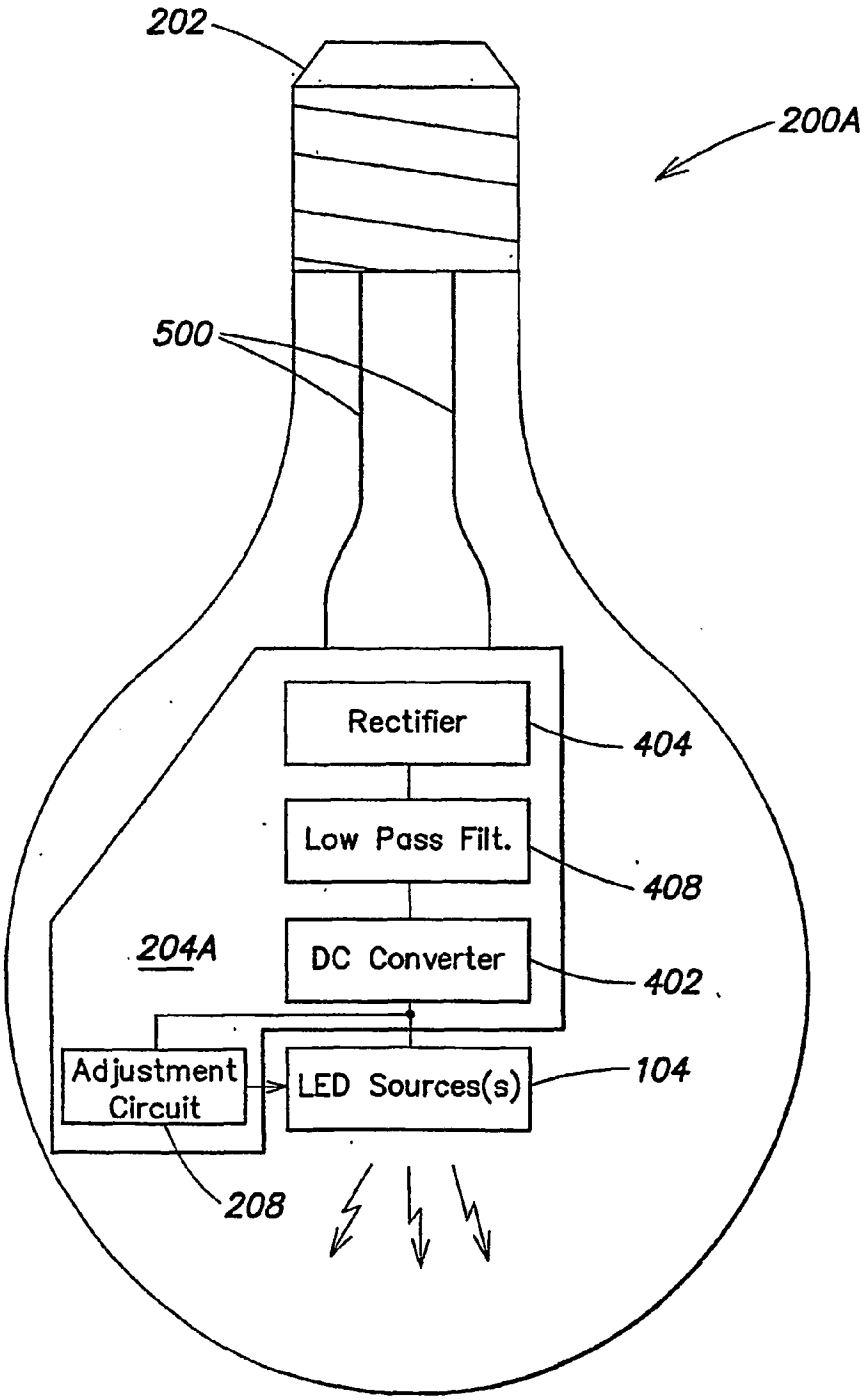


FIG. 5

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Ex. 1003 - Page 1656

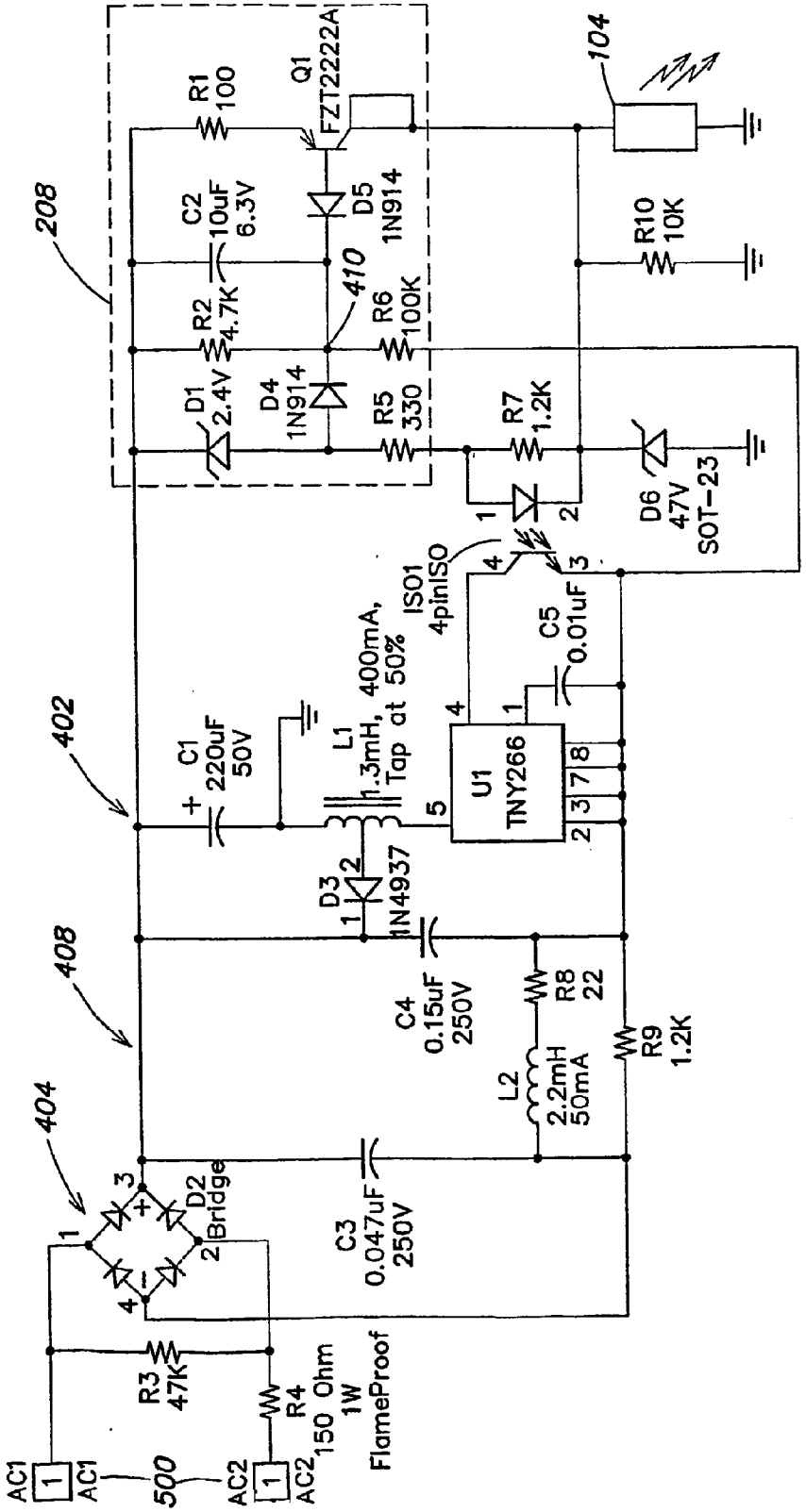


FIG. 6

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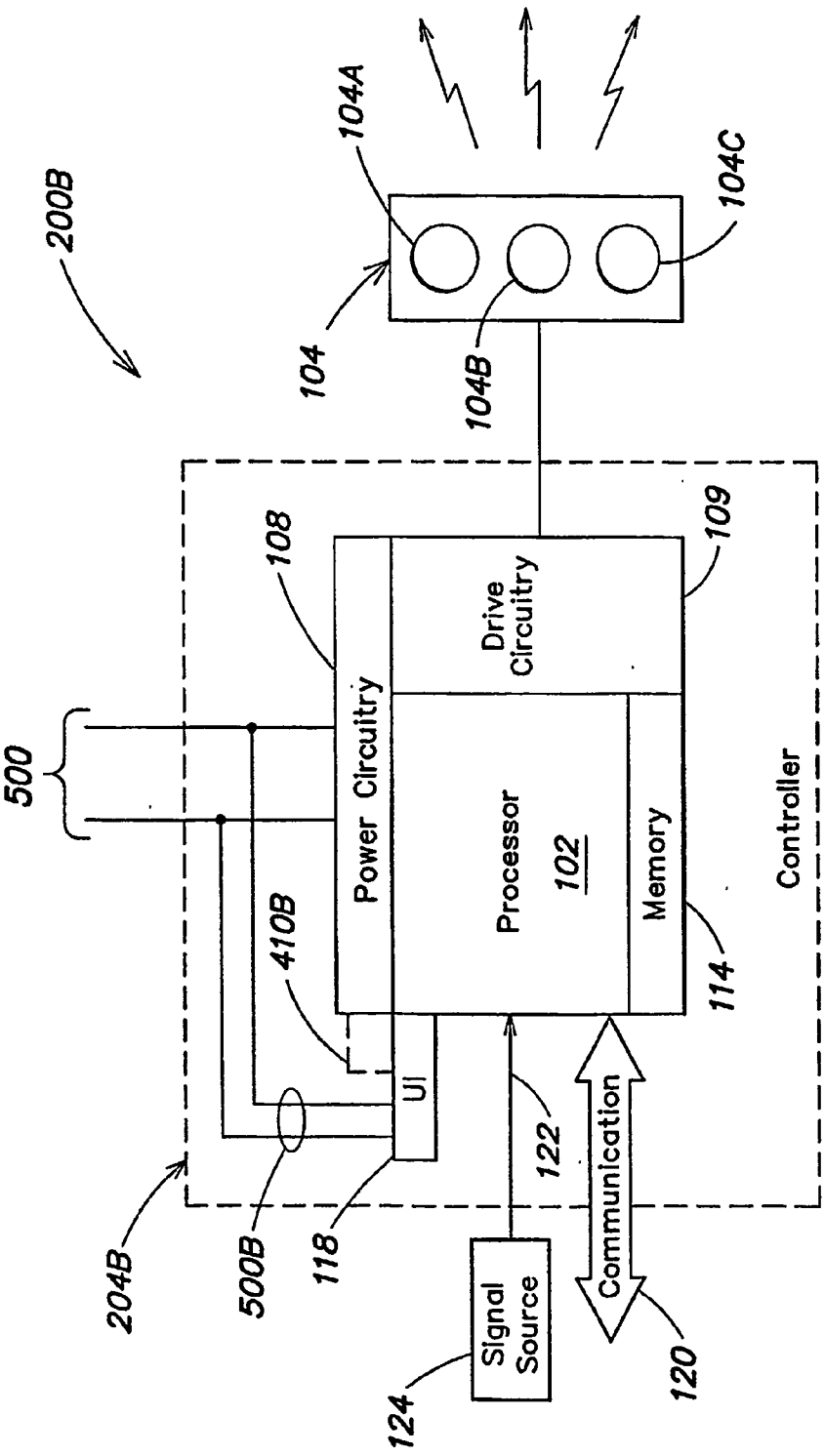


FIG. 7

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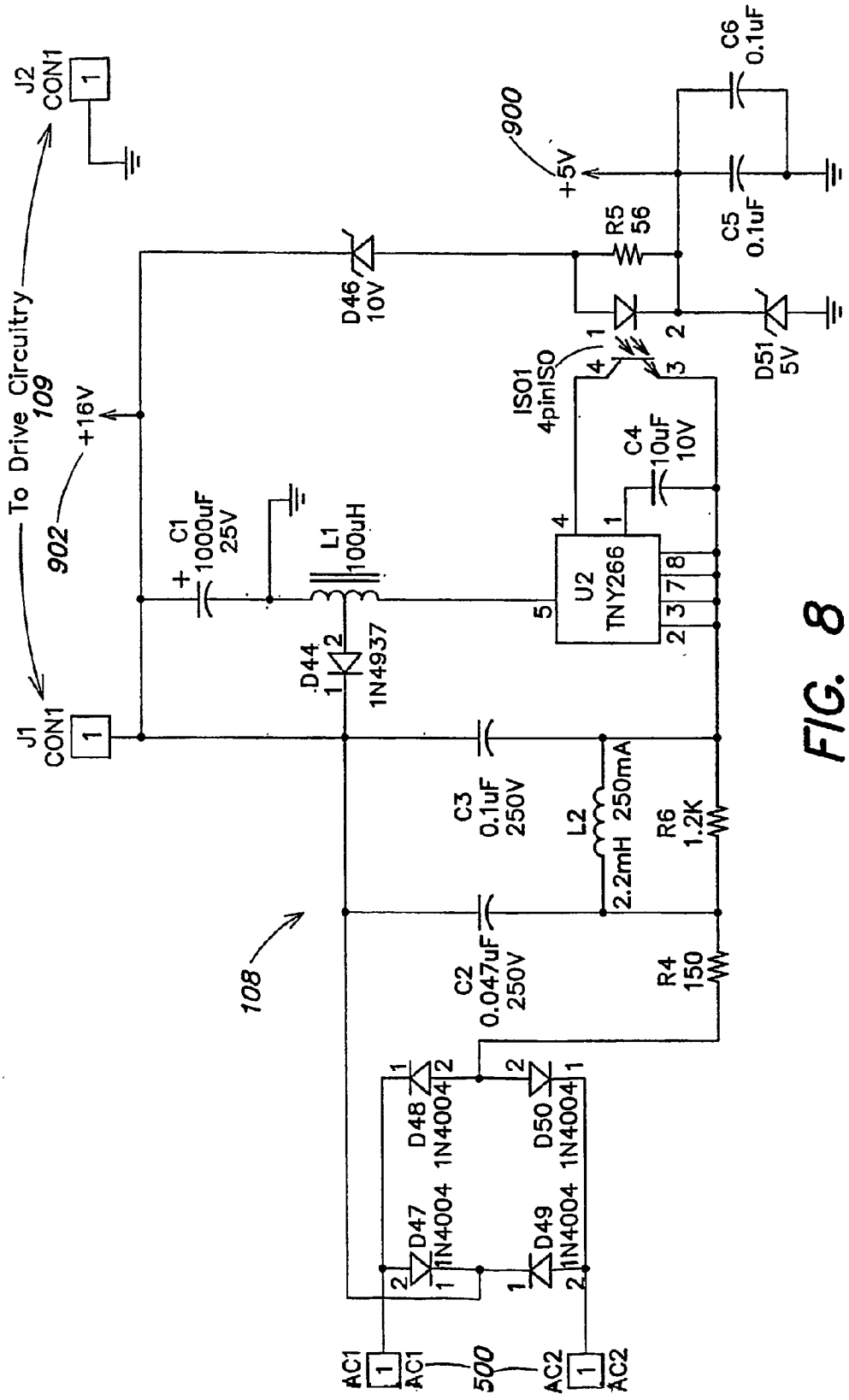


FIG. 8

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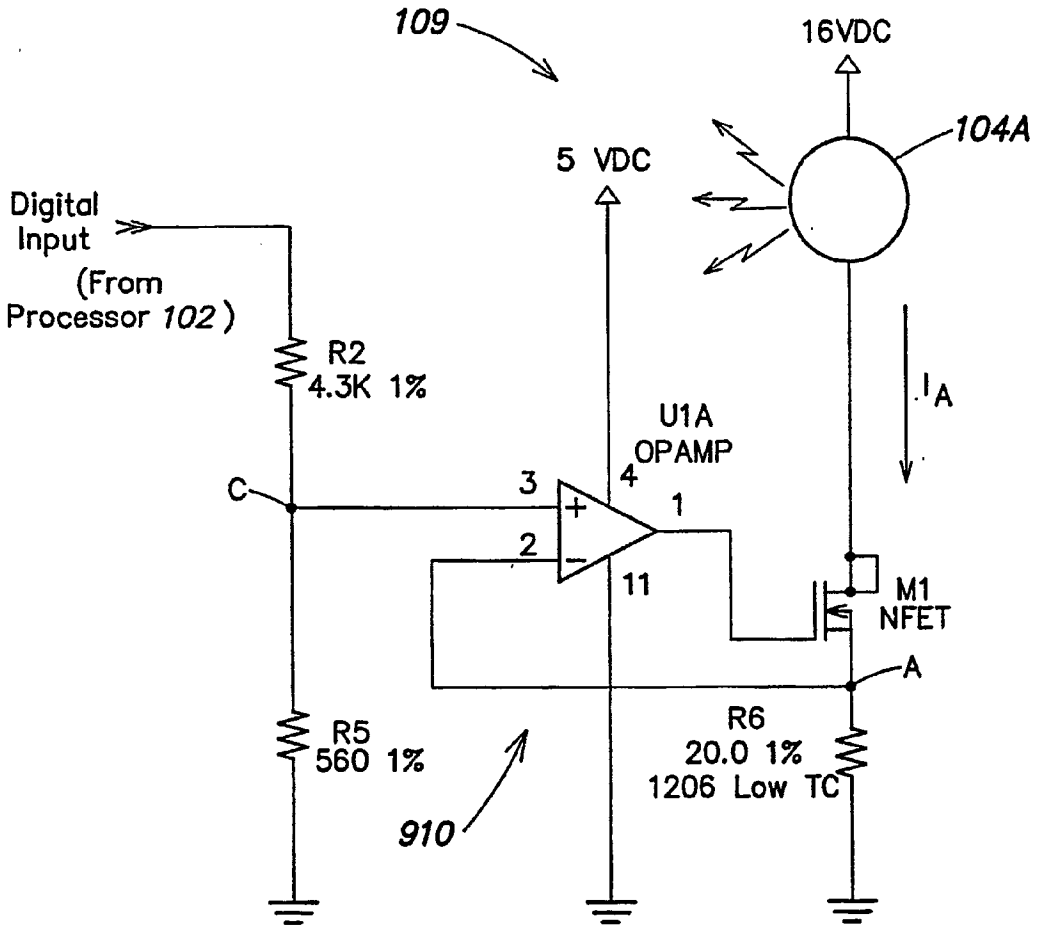


FIG. 9

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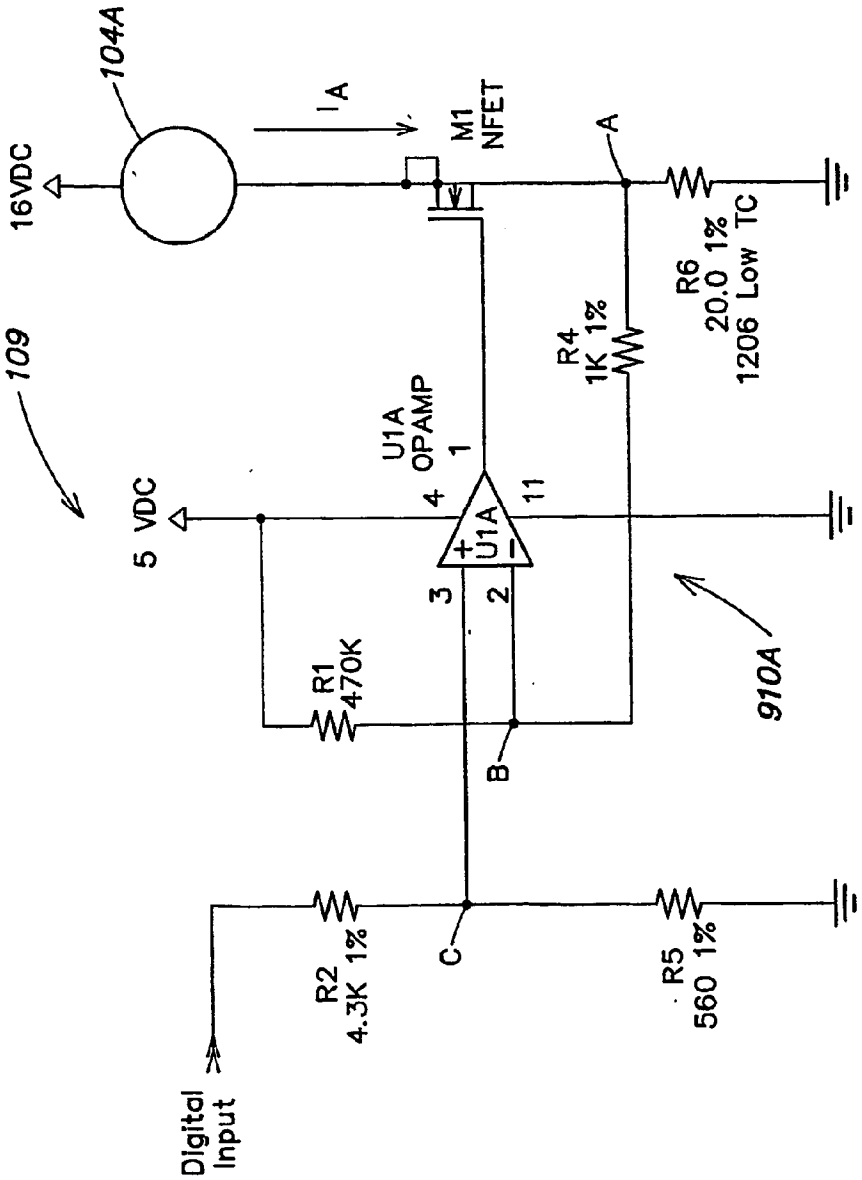


FIG. 10

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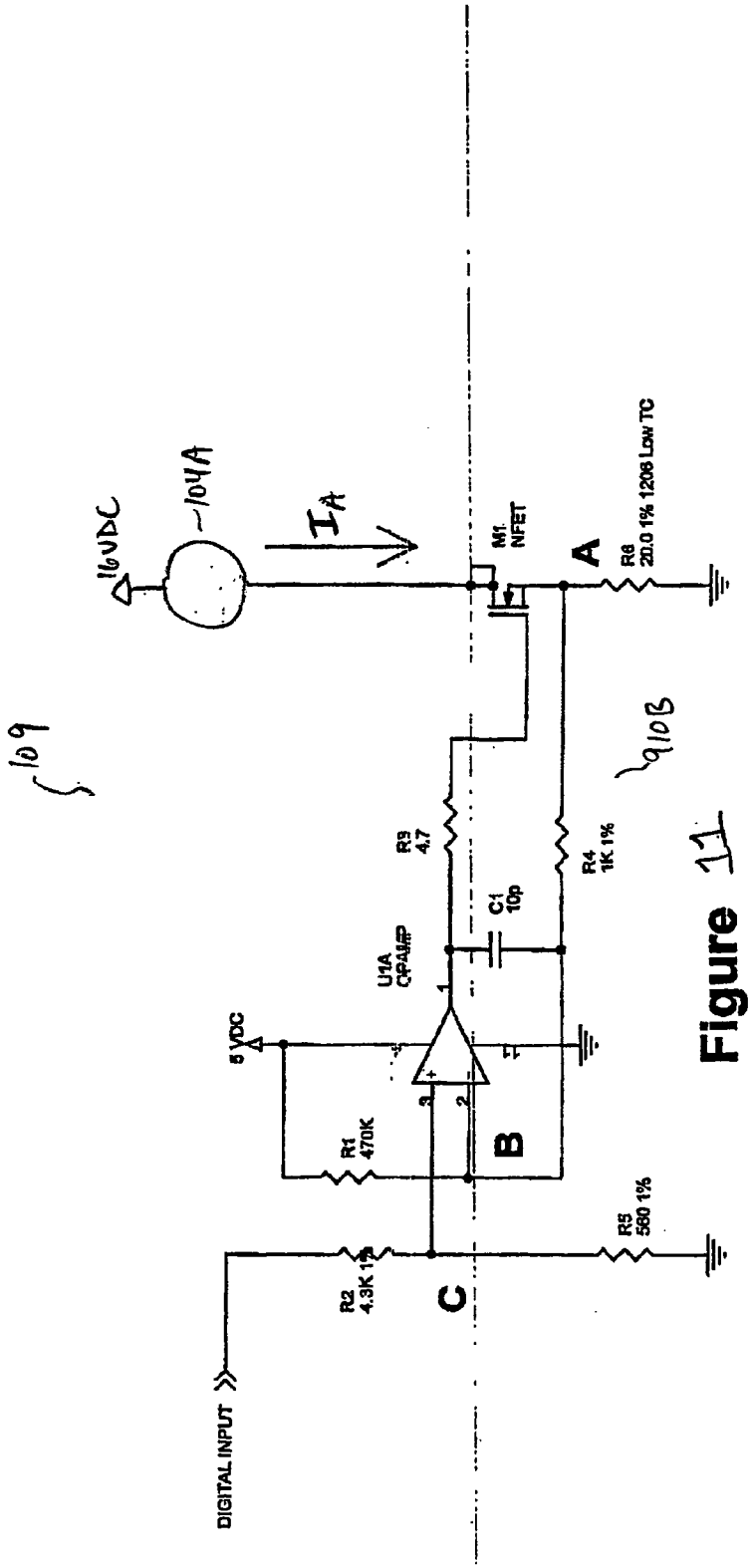


Figure 11

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REFERENCES CITED IN THE DESCRIPTION

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- **THOMAS M. FREDERIKSEN.** *Intuitive IC OPAMPS,* 1984, 186-189 **[0105]**

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(12) UK Patent (19) GB (11) 2 264 555 (13) B

(54) Title of Invention

Flame effect display and method of producing a flame effect

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(52) Domestic classification
(Edition O)
F4W W57

(56) Documents cited
GB2210969 A
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(58) Field of search

As for published application
2264555 A *viz:*
UK CL(Edition L) **F4W**
INT CL[5] **F24C, H05B**
updated as appropriate

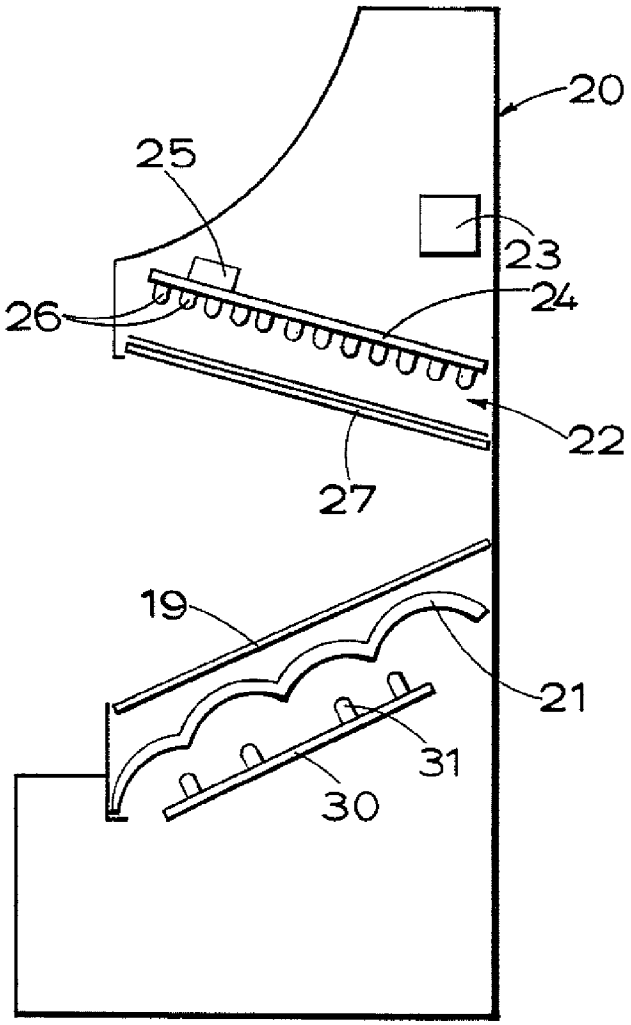


FIG.1.

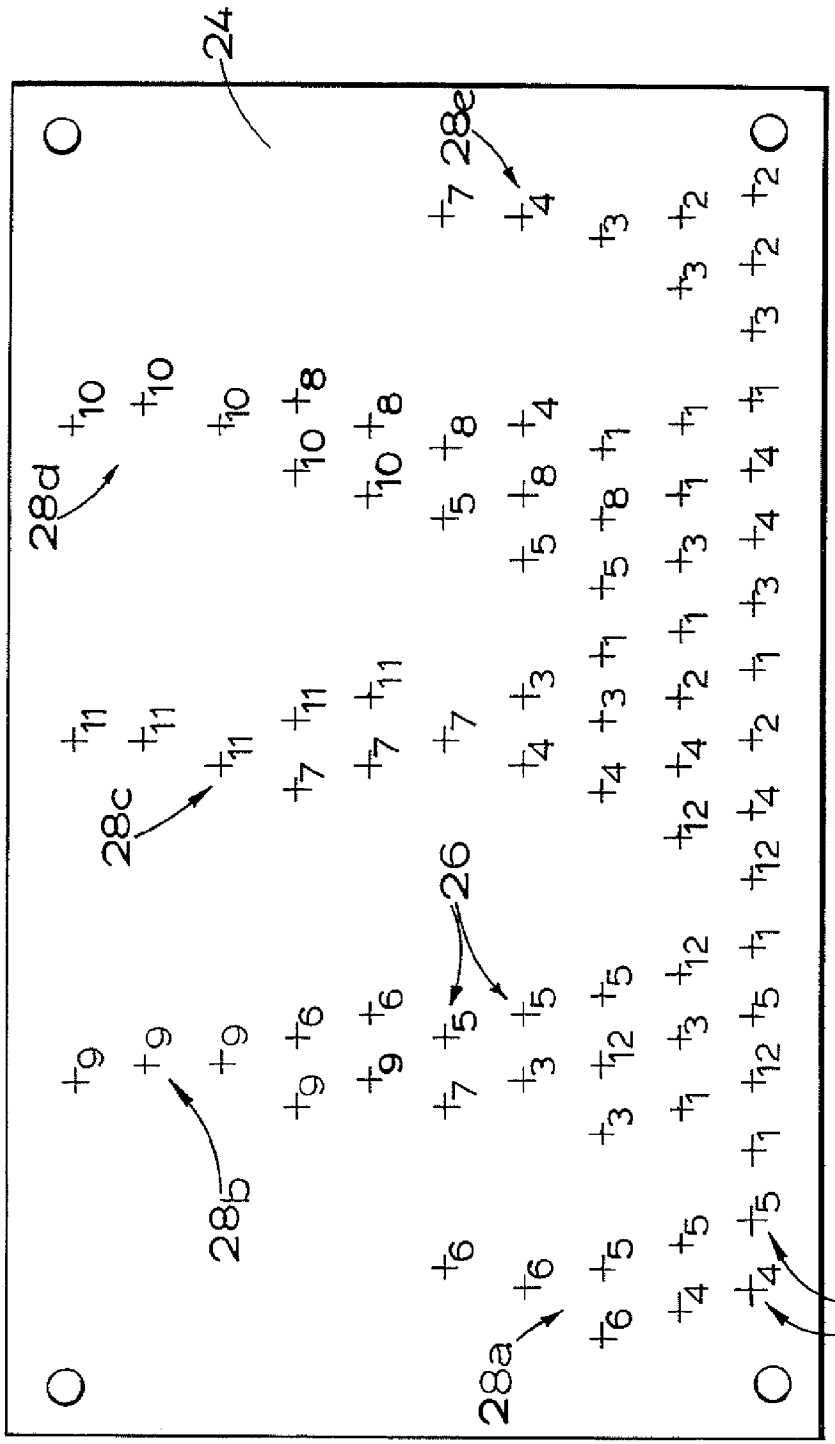


FIG. 2.

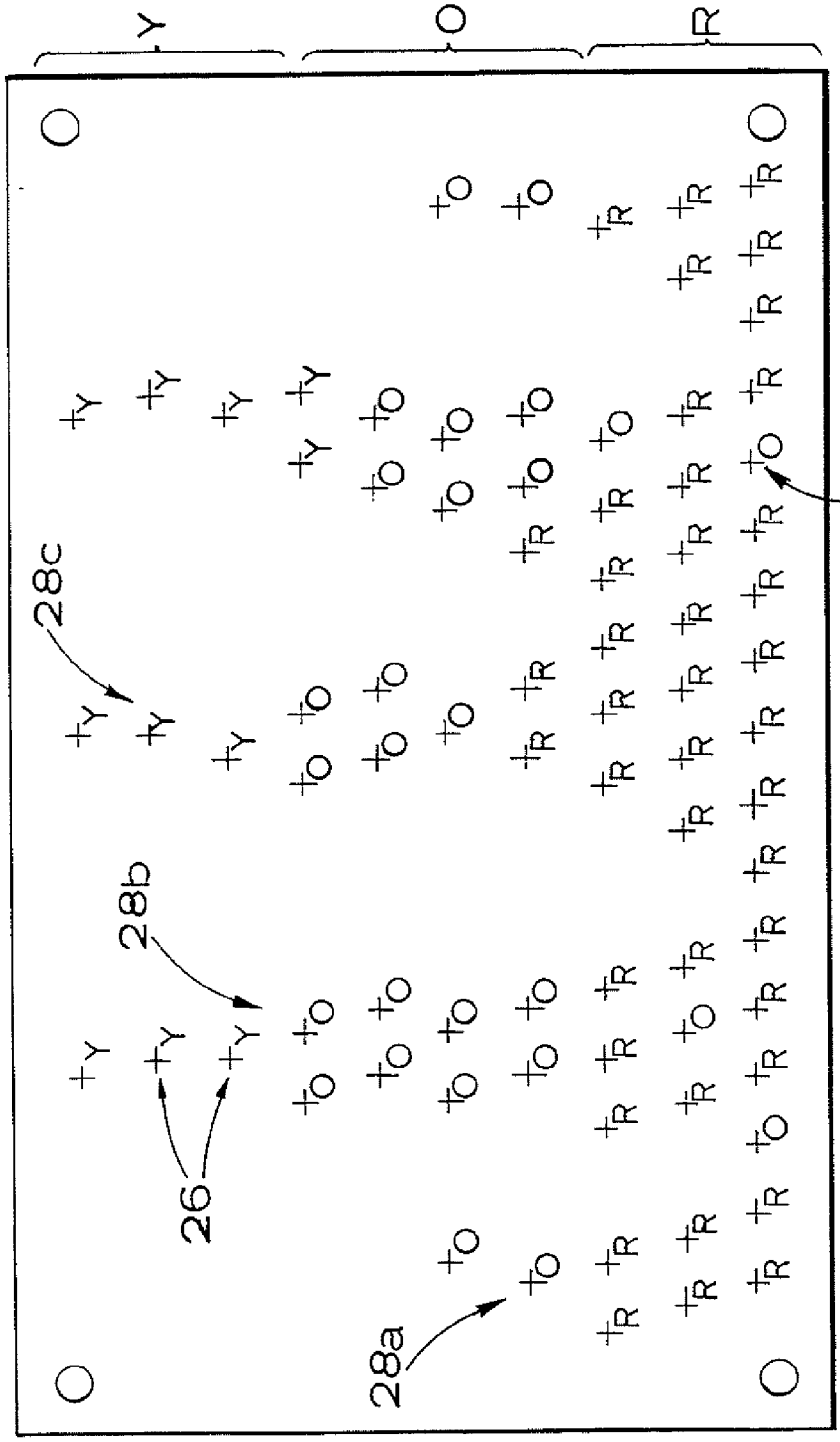


FIG.3.

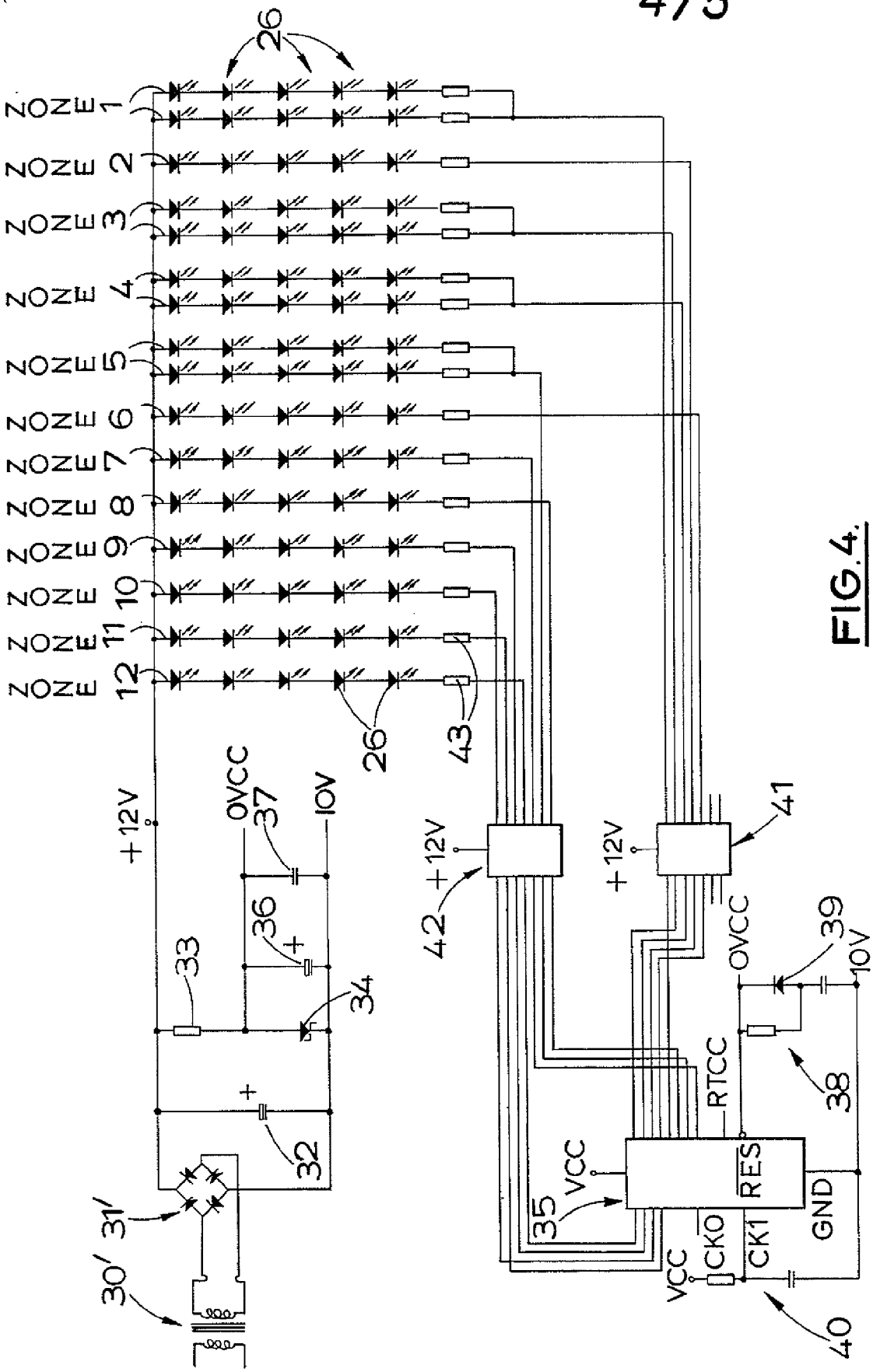

26
ZONE 1
ZONE 2
ZONE 3
ZONE 4
ZONE 5
ZONE 6
ZONE 7
ZONE 8
ZONE 9
ZONE 10
ZONE 11
ZONE 12
26
43
+12V
0VCC
37
10V
36
33
34
32
31
30
42
+12V
+12V
41
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39
10V
38
RTCC
VCC
RES
35
GND
CKO
CK1
VCC
40

FIG. 4.

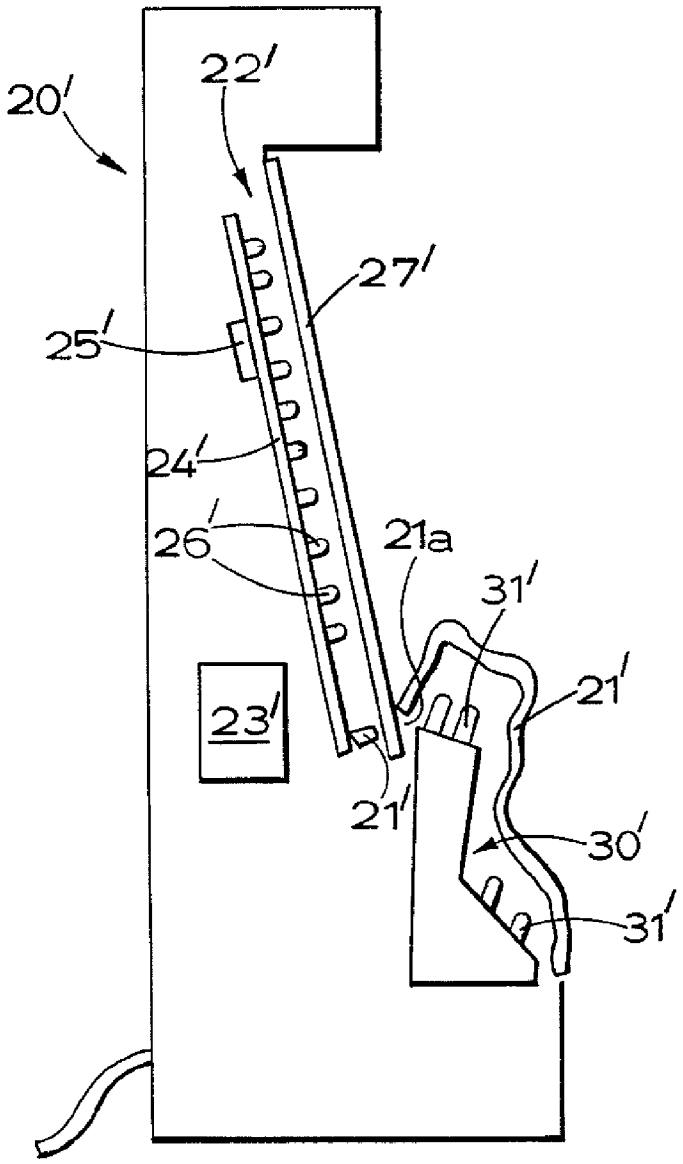


FIG.5.

FLAME EFFECT DISPLAY AND METHOD OF PRODUCING A FLAME EFFECT

This invention relates to mimicking at least one flickering flame.

It is known to simulate a flickering flame in an electrical fire by rotating a reflector in front of light bulbs. The reflector interferes with the direct passage of light to a coal-effect, or log-effect, moulding and simulates flickering, both on the moulding and on a back panel. It is also known from GB 2 232 481 to modulate light from a light source using a different intervening mechanism, namely a randomly or pseudorandomly switched LCD array interposed between a light bulb and a log or coal-effect moulding. Furthermore, we are aware of the proposal set forth in US 4 253 045 in which light bulbs in an array of electric light bulbs are pseudorandomly switched on and off by a controller so as to generate a controlled variable light so as to simulate a flickering light.

According to a first aspect of the invention, there is provided a flame effect display comprising: a plurality of electrically powered light sources arranged to come on and go off in groups; and an electronic controller arranged to control the currents to the light sources so as to cause the groups to come on and go off in such a sequence as to mimic at least one flickering flame.

The light sources may be set out in a grid or regular pattern, but we prefer to arrange them in the shape of one or more flames. This can enable us to use fewer light sources.

Our flame may appear to increase and decrease in size as well as an overall region of the flame increasing and decreasing in intensity. The flame may also be controlled so as to move sideways, for example as if caught by a draught.

The light sources are preferably LED's. We have found that LED's are suitable for simulating a flickering flame, despite a prejudice against them because they generate so little light.

Preferably the display has a diffuser screen provided in front of the light sources.

The light sources may comprise light sources of a first colour and light sources of a second colour. Light sources of a third colour, or further colours, may also be provided.

Preferably, a particular flame of the display includes light sources of more than one colour. When we arrange our lights sources to be in flame shapes a particular flame shape preferably includes light sources of more than one colour.

Light sources in a particular group may be present in different flames of the display, and/or may have different colours. Light sources at the base

of the flames may be of a different colour from those at the top of the flame shapes. A third band of light sources of a third colour may be provided at the central region of the flames. Of course, occasional light sources of the "wrong" colour may be interspersed in a band of generally one colour.

Preferably, the controller is arranged to switch on and off sharply one or more groups of the light sources and to fade on and off more gradually one or more other groups.

Preferably, the display is arranged to produce a shooting flame effect in which a flame, or part of a flame, increases in height rapidly and then dies away again rapidly. The shooting effect may be provided at the uppermost tips of a flame, at the base of a display of flames (thereby comprising what is in effect a separate transient flame), or at any other part of the display. The shooting effect may be of a relatively few (for example one or two) light sources in width.

Preferably, the electronic controller is arranged to cause the groups of light sources to mimic all or part of a life-cycle of a fire, from initial kindling to full burning to dying away to small flames or embers. The life-cycle may take several hours.

Preferably a coal or log, or other fuel, effect display (such as a moulding) is provided adjacent the flame effect display, to produce a combined display.

The flame effect display may extend upwardly from the fuel effect display.

Alternatively, or additionally, a reflective member, such as a sheet, may be provided to reflect light from the flame effect display towards the viewer, and may substantially cover the fuel effect display. This can provide the appearance that the flame(s) are associated with the fuel and gives a realistic simulation of burning fuel.

Preferably the reflective member is partially transparent to enable a viewer to see the fuel effect display.

A viewer situated away from the combined display may only be able to see the flame effect display by means of the reflective member.

The reflective member may be a glass sheet. The arrangement of the reflective sheet may be as described in published Patent Application No. GB 9001104.0, the contents of which are hereby incorporated by reference.

According to a second aspect of the invention, there is provided a fire having a display or combined display in accordance with the first aspect of the invention.

According to a third aspect of the present invention, there is provided a method of producing a flame effect comprising providing a plurality of light sources which are arranged to come on and go off in groups, and controlling

the groups so as to cause them to go on/go off in such a sequence as to mimic at least one flickering flame.

Non-limiting embodiments of the invention will now be described with reference to the accompanying drawings of which:-

Figure 1 schematically represents an electric fire having an electric flame effect display;

Figure 2 illustrates schematically the layout of LED's on a display panel of the fire of Figure 1, showing the LED's in different groups;

Figure 3 is similar to Figure 2, but shows the colours of the LED's;

Figure 4 is a circuit diagram for the display of the fire of Figure 1, and

Figure 5 schematically represents an alternative electric fire having an electric flame effect display.

An electric fire 20 is shown in Figure 1 and has a heating element (not shown), a coal-effect moulding 21, a flame-effect display 22, and a power supply 23 for

the display 22. The display 22 comprises a printed circuit board 24 carrying a controller 25 and eighty LED's 26 and a diffuser screen 27.

The LED's 26 are laid out in the shape of five flames 28a to 28e and are controlled in twelve groups 1 to 12 as shown in Figures 2 and 4. The number of LED's in each of the groups 1 to 12 is shown in Figure 2. LED'S of the groups 1 to 7, and 12, are present in more than one flame 28. LED's of the groups 8 to 11 are present in respective single flames only. Each LED 26 of a particular group is controlled by the controller 25 in the same way. It will be seen that many of the groups of LED's are interwoven on the display.

The controller 25 controls the LED's of groups 1 to 8 so as to change the light output from them relatively gradually (fade them in and out), but groups 9 to 12 are arranged to be switched on and off abruptly. This abrupt, sharp, switching simulates brief flickering or shooting, usually associated with the tops of flames. The more gradual changes of the heart of the fire are reproduced by groups 1 to 8.

Figure 3 shows the colours of the LED's 26. The LED's are, of course, represented by crosses and the colours by the letters O (Orange), R (Red), and Y (Yellow). The colours are predominantly in three horizontal bands, red, orange, and yellow as the height of the flame increases. There are exceptions to this general rule, such as the LED referred as 29 in Figure 3. It will be noted that some groups have LED's of more than one colour. For example, group 4 has seven red LED's and three orange LED's, and group 9 had three yellow LED's and two orange LED's.

Figure 4 shows the electronic circuit for the printed circuit board 24.

A mains transformer 30' steps the mains supply down to about 15.5V AC. The mains transformer is included in the power supply 23. A bridge rectifier 31' and smoothing capacitor 32 produce a fairly smooth DC voltage of about 15 volts to supply the LED's 26. A dropper resistor 33 and zener diode 34 provide a 5V rail for a microcontroller 35. This is smoothed by a capacitor 36 and protected against noise by a further capacitor 37.

The microcontroller 35 has a conventional reset circuit 38 and with protection against residual voltage on the capacitor being provided by a diode 39. A clock is provided by the RC circuit 40. The resistor of the RC circuit 40 could be replace by a potentiometer to give some speed variation of the flame effect. This speed variation could be manually controllable by the end user, or could be set upon manufacture of the fire.

Driver circuits 41 and 42 are used to provide increased voltage and current levels to the LED's. The LED's are supplied in fives, each set of five having a current limiting resistor 43. These sets of five are driven by the microcontroller. The resistors 43 need not all be the same, different value resistors can give different sets of LED's different intensities.

It will be appreciated that in the specific example described the groups 1-12 contain a integral number of sets of five LED'S.

The power supply 23 generates a 15.5v supply and may be mounted on the circuit board 24 if desired.

In operation, the controller 25 (comprising the microprocessor 35 and its associated driver circuits 41 and 42) switches on groups of LED's either individually or as combinations of more than one group. The described features are blended by the manufacturer through experimentation to combine to give the desired visual effect. The sequence of operation of the LED's can be quite long and complex and as such can mimic the variable intensity and vertical, and possibly horizontal, movement of a flame.

The precise switching details for the groups 1-12 are not central to the invention since deciding upon the group switching frequencies and order is a subjective exercise well within the capabilities of the skilled practitioner: what looks attractive to one man may not be quite right for another. However, the present invention allows us to mimic a real flame in that the apparent size of our flames 28a to 28e can be varied by turning on only the LED's at their lower, central, or upper regions, and their apparent intensity as seen by the user can be varied by having more or fewer of spatially adjacent groups of LED'S in a flame on simultaneously. For example, flame 28d will appear wider and brighter if groups 5, 8 and 10 are on, whereas if group 8 is off it will appear dimmer.

The diffuser assists this effect, and indeed the diffuser makes the fire look far more realistic than if we were to have the LED's viewed directly.

The flame-effect display 22 is mounted in the upper portion of the electric fire 20. The diffuser 27 is mounted to face generally downwards, towards a fuel display 30.

The fuel display 30 is in the lower portion of the electric fire 20 and is provided adjacent the moulding 21. A sheet of glass 19 is inclined at an angle in front of the moulding 21, and this sheet faces generally towards the flame effect display 22. The display 30 has an array of light sources 31, which may be LED's, but which are in this case light bulbs. The bulbs 31 are controlled by the controller 25 (or a separate controller) so as to come on and go off, and possibly to be at varying levels of brightness, so as to give the effect of the coals of the moulding 21 glowing more or less brightly. Different regions of the coals will, of course, glow more brightly than other regions at any one particular time, but at another moment the relative intensity of the two coal regions could be completely different, possibly even reversed. The changes in the glowing "coals" may be arranged to be associated with corresponding changes in the flames of the display 22. For example, a particular coal may appear to glow brightly when a "shooting" flame appears above or near it.

When the two displays are in operation, an observer will be able to see clearly the moulding 21 through the sheet 19. The glowing "coals" will be visible. In addition the flame-effect produced by display 22 will be reflected to the observer by the sheet 19 and it will appear as though flames are dancing over the "coals" themselves. In this arrangement the flame-effect appears realistic.

The displays 22 and 30 may be separate integral units with their own electronic controllers so that a range of fuel displays and a range of flame displays could be used in a wide variety of combinations.

Figure 5 shows an alternative electric fire 20' which is similar to that of Figure 1 and similar structures have been given similar reference numerals.

The fire 20' has a fuel effect moulding 21' which is not covered by a sheet of glass and can be observed directly. A flame effect display 22' extends generally upwards from the rear of the moulding 21' so that flames can be seen above the moulding 21'. A diffuser 27' extends through, or is received in, a hole 21a in the moulding 21'. An observer of the fire 20' will see glowing coals provided by the fuel effect 30' with a flickering flame effect above the coals. It will be appreciated that the circuit board 24' and the arrangement of LED's 26' is as shown in Figures 2 to 4.

The fuel effect display 30' has an array of light sources 31', which may be LED's but which are in this case light bulbs. The bulbs 31' are controlled by the controller 23' (or a separate controller) so as to come on and go off, and possibly to be at varying levels of brightness, so as to give the effect of the coals of the moulding 21' glowing more or less brightly. Different regions of the coals will, of course, glow more brightly than other regions at any one particular time, but at another moment the relative intensity of the two coal regions could be completely different, possibly even reversed. The changes in the glowing "coals" may be arranged to be associated with corresponding changes in the flames of the flame effect display 22'. For example, a particular coal may appear to glow brightly when a "shooting" flame appears above or near it.

The displays 22' and 30' may be separate integral units with their own electronic controllers so that a range of fuel displays and a range of flame displays could be used in a wide variety of combinations.

An example of the way that the control software (or hardware) for the flame effect could operate in either of the fires shown in Figure 1 or Figure 5 is as follows:-

The groups of LED's may have a main sequence cycle of about 250 (say 248) on/off patterns or states which the controller 25 cycles them through. A counter (not shown) counts down from 25 (giving 24 cycles to zero) and then introduces a "lull" in which the tips of some of the flames, say groups 8, 9 and 7, are not illuminated during the next cycle. The counter then resets to 25 and counts down again. Upon initial power up the counter is set to 2.

The controller 25 may include a test function to test that the board 24 is fully operative. This would be useful during the manufacture of the fire.

The fade feature described earlier can be achieved by transferring the on/off state data for some groups of LED's (say groups 1 to 8) to one of a number (say 8) of registers. As a new illumination pattern is reached in the LED lamp sequence table it is fed into the first register, registers 2 to 8 holding the previous pattern. The controller controls the LED's to show the patterns of registers 1 to 8 in sequence for a time, so that the new pattern is shown initially for 1/8 of the time, and the old pattern for 7/8 of the time. Each time that the sequence 1 to 8 of the fade registers is complete the controller rolls the contents of the

registers down one, so that on the second pass the ratio of new pattern to old pattern is 2: 6, on the third 3: 5, and so on.

The fade routine is used each time an LED in the group 1 to 8 changes from ON to OFF or OFF to ON producing a softening or glimmering effect.

There is, of course, a delay routine between execution of successive LED lamp patterns, so that the LED's stay fixed in a particular pattern for a predetermined time.

CLAIMS

1. A flame effect display comprising:

a plurality of electrically powered light sources arranged to come on and go off in groups; and

an electronic controller arranged to control the currents to the light sources so as to cause the groups to come on and go off in such a sequence as to mimic at least one flickering flame.

2. A display according to claim 1 in which the light sources are arranged in the shape of at least one flame.

3. A display according to claim 2 in which the controller is arranged to control the groups of light sources so as to make the flame or flames increase or decrease in size.

4. A display according to any preceding claim which is provided with a diffuser screen in front of the light sources.

5. A display according to any preceding claim in which the light sources comprise light sources of a first colour and light sources of a second colour.

6. A display according to claim 5 in which light sources of further colours are provided.

7. A display according to any preceding claim in which the controller is arranged to switch on and off sharply one or more groups of the light sources and to fade on and off more gradually one or more other groups.

8. A display according to any preceding claim in which the controller is arranged to cause the groups of light sources to mimic all or part of a life-cycle of a fire, from initial kindling to full burning to dying away to small flames or embers.

9. A display according to any preceding claim in which each light source is an LED.

10. A combined display comprising a flame effect display according to any preceding claim and a fuel effect display provided adjacent the flame effect display.

11. A combined display according to claim 10 in which the flame effect display extends upwardly from the fuel effect display.

12. A combined display according to claim 10 or claim 11 in which a reflective member substantially covers the fuel effect display and is arranged to reflect light from the flame effect display towards a viewer.

13. A combined display according to claim 12 in which the reflective member is partially transparent to enable a viewer to see the fuel effect display.

14. A display or combined display substantially as described herein with reference to Figures 1, 2, 3 and 5 of the accompanying drawings.

15. A fire having a display or combined display in accordance with any one of the preceding claims.

16. A fire substantially as described herein with reference to Figures 1, 2, 3 and 5 of the accompanying drawings.

17. A method of producing a flame effect comprising providing a plurality of light sources which are arranged to come on and go off in groups, and controlling the groups so as to cause them to go on/go off in such a sequence as to mimic at least one flickering flame.

18. A method according to claim 17 in which each light source is an LED.

19. A method of producing a flame effect substantially as described herein with reference to Figures 2, 3 and 4 of the accompanying drawings.

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(54) **Power surface mount light emitting die package**

Oberflächenmontiertes Gehäuse für lichtemittierenden Leistungschip

Ensemble de puces photoémettrices de puissance à montage en surface

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Description

[0001] The present invention relates to a light-emitting die package.

[0002] From U.S. 2002/0084462 A1 a light-emitting die package is known which includes a light emitter, a light reflection member, and a resin sealing the light emitter by covering the light reflection member and the light emitter. Light deviated from a predetermined front region in the light emitted from the light emitter is totally reflected by a boundary surface of the resin to be forwardly emitted by the light reflection member, and the emitter is thermally contacted with the reflection member to dissipate the heat generated from the light emitter. Particularly, the lens is integrally formed with the encapsulating mold resin.

[0003] Light emitting diodes (LEDS) are often packaged within leadframe packages. A leadframe package typically includes a molded or cast plastic body that encapsulates an LED, a lens portion, and thin metal leads connected to the LED and extending outside the body. The metal leads of the leadframe package serve as the conduit to supply the LED with electrical power and, at the same time, may act to draw heat away from the LED. Heat is generated by the LED when power is applied to the LED to produce light. A portion of the leads extends out from the package body for connection to circuits external to the leadframe package.

[0004] Some of the heat generated by the LED is dissipated by the plastic package body; however, most of the heat is drawn away from the LED via the metal components of the package. The metal leads are typically very thin and has a small cross section. For this reason, capacity of the metal leads to remove heat from the LED is limited. This limits the amount of power that can be sent to the LED thereby limiting the amount of light that can be generated by the LED.

[0005] To increase the capacity of an LED package to dissipate heat, in one LED package design, a heat sink slug is introduced into the package. The heat sink slug draws heat from the LED chip. Hence, it increases the capacity of the LED package to dissipate heat. However, this design introduces empty spaces within the package that is be filled with an encapsulant to protect the LED chip. Furthermore, due to significant differences in CTE (coefficient of thermal expansion) between various components inside the LED package, bubbles tend to form inside the encapsulant or the encapsulant tends to delaminate from various portions within the package. This adversely affects the light output and reliability of the product. In addition, this design includes a pair of flimsy leads which are typically soldered by a hot-iron. This manufacturing process is incompatible with convenient surface mounting technology (SMT) that is popular in the art of electronic board assembly.

[0006] In another LED package design, the leads of the leadframe package have differing thicknesses extended (in various shapes and configurations) beyond the immediate edge of the LED package body. A thicker lead is utilized as a heat-spreader and the LED chip is mounted on it. This arrangement allows heat generated by the LED chip to dissipate through the thicker lead which is often connected to an external heat sink. This design is inherently unreliable due to significant difference in coefficient of thermal expansion (CTE) between the plastic body and the leadframe material. When subjected to temperature cycles, its rigid plastic body that adheres to the metal leads experiences high degree of thermal stresses in many directions. This potentially leads to various undesirable results such as cracking of the plastic body, separation of the plastic body from the LED chip, breaking of the bond wires, delaminating of the plastic body at the interfaces where it bonds to various parts, or resulting in a combination of these outcomes. In addition, the extended leads increase the package size and its footprint. For this reason, it is difficult to populate these LED packages in a dense cluster on a printed circuit board (PCB) to generate brighter light.

[0007] Another disadvantage of the current leadframe design is that the thick lead cannot be made or stamped into a fine circuit for flip-chip mounting of a LED - which is commonly used by some manufacturers for cost-effective manufacturing and device performance.

[0008] Consequently, there remains a need for an improved LED package that overcomes or alleviates one or more of the shortcomings of the prior art packages.

SUMMARY

[0009] The need is met by the present invention as defined in independent claim 1. Embodiments of the present invention provide a package for a semiconductor die such as a light emitting diode, the package including a substrate having traces for connecting to a light emitting diode at a mounting pad, a reflector plate coupled to the substrate and substantially surrounding the mounting pad, and lens substantially covering the mounting pad.

[0010] Other embodiments of the present invention provide a semiconductor die package includes a bottom heat sink and a top heat sink. The bottom heat sink has traces on its top surface. A semiconductor chip is mounted on the top surface of the bottom heat sink and electrically connected to the traces. The top heat sink is coupled to the bottom heat sink.

[0011] Other aspects and advantages of the present invention will become apparent from the following detailed description, taken in conjunction with the accompanying drawings, illustrating by way of example the principles of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] Figure 1A is a perspective view of a semiconductor die package according to one embodiment of the present invention;

[0013] Figure 1B is an exploded perspective view of

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the semiconductor package of Figure 1A;

[0014] Figure 2A is a top view of a portion of the semiconductor package of Figure 1A;

[0015] Figure 2B is a side view of a portion of the semiconductor package of Figure 1A;

[0016] Figure 2C is a front view of a portion of the semiconductor package of Figure 1A;

[0017] Figure 2D is a bottom view of a portion of the semiconductor package of Figure 1A;

[0018] Figure 3 is a cut-away side view of portions of the semiconductor package of Figure 1A;

[0019] Figure 4 is a side view of the semiconductor package of Figure 1A with additional elements;

[0020] Figure 5 an exploded perspective view of a semiconductor die package according to another embodiment of the present invention;

[0021] Figure 6A is a top view of a portion of the semiconductor package of Figure 5;

[0022] Figure 6B is a side view of a portion of the semiconductor package of Figure 5;

[0023] Figure 6C is a front view of a portion of the semiconductor package of Figure 5; and

[0024] Figure 6D is a bottom view of a portion of the semiconductor package of Figure 5.

DETAILED DESCRIPTION

[0025] The present invention will now be described with reference to the Figures 1 through 6D, which illustrate various embodiments of the present invention. As illustrated in the Figures, the sizes of layers or regions are exaggerated for illustrative purposes and, thus, are provided to illustrate the general structures of the present invention. Furthermore, various aspects of the present invention are described with reference to a layer or structure being formed on a substrate or other layer or structure. As will be appreciated by those of skill in the art, references to a layer being formed "on" another layer or substrate contemplates that additional layers may intervene. References to a layer being formed on another layer or substrate without an intervening layer are described herein as being formed "directly on" the layer or substrate. Furthermore, relative terms such as beneath may be used herein to describe one layer or regions relationship to another layer or region as illustrated in the Figures. It will be understood that these terms are intended to encompass different orientations of the device in addition to the orientation depicted in the Figures. For example, if the device in the Figures is turned over, layers or regions described as "beneath" other layers or regions would now be oriented "above" these other layers or regions. The term "beneath" is intended to encompass both above and beneath in this situation. Like numbers refer to like elements throughout.

[0026] As shown in the figures for the purposes of illustration, embodiments of the present invention are exemplified by a light emitting die package including a bottom heat sink (substrate) having traces for connecting to a light emitting diode at a mounting pad and a top heat sink (reflector plate) substantially surrounding the mounting pad. A lens covers the mounting pad. In effect, the die package according to some embodiments of the present invention comprises a two part heat sink with the bottom heat sink utilized (in additional to its utility for drawing and dissipating heat) as the substrate on which the LED is mounted and connected, and the top heat sink utilized (in additional to its utility for drawing and dissipating heat) as a reflector plate to direct light produced by the LED. Because both the bottom and the top heat sinks draw heat away from the LED, more power can be delivered to the LED, and the LED can thereby produce more light.

[0027] Further, in the present invention, the body of the die package itself may act as the heat' sink removing heat from the LED and dissipating it. For this reason, the LED die package of the present invention may not require a separate heat sink slugs or leads that extend away from the package. Accordingly, the LED die package of the present invention may be more compact, more reliable, and less costly to manufacture than the die packages of the prior art.

[0028] Figure 1A is a perspective view of a semiconductor die package 10 according to one embodiment of the present invention and Figure 1B is an exploded perspective view of the semiconductor package of Figure 1A. Referring to Figures 1A and 1B, the light emitting die package 10 of the present invention includes a bottom heat sink 20, a top heat sink 40, and a lens 50.

[0029] The bottom heat sink 20 is illustrated in more detail in Figures 2A through 2D. Figures 2A, 2B, 2C, and 2D provide, respectively, a top view, a side view, a front view, and a bottom view of the bottom heat sink 20 of Figure 1A. Further, Figure 2C also shows an LED assembly 60 in addition to the front view of the bottom heat sink 20. The LED assembly 60 is also illustrated in Figure 1B. Referring to Figures 1A through 2D, the bottom heat sink 20 provides support for electrical traces 22 and 24; for solder pads 26, 32, and 34; and for the LED assembly 60. For this reason, the bottom heat sink 20 is also referred to as a substrate 20. In the Figures, to avoid clutter, only representative solder pads 26, 32, and 34 are indicated with reference numbers. The traces 22 and 24 and the solder pads 32, 34, and 36 can be fabricated using conductive material. Further, additional traces and connections can be fabricated on the top, side, or bottom of the substrate 20, or layered within the substrate 20. The traces 22 and 24, the solder pads 32, 34, and 36, and any other connections can be interconnected to each other in any combinations using known methods, for example via holes.

[0030] The substrate 20 is made of material having high thermal conductivity but is electrically insulating, for example, aluminum nitride (AlN) or alumina (Al_2O_3). Dimensions of the substrate 20 can vary widely depending on application and processes used to manufacture the die package 10. For example, in the illustrated embodi-

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ment, the substrate 20 may have dimensions ranging from fractions of millimeters (mm) to tens of millimeters. Although the present invention is not limited to particular dimensions, one specific embodiment of the die package 10 of the present invention is illustrated in Figures having the dimensions denoted therein. All dimensions shown in the Figures are in millimeters (for lengths, widths, heights, and radii) and degrees (for angles) except as otherwise designated in the Figures, in the Specification herein, or both.

[0031] The substrate 20, in the illustrated embodiment, has a top surface 21, the top surface 21 including the electrical traces 22 and 24. The traces 22 and 24 provide electrical connections from the solder pads (for example top solder pads 26) to a mounting pad 28. The top solder pads 26 are portions of the traces 22 and 24 generally proximal to sides of the substrate 20. The top solder pads 26 are electrically connected to side solder pads 32. The mounting pad 28 is a portion of the top surface (including portions of the trace 22, the trace 24, or both) where the LED assembly 60 is mounted. Typically the mounting pad 28 is generally located proximal to center of the top surface 21. In alternative embodiments of the present invention, the LED assembly 60 can be replaced by other semiconductor circuits or chips.

[0032] The traces 22 and 24 provide electrical routes to allow the LED assembly 60 to electrically connect to the solder pads 26, 32, or 34. Accordingly, some of the traces are referred to as first traces 22 while other traces are referred to as second traces 24. In the illustrated embodiment, the mounting pad 28 includes portions of both the first traces 22 and the second traces 24. In the illustrated example, the LED assembly 60 is placed on the first trace 22 portion of the mounting pad 28 thereby making contact with the first trace 22. In the illustrated embodiment, top of the LED assembly 60 and the second traces 24 are connected to each other via a bond wire 62. Depending on the construction and orientation of LED assembly 60, first traces 22 may provide anode (positive) connections and second traces 24 may comprise, cathode (negative) connections for the LED assembly 60 (or vice versa).

[0033] The LED assembly 60 can include additional elements. For example, in Figures 1B and 2C, the LED assembly 60 is illustrated including the LED bond wire 62, an LED subassembly 64, and a light emitting diode (LED) 66. Such LED subassembly 64 is known in the art and is illustrated for the purposes of discussing the invention and is not meant to be a limitation of the present invention. In the Figures, the LED assembly 60 is shown die-attached to the substrate 20. In alternative embodiments, the mounting pad 28 can be configured to allow flip-chip attachment of the LED assembly 60. Additionally, multiple LED assemblies can be mounted on the mounting pad 28. In alternative embodiments, the LED assembly 60 can be mounted over multiple traces. This is especially true if flip-chip technology is used.

[0034] The topology of the traces 22 and 24 can vary widely from the topology illustrated in the Figures while still remaining within the scope of the present invention. In the Figures, three separate cathode (negative) traces 24 are shown to illustrate that three LED assemblies can be placed on the mounting pad 28, each connected to a different cathode (negative) trace; thus, the three LED assemblies may be separately electrically controllable. The traces 22 and 24 are made of conductive material such as gold, silver, tin, or other metals. The traces 22 and 24 can have dimensions as illustrated in the Figures and having thickness in the order of microns or tens of microns depending on application. For example, the traces 22 and 24 can be 15 microns thick. Figures 1A and 2A illustrate an orientation marking 27. Such markings can be used to identify the proper orientation of the die package 10 even after assembling the die package 10. The orientation marking 27 is not a via or a through hole. The traces 22 and 24, as illustrated, can extend from the mounting pad 28 to sides of the substrate 20.

[0035] Continuing to refer to Figures 1A through 2D, the substrate 20 defines semi-cylindrical spaces 23 and quarter-cylindrical spaces 25 proximal to its sides. In the Figures, to avoid clutter, only representative spaces 23 and 25 are indicated with reference numbers. The semi-cylindrical spaces 23 and the quarter-cylindrical spaces 25 provide spaces for solder to flow-through and solidify-in when the die package 10 is attached to a printed circuit board (PCB) or another apparatus (not shown) to which the die package 10 is a component thereof. Moreover, the semi-cylindrical spaces 23 and the quarter-cylindrical spaces 25 provide convenient delineation and break points during the manufacturing process.

[0036] The substrate 20 can be manufactured as one individual section of a strip or a plate having a plurality of adjacent sections, each section being a substrate 20. Alternatively, the substrate 20 can be manufactured as one individual section of an array of sections, the array having multiple rows and columns of adjacent sections. In such configuration, the semi-cylindrical spaces 23 and quarter-cylindrical spaces 25 can be utilized as tooling holes for the strip, the plate, or the array during the manufacturing process.

[0037] Furthermore, the semi-cylindrical spaces 23 and the quarter-cylindrical spaces 25, combined with scribed grooves or other etchings between the sections, assist in separating each individual substrate from the strip, the plate, or the wafer. The separation can be accomplished by introducing physical stress to the perforation (semi through holes at a close pitch) or scribe lines made by laser, or premolded, or etched lines (crossing the semi-cylindrical spaces 23 and the quarter-cylindrical spaces 25) by bending the strip, the plate, or the wafer. These features simplify the manufacturing process thus reducing costs by eliminating the need for special carrier fixtures to handle individual unit of the substrate 20 during the manufacturing process. Furthermore, the semi-cylindrical spaces 23 and the quarter-cylindrical spaces 25 serve as via holes connecting the top solder pads 26, the

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side solder pads 32, and the bottom solder pads 34.

[0038] The substrate 20 has a bottom surface 29 including a thermal contact pad 36. The thermal contact pad 36 can be fabricated using material having high thermally and electrically conductive material such as gold, silver, tin, or other material including but not limited to precious metals.

[0039] Figure 3 illustrates a cut-away side view of portions of the semiconductor package of Figures 1A and 1B. In particular, the Figure 3 illustrates a cut-away side view of the top heat sink 40 and the lens 50. Referring to Figures 1A, 1B, and 3, the top heat sink 40 is made from material having high thermal conductivity such as aluminum, copper, ceramics, plastics, composites, or a combination of these materials. A high temperature, mechanically tough, dielectric material can be used to overcoat the traces 22 and 24 (with the exception of the central die-attach area) to seal the traces 22 and 24 and provide protection from physical and environmental harm such as scratches and oxidation. The overcoating process can be a part of the substrate manufacturing process. The overcoat, when used, may insulate the substrate 20 from the top heat sink 40. The overcoat may then be covered with a high temperature adhesive such as thermal interface material manufactured by THERMOSET that bonds the substrate 20 to the top heat sink 40.

[0040] The top heat sink 40 may include a reflective surface 42 substantially surrounding the LED assembly 60 mounted on the mounting pad 28 (of Figures 2A and 2C). When the top heat sink 40 is used to dissipate heat generated by the LED in the die package 10, it can be "top-mounted" directly on to an external heat sink by an adhesive or solder joint to dissipate heat efficiently. In another embodiment, if heat has to be dissipated by either a compressible or non-compressible medium such as air or cooling fluid, the top heat sink 40 may be made to equip with cooling fins or any feature that will enhance heat transfer between the top heat sink 40 and the cooling medium. In both of these embodiments, the electrical terminals and the bottom heat sink 20 of the die package 10, can still be connected to its application printed circuit board (PCB) using, for example, the normal surface-mount-technology (SMT) method.

[0041] The reflective surface 42 reflects portions of light from the LED assembly 60 as illustrated by sample light rays 63. Other portions of the light are not reflected by the reflective surface 42 as illustrated by sample light ray 61. Illustrative light rays 61 and 63 are not meant to represent light traces often use in the optical arts. For efficient reflection of the light, the top heat sink 40 is preferably made from material that can be polished, coined, molded, or any combination of these. Alternatively, to achieve high reflectivity, the optical reflective surface 42 or the entire heat sink 40 can be plated or deposited with high reflective material such as silver, aluminum, or any substance that serves the purpose. For this reason, the top heat sink 40 is also referred to as a reflector plate 40. The reflector plate 40 is made of material having high thermal conductivity if and when required by the thermal performance of the package 10. In the illustrated embodiment, the reflective surface 42 is illustrated as a flat surface at an angle, for example 45 degrees, relative to the reflective plate's horizontal plane. The present invention is not limited to the illustrated embodiment. For example, the reflective surface 42 can be at a different angle relative to the reflective plate's horizontal plane. Alternatively, the reflective plate can have a parabolic, toroid or any other shape that helps to meet the desired spectral luminous performance of the package.

[0042] The reflective plate 40 includes a ledge 44 for supporting and coupling with the lens 50. The LED assembly 60 is encapsulated within the die package 10 (of Figures 1A and 1B) using encapsulation material 46 such as, for example only, soft and elastic silicones or polymers. The encapsulation material 46 is preferably high temperature polymer with high light transmissivity and refractive index that matches or closely matches refractive index of the lens 50. The encapsulant 46 is preferably not affected by most wavelengths that alter its light transmissivity or clarity.

[0043] The lens 50 is made from material having high light transmissivity such as, for example only, glass, quartz, high temperature and transparent plastic, or a combination of these materials. The lens 50 is placed on top of and adheres to the encapsulation material 46. The lens 50 is not rigidly bonded to the reflector 40. This "floating lens" design will ensure that the encapsulant 46 can expand and contract under high and low temperature conditions without problem. For instance, when the die package 10 is operating or being subjected to high temperature environment, encapsulant 46 experiences greater volumetric expansion than the cavity space that contains it. By allowing the lens 50 to float up somewhat freely on top of the encapsulant 46, no encapsulant will be squeezed out of its cavity space. Likewise, when the die package 10 is subjected to cold temperature, the encapsulant 46 will contract more than the other components that make up the cavity space for the encapsulant 46; the lens will float freely on top of the encapsulant 46 as the latter shrinks and its level drops. Hence, the reliability of the die package 10 is maintained over a relatively large temperature ranges as the thermal stresses induced on its encapsulant 46 is reduced by the floating lens design.

[0044] In some embodiments, the lens 50 defines a recess 52 having a curved, hemispherical, or other geometry, which can be filled with optical materials intended to influence or change the nature of the light emitted by the LED chip(s) before it leaves the die package 10. Examples of one type of optical materials are luminescence converting phosphors, dyes, fluorescent polymers or other materials which absorb some of the light emitted by the chip(s) and re-emit light of different wavelengths. Examples of another type of optical materials are light diffusants such as calcium carbonate, scattering particles (such as Titanium oxides) or voids which disperse or scat-

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ter light. Any single or combination of the above materials can be applied on the lens to obtain certain spectral luminous performance.

[0045] Figure 4 illustrates the die package 10 coupled to an external heat sink 70. Referring to Figure 4, the thermal contact pad 36 can be attached to the external heat sink 70 using epoxy, solder, or any other thermally conductive adhesive, electrically conductive adhesive, or thermally and electrically conductive adhesive 74. The external heat sink 70 can be a printed circuit board (PCB) or other structure that draws heat from the die package 10. The external heat sink can include circuit elements (not shown) or heat dissipation fins 72 in various configurations.

[0046] An embodiment of the invention having certain alternate configuration is shown in Figures 5 through 6D. Portions of this second embodiment are similar to corresponding portions of the first embodiment illustrated in Figures 1A through 4. For convenience, portions of the second embodiment as illustrated in Figures 5 through 6D that are similar to portions of the first embodiment are assigned the same reference numerals, analogous but changed portions are assigned the same reference numerals accompanied by letter "a," and different portions are assigned different reference numerals.

[0047] Figure 5 is an exploded perspective view of an LED die package 10a in accordance with other embodiments of the present invention. Referring to Figure 5, the light emitting die package 10a of the present invention includes a bottom heat sink (substrate) 20a, a top heat sink (reflector plate) 40a, and a lens 50.

[0048] Figures 6A, 6B, 6C, and 6D, provide, respectively, a top view, a side view a front view, and a bottom view of the substrate 20a of Figure 5. Referring to Figures 5 through 6D, in the illustrated embodiment, the substrate 20a includes one first trace 22a and four second traces 24a. These traces 22a and 24a have are configured differently than the traces 22 and 24 of Figure 2A. The substrate 20a includes flanges 31 that define latch spaces 33 for reception of legs 35 of the reflector plate 40a thereby mechanically engaging the reflector plate 40a with the substrate 20a.

Claims

1. A light emitting die package (10; 10a), comprising:

   a substrate (20; 20a) supporting an LED chip (66) thereon that is encapsulated within a encapsulant (46);
   a reflector plate (40; 40a) on the substrate, said reflector plate (40; 40a) substantially surrounding the LED chip (66) and having a circular-opening which forms a circular sidewall within the reflector plate; and
   a lens (50) which sits within the opening on top of the encapsulant and which adheres to the encapsulant, the lens being free to move relative to the circular sidewall of the reflector plate as the encapsulant expands and contracts.

2. A light emitting die package (10, 10a) according to claim 1, wherein each of the substrate (20, 20a) and reflector plate (40, 40a) have a heat sink capability to draw away heat generated by the LED chip (66) during package operation.

3. A light emitting die package (10; 10a) according to Claim 1, wherein the reflector plate (40; 40a) is mechanically coupled to the substrate (20; 20a).

4. A light emitting die package (10a) according to Claim 3, wherein the substrate (20a) includes flanges (31) along at least one side thereof for mechanically engaging the reflector plate (40a).

5. The light emitting die package (10a) of claim 4, wherein the reflector plate (40a) includes legs (35) for mechanically engaging the substrate (20a) between the flanges (31) for increased thermal contact area.

6. The light emitting die package (10; 10a) of claim 1, wherein the substrate (20; 20a) comprises an electrically insulating material having high thermal conductivity.

7. The light emitting die package (10; 10a) of claim 6, wherein the substrate (20; 20a) has a bottom side with a thermal contact pad (36) for coupling with an external heat sink (70).

8. The light emitting die package (10; 10a) of claim 7, further comprising an external heat sink (70) coupled to the substrate (20; 20a).

9. The light emitting die package (10; 10a) of claim 1, wherein the lens (50) is composed of a material selected from a group consisting of glass, quartz, and a high temperature plastic material.

10. The light emitting die package (10; 10a) of claim 1, wherein the lens (50) includes luminescence converting phosphors.

11. The light emitting die package (10; 10a) of claim 1, wherein the lens (50) includes an optical diffusant.

12. The light emitting die package of claim 1, wherein the lens (50) includes a phosphor.

Patentansprüche

1. Leuchtchip-Gehäuse (10; 10a), aufweisend:

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- ein Substrat (20; 20a), das einen LED-Chip (66) trägt, der in einer Kapsel (46) eingekapselt ist;
- eine Reflektorplatte (40; 40a) auf dem Substrat, wobei die Reflektorplatte (40; 40a) den LED-Chip (66) im Wesentlichen umgibt und eine kreisförmige Öffnung aufweist, die eine kreisförmige Seitenwand innerhalb der Reflektorplatte bildet; und
- eine Linse (50), die sich innerhalb der Öffnung oben auf der Kapsel befindet und an der Kapsel haftet, wobei die Linse relativ zu der kreisförmigen Seitenwand der Reflektorplatte frei beweglich ist, wenn sich die Kapsel ausdehnt und zusammenzieht.

2. Leuchtchip-Gehäuse (10; 10a) nach Anspruch 1, wobei jedes Element von Substrat (20, 20a) und Reflektorplatte (40, 40a) eine Wärmesenkkapazität aufweist, um während des Gehäusebetriebs erzeugte Wärme von dem LED-Chip (66) abzuführen.

3. Leuchtchip-Gehäuse (10; 10a) nach Anspruch 1, wobei die Reflektorplatte (40; 40a) mechanisch an das Substrat (20; 20a) gekoppelt ist.

4. Leuchtchip-Gehäuse (10a) nach Anspruch 3, wobei das Substrat (20a) entlang mindestens einer seiner Seiten Flansche (31) zum mechanischen Eingriff in die Reflektorplatte (40a) aufweist.

5. Leuchtchip-Gehäuse (10a) nach Anspruch 4, wobei die Reflektorplatte (40a) Schenkel (35) zum mechanischen Eingriff des Substrats (20a) zwischen den Flanschen (31) für eine vergrößerte Wärmekontaktfläche aufweist.

6. Leuchtchip-Gehäuse (10; 10a) nach Anspruch 1, wobei das Substrat (20; 20a) ein elektrisch isolierendes Material mit einer hohen Wärmeleitfähigkeit aufweist.

7. Leuchtchip-Gehäuse (10; 10a) nach Anspruch 6, wobei das Substrat (20; 20a) eine Unterseite mit einer Wärmekontaktfläche (36) zum Koppeln mit einer externen Wärmesenke (70) aufweist.

8. Leuchtchip-Gehäuse (10; 10a) nach Anspruch 7, ferner aufweisend eine externe Wärmesenke (70), die an das Substrat (20; 20a) gekoppelt ist.

9. Leuchtchip-Gehäuse (10; 10a) nach Anspruch 1, wobei die Linse (50) aus einem Material besteht, das ausgewählt ist aus einer Gruppe bestehend aus Glas, Quarz und einem Hochtemperatur-Kunststoffmaterial.

10. Leuchtchip-Gehäuse (10; 10a) nach Anspruch 1, wobei die Linse (50) Lumineszenz umwandelnde Phosphore aufweist.

11. Leuchtchip-Gehäuse (10; 10a) nach Anspruch 1, wobei die Linse (50) einen optischen Streukörper aufweist.

12. Leuchtchip-Gehäuse nach Anspruch 1, wobei die Linse (50) ein Phosphor aufweist.

Revendications

1. Boîtier de puce électroluminescent (10 ; 10a), comprenant :

- un substrat (20 ; 20a) supportant une puce de LED (66) sur celui-ci qui est encapsulée dans un matériau d'encapsulation (46) ;
- une plaque réflectrice (40 ; 40a) sur le substrat, ladite plaque réflectrice (40 ; 40a) entourant sensiblement la puce de LED (66) et comportant une ouverture circulaire qui forme une paroi latérale circulaire à l'intérieur de la plaque réflectrice ; et
- une lentille (50) qui est logée dans l'ouverture au-dessus du matériau d'encapsulation et qui adhère au matériau d'encapsulation, la lentille étant libre de bouger par rapport à la paroi latérale circulaire de la plaque réflectrice lorsque le matériau d'encapsulation se dilate et se contracte.

2. Boîtier de puce électroluminescent (10 ; 10a) selon la revendication 1, dans lequel chacun du substrat (20 ; 20a) et de la plaque réflectrice (40 ; 40a) possède une capacité de dissipation de chaleur pour éloigner la chaleur générée par la puce de LED (66) pendant le fonctionnement du boîtier.

3. Boîtier de puce électroluminescent (10 ; 10a) selon la revendication 1, dans lequel la plaque réflectrice (40 ; 40a) est couplée mécaniquement au substrat (20 ; 20a).

4. Boîtier de puce électroluminescent (10a) selon la revendication 3, dans lequel le substrat (20a) comprend des brides (31) le long d'au moins un côté de celui-ci pour venir en prise mécaniquement avec la plaque réflectrice (40a).

5. Boîtier de puce électroluminescent (10a) selon la revendication 4, dans lequel la plaque réflectrice (40a) comprend des pattes (35) pour venir en prise mécaniquement avec le substrat (20a) entre les brides (31) afin d'augmenter la surface de contact thermique.

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6. Boîtier de puce électroluminescent (10 ; 10a) selon la revendication 1, dans lequel le substrat (20 ; 208) comprend un matériau électro-isolant présentant une conductivité thermique élevée.

7. Boîtier de puce électroluminescent (10 ; 10a) selon la revendication 6, dans lequel le substrat (20 ; 20a) a un côté inférieur muni d'une plage de contact thermique (36) pour le couplage avec un dissipateur de chaleur externe (70).

8. Boîtier de puce électroluminescent (10 ; 10a) selon la revendication 7, comprenant en outre un dissipateur de chaleur externe (70) couplé au substrat (20 ; 20a).

9. Boîtier de puce électroluminescent (10 ; 10a) selon la revendication 1, dans lequel la lentille (50) est composée d'un matériau choisi dans un groupe constitué par le verre, le quartz et une matière plastique haute température.

10. Boîtier de puce électroluminescent (10 ; 10a) selon la revendication 1, dans lequel la lentille (50) comprend des substances luminescentes de conversion de luminescence.

11. Boîtier de puce électroluminescent (10 ; 10a) selon la revendication 1, dans lequel la lentille (50) comprend un diffusant optique.

12. Boîtier de puce électroluminescent selon la revendication 1, dans lequel la lentille (50) comprend une substance luminescente.

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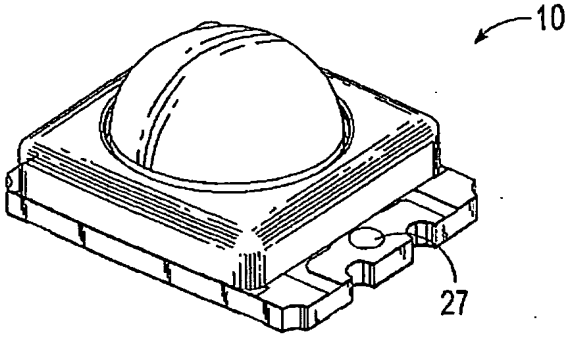


FIG. 1A

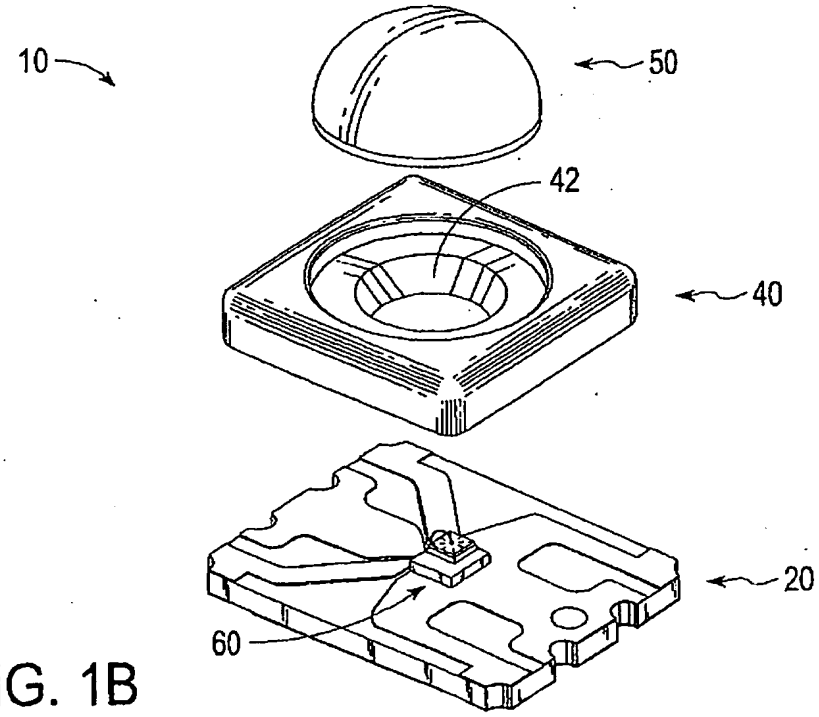


FIG. 1B

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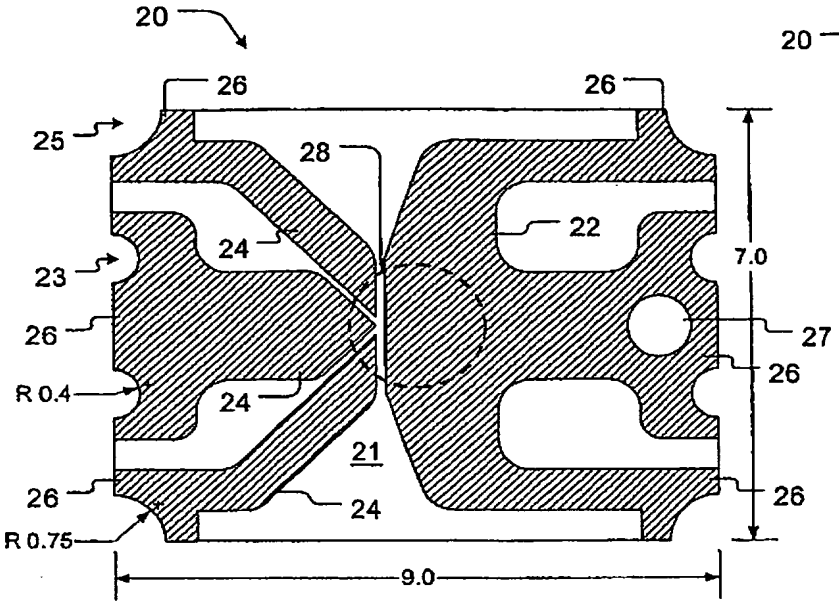


FIG. 2A

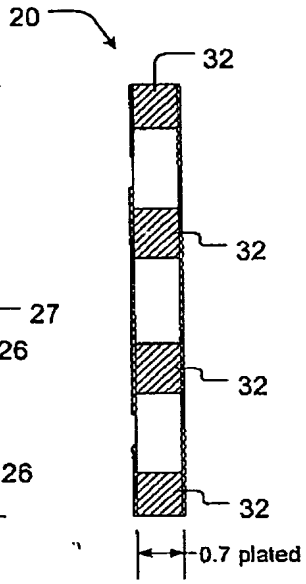


FIG. 2B

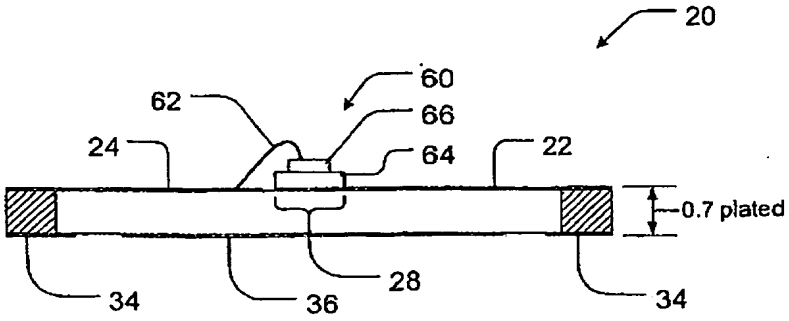


FIG. 2C

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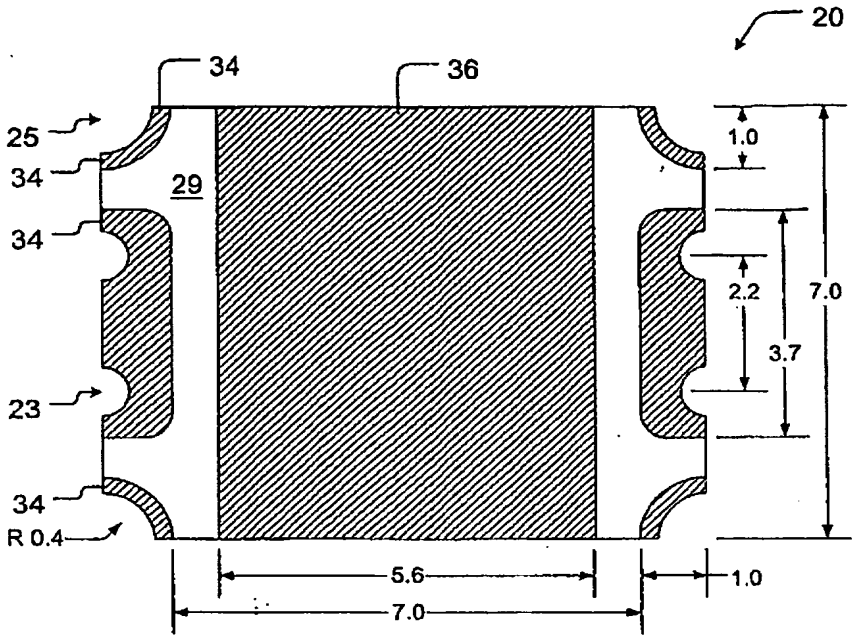


FIG. 2D

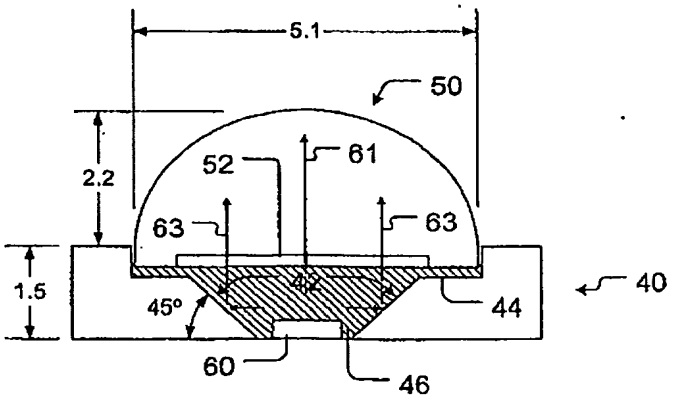


FIG. 3

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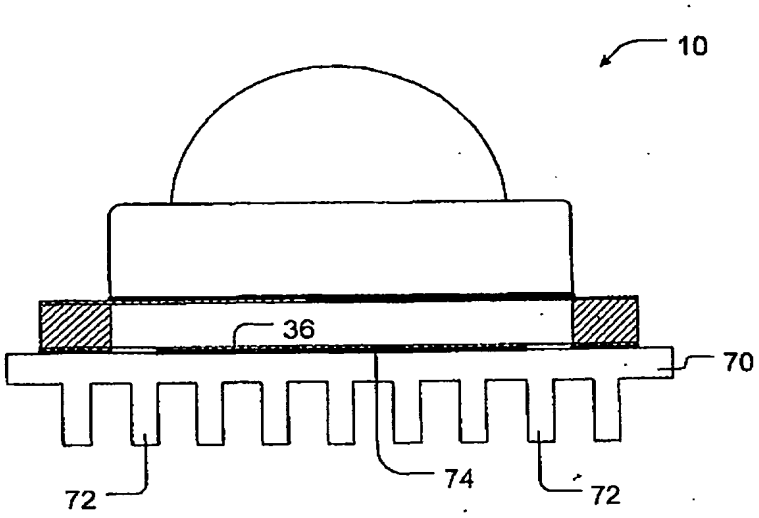


FIG. 4

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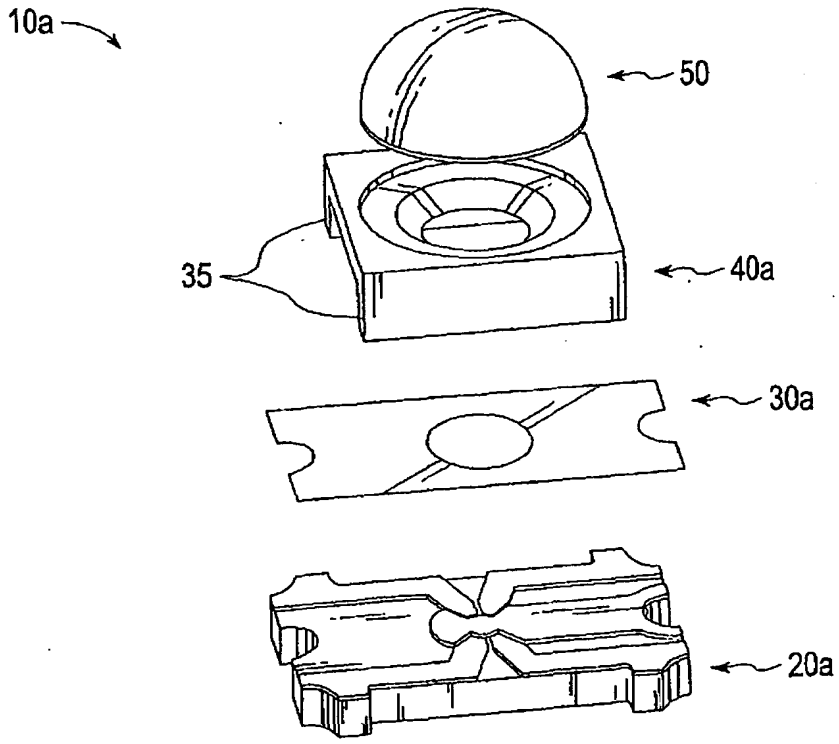


FIG. 5

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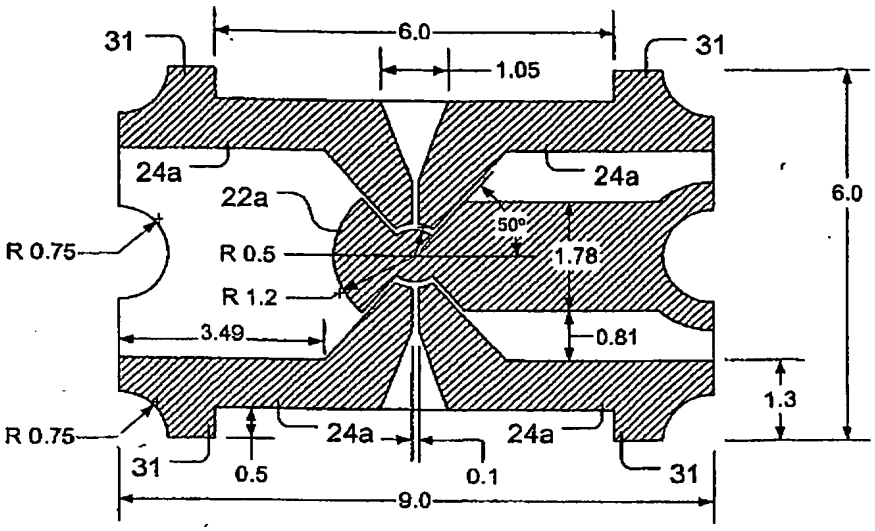


FIG. 6A

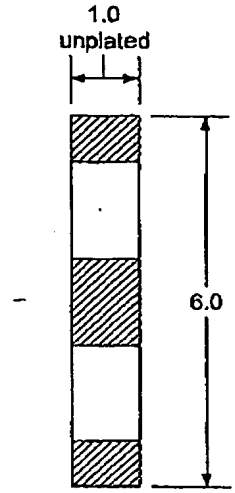


FIG. 6B



FIG. 6C

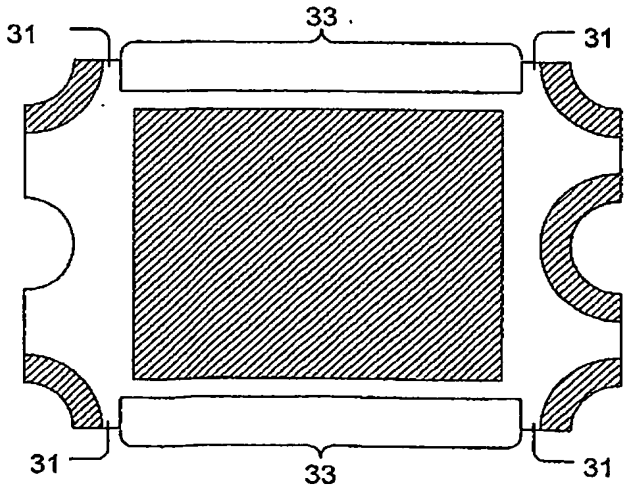


FIG. 6D

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REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- US 20020084462 A1 **[0002]**

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Ex. 1003 - Page 1700

Espacenet

IL123123A ILLUMINATED SIGN SYSTEM

Applicants: LEDI LITE LTD

Inventors: FILIPOVSKY MENACHEM,SAMUEL BOAZ,SPERO YECHEZEKEL

Classifications:

IPC ***F21K99/00; G09F9/33;*** *G09F13/04;* (IPC1-7): G09F13/00;

CPC **F21K9/00 (EP,US); G09F13/0404 (EP,US); G09F13/0472 (EP); G09F9/33 (EP); H05B45/3725 (EP,US); H05B45/40 (EP,US);**

Priorities: IL12312398A 1998-01-29

Application: IL123123A·1998-01-29

Publication: IL123123A·2004-03-28

Published as: **AU2297499A; EP1050036A2;** IL123123A;**WO9939319A2; WO9939319A3**

ILLUMINATED SIGN SYSTEM

Abstract

No abstract found. Please consult other publications of this patent family in "Available in", if displayed above.

PCT WORLD INTELLECTUAL PROPERTY ORGANIZATION
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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 : G09F 9/33, H05B 33/08

A3

(11) International Publication Number: **WO 99/39319**

(43) International Publication Date: 5 August 1999 (05.08.99)

(21) International Application Number: PCT/IL99/00061

(22) International Filing Date: 29 January 1999 (29.01.99)

(30) Priority Data:
123123 29 January 1998 (29.01.98) IL

(71) Applicant *(for all designated States except US)*: LEDI–LITE LTD. [IL/IL]; Ofakim Technology Center, P.O. Box 633, 80300 Ofakim (IL).

(71)(72) Applicants and Inventors: FILIPOVSKY, Menachem [IL/IL]; P.O. Box 633, 80300 Ofakim (IL). SAMUEL, Boaz [IL/IL]; P.O. Box 633, 80300 Ofakim (IL). SPERO, Yechezkel [IL/IL]; P.O. Box 633, 80300 Ofakim (IL).

(74) Agent: FRIEDMAN, Mark, M.; Beit Samueloff, Haomanim Street 7, 67897 Tel Aviv (IL).

(81) Designated States: AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

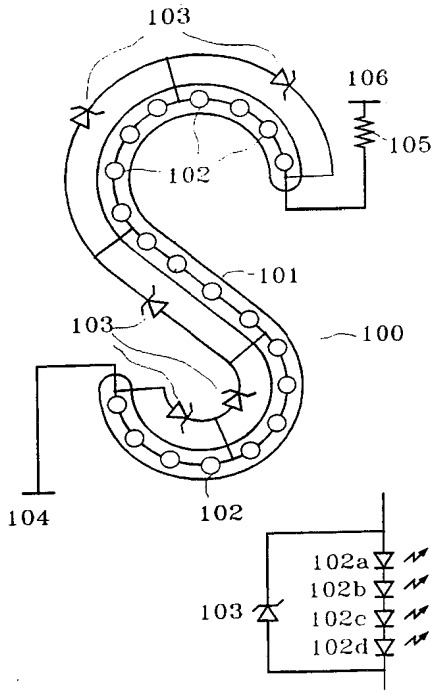
Published
With international search report.

(88) Date of publication of the international search report:
9 March 2000 (09.03.00)

(54) Title: ILLUMINATED SIGN SYSTEM

(57) Abstract

Low energy consuming sign system composed of discrete light sources, used singly or in groups to create patterns which are observed to constitute single letters, numerals symbols, pictures or complete signs. A group of discrete light sources comprises for example a series-string connection of LED's shunted by a Zener diode. Light energy is only produced when needed, the signs having a high readability in daylight without electrical power. The sign system comprises also a blinking control system and an adapted power supply system with battery back-up facility.



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INTERNATIONAL SEARCH REPORT

International Application No
P /IL 99/00061

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 G09F9/33 H05B33/08

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 G09F H05B G09G

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

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	FR 2 563 648 A (POITIERS UNIVERSITE) 31 October 1985 (1985-10-31)	1
X	abstract; figures 1,2	2,7,33
A	page 6, line 30 -page 7, line 5	57

Y	PATENT ABSTRACTS OF JAPAN vol. 095, no. 006, 31 July 1995 (1995-07-31) & JP 07 085377 A (OKAYA ELECTRIC IND CO LTD), 31 March 1995 (1995-03-31)	1
A	abstract	5,6,9, 25,57

A	US 3 755 679 A (OTSUKA W) 28 August 1973 (1973-08-28) abstract; figure 1	9

	-/--	

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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"E" earlier document but published on or after the international filing date

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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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Date of the actual completion of the international search	Date of mailing of the international search report
7 July 1999	19. 11. 1999

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	VAN ROOST, L

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Form PCT/ISA/210 (second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

International Application No
P. /IL 99/00061

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	GB 2 239 746 A (AMOURGAM VIVIAN JUDE) 10 July 1991 (1991-07-10) -----	1,3,6,8, 21,25,57

3

INTERNATIONAL SEARCH REPORT

ernational application No.
PCT/IL 99/00061

Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this International Search Report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

1-11, 21, 25, 33, 34, 57

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest.

☐ No protest accompanied the payment of additional search fees.

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Ex. 1003 - Page 1706

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

1. Claims: 1-11,21,25,33,34,57

   A sign system comprising a series-string connection of LED's, a Zener diode shunting a group of LED's, a blinking-off circuit and a current source

2. Claims: 12-19,22,26,32,51-53

   Power supply and current control for a sign system

3. Claims: 58-64

   Current source for inhibiting electrocution

4. Claims: 20,23,24,27-31,35-50,54-56

   Construction details of a sign system

5. Claims: 65-66

   Display of two messages on the same sign

6. Claims: 67-71

   LED light and light tube comprising LED lamps

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PC./IL 99/00061

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
FR 2563648 A	31-10-1985	FR 2571527 A	11-04-1986
JP 07085377 A	31-03-1995	NONE	
US 3755679 A	28-08-1973	NONE	
GB 2239746 A	10-07-1991	EP 0549589 A	07-07-1993
		WO 9301570 A	21-01-1993

Espacenet

Bibliographic data: JP2011159495 (A) — 2011-08-18

LIGHTING SYSTEM

Inventor(s): UCHIO SEIICHIRO ± (UCHIO SEIICHIRO)

Applicant(s): KAGA ELECTRONICS CO LTD ± (KAGA ELECTRONICS CO LTD)

Classification: **- international:** ***F21S2/00; H05B37/02;*** *F21Y101/02*
- cooperative:

Application number: JP20100020309 20100201 Global Dossier

Priority number(s): JP20100020309 20100201

Abstract of JP2011159495 (A)

PROBLEM TO BE SOLVED: To provide an LED lighting system stably operating LEDs (light emitting diodes) regardless of the fluctuation of AC voltage. ;SOLUTION: The LED lighting system has: a first LED group 10 constituted by connecting LEDs 10-1, 10-2, ..., 10-m, 10-n in series; a second LED group 20 constituted by connecting LEDs 20-1, 20-2, ..., 20-m, 20-n in series; a first constant current diode 12 connected to the LED 10-n of the first LED group 10; and a second constant current diode 22 connected to the LED 20-n of the second LED group 20. ;COPYRIGHT: (C)2011,JPO&INPIT

Espacenet

Bibliographic data: JP2001176677 (A) — 2001-06-29

LIGHTING DEVICE

Inventor(s): SETOMOTO TATSUMI; TAGUCHI TSUNEMASA ± (SETOMOTO TATSUMI, ; TAGUCHI TSUNEMASA)

Applicant(s): SANYO HIGHTECH KK; TAGUCHI TSUNEMASA ± (SANYO HIGHTECH:KK, ; TAGUCHI TSUNEMASA)

Classification: - international: ***H05B37/02;*** (IPC1-7): H05B37/02
- cooperative: Y02B20/40 (EP)

Application number: JP19990356644 19991215

Priority number (s): JP19990356644 19991215

Also published as: JP3177234 (B1)

Abstract of JP2001176677 (A)

PROBLEM TO BE SOLVED: To provide a lighting device using as a light source one or a combination of 2 or more of light-emitting diodes of white color, orange color and yellow color with a long life, low power consumption and high brightness. SOLUTION: With a lighting device 10 comprising an illuminating part 23 having a light-emitting diode 29, a power supply part 22, a control part 18, a temperature sensor 25 for detecting temperature of the light-emitting diode 29, a human body detecting sensor 24, and a day/night discriminating sensor 23a, the control part 18 consists of a lighting timer for counting time after the human body detecting sensor 24 sensing a human body, a high-brightness lighting means for lighting the light-emitting diode 29 in high brightness in a given condition, and a low-brightness lighting means for lighting in a low brightness.

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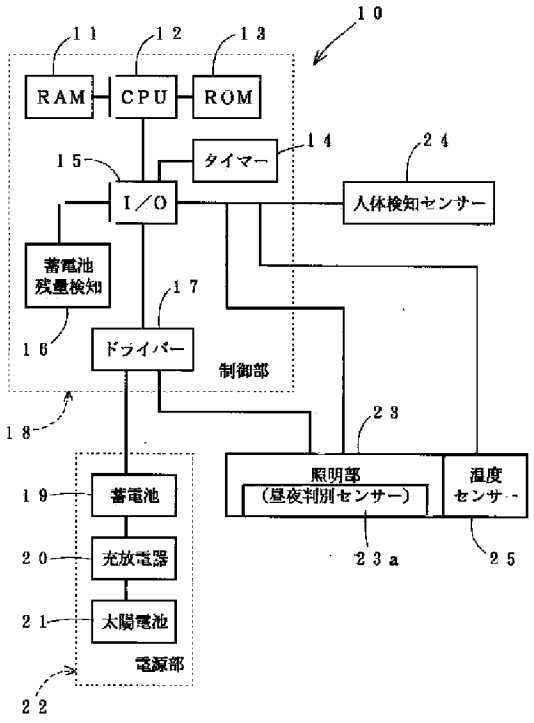
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(54)【発明の名称】　照明装置

(57)【要約】
【課題】　寿命が長く低消費電力で高照度な白色光を発する発光ダイオード、橙色光を発する発光ダイオード、及び黄色光を発する発光ダイオードの何れか１又は２以上を組み合わせて光源として使用する照明装置を提供する。
【解決手段】　発光ダイオード２９を有する照明部２３と、電源部２２と、制御部１８と、照明部２３の発光ダイオード２９の温度を検知する温度センサー２５と、人体検知センサー２４と、昼夜判別センサー２３ａとを有する照明装置１０において、制御部１８には、人体検知センサー２４が人体を検知した後の時間をカウントする点灯用タイマーと、所定の条件で発光ダイオード２９を高照度に点灯する高照度点灯手段と、低照度で点灯する低照度点灯手段とを有する。



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【特許請求の範囲】
【請求項１】　低消費電力で高照度な白色光を発する発光ダイオード、橙色光を発する発光ダイオード、及び黄色光を発する発光ダイオードの何れか１又は２以上を組み合わせて光源として使用する照明部と、該照明部に電源部から供給する電力を制御する制御部と、昼夜の区別を検知する昼夜判別センサーと、前記照明部の発光ダイオードの温度を検知する温度センサーと、前記照明部の近傍に配置された人体検知センサーとを有する照明装置において、前記制御部には前記人体検知センサーが人体を検知した後の時間をカウントする点灯用タイマーと、前記昼夜判別センサーが夜を検知したこと、前記人体検知センサーが人を検知したこと、前記点灯用タイマーがカウントオンであること、及び前記温度センサーによる前記発光ダイオードの温度が所定温度未満であることを条件にして、前記発光ダイオードを高照度に点灯する高照度点灯手段と、前記昼夜判別センサーが夜を検知したことを条件として、前記人体検知センサーが人を検知していないこと、前記点灯用タイマーがカウントオフであること、及び前記温度センサーによる前記発光ダイオードの温度が所定温度以上であることの少なくとも１つを更なる条件にして、前記発光ダイオードを低照度で点灯する低照度点灯手段とを有することを特徴とする照明装置。
【請求項２】　請求項１記載の照明装置において、前記照明部には放熱器が設けられ、前記発光ダイオードが点灯中に発生する熱を外部に放散していることを特徴とする照明装置。
【請求項３】　請求項１又は２記載の照明装置において、前記電源部は太陽電池と蓄電池の組み合わせであることを特徴とする照明装置。
【請求項４】　請求項３記載の照明装置において、前記制御部には前記昼夜判別センサーが夜を検知した後の時間をカウントする照明装置用タイマーと、前記蓄電池の残量が所定値より減少した場合は前記発光ダイオードの点灯を停止する電源停止手段とが設けられていることを特徴とする照明装置。
【請求項５】　請求項１～４のいずれか１項に記載の照明装置において、前記照明部には前記白色光を発する発光ダイオードが選択使用され、更に該白色光を発する発光ダイオードの他に赤色光を発する発光ダイオードが少数混在し、前記照明部からの光を温かみのある電球色に近い照明とすることを特徴とする照明装置。
【請求項６】　請求項１～５のいずれか１項に記載の照明装置において、前記昼夜判別センサーに、前記照明部の発光ダイオードの何れか１又は２以上を使用し、前記発光ダイオードが外部光によって生ずる起電力を検知して、昼夜を検知することを特徴とする照明装置。
【発明の詳細な説明】
【０００１】
【発明の属する技術分野】本発明は、街灯等に使用する低消費電力で高照度な白色光、橙色光及び黄色光を発する発光ダイオードを単独若しくは組み合わせて光源として使用する照明装置に関する。
【０００２】
【従来の技術】従来、街灯に使用する照明装置のランプは、温度放射型と放電型に大別される。温度放射型は、加熱したタングステンフィラメントの発光（熱輻射）を利用するもので、種類としては一般電球とハロゲン電球とがある。一方、放電型は、金属蒸気中での放電発光を利用するもので、更に低圧放電型と高圧放電型とに分けられる。低圧放電型は、水銀からの紫外放射を蛍光体で可視光に変換するもので、蛍光ランプがこれに当たる。また、高圧放電型は封入金属蒸気の発光を利用するＨＩＤランプがこれに当たり、具体的には高圧水銀ランプ、メタルハイドランプ、高圧ナトリウムランプがある。
【０００３】
【発明が解決しようとする課題】しかしながら、加熱したタングステンフィラメントの発光や放電発光を利用したランプの寿命は、一般電球で１０００～２０００時間、蛍光灯で４０００～１００００時間、高圧ナトリウムランプ（高演色型）で６０００～９０００時間であり、街灯のランプの寿命切れの確認を行い寿命切れランプの交換を行なうことには非常に労力を要するという問題がある。また、加熱したタングステンフィラメントの発光や放電発光を利用したランプでは消費電力が大きいため、使用状況に応じて適宜点灯、消灯を行い消費電力を節約することが考えられるが、水銀灯等に代表されるように点灯、消灯の応答性が非常に悪いため頻繁に点灯、消灯を行なうような使用方法に適さないものがあり、点灯、消灯を繰り返すことでランプの寿命が短くなることもあって、点灯、消灯による低消費電力化に適するランプが存在しないという問題がある。本発明はかかる事情に鑑みてなされたもので、寿命が長く低消費電力で高照度な白色光を発する発光ダイオード、橙色光を発する発光ダイオード、及び黄色光を発する発光ダイオードの何れか１又は２以上を組み合わせて光源として使用する照明装置を提供することを目的とする。
【０００４】
【課題を解決するための手段】前記目的に沿う本発明の照明装置は、低消費電力で高照度な白色光を発する発光ダイオード、橙色光を発する発光ダイオード、及び黄色光を発する発光ダイオードの何れか１又は２以上を組み合わせて光源として使用する照明部と、該照明部に電源部から供給する電力を制御する制御部と、昼夜の区別を検知する昼夜判別センサーと、前記照明部の発光ダイオードの温度を検知する温度センサーと、前記照明部の近傍に配置された人体検知センサーとを有する照明装置において、前記制御部には前記人体検知センサーが人体を検知した後の時間をカウントする点灯用タイマーと、前

記昼夜判別センサーが夜を検知したこと、前記人体検知センサーが人を検知したこと、前記点灯用タイマーがカウントオン（カウント中）であること、及び前記温度センサーによる前記発光ダイオードの温度が所定温度未満であることを条件にして、前記発光ダイオードを高照度に点灯する高照度点灯手段と、前記昼夜判別センサーが夜を検知したことを条件として、前記人体検知センサーが人を検知していないこと、前記点灯用タイマーがカウントオフ（カウント中を除くすべて）であること、及び前記温度センサーによる前記発光ダイオードの温度が所定温度以上であることの少なくとも１つを更なる条件にして、前記発光ダイオードを低照度で点灯する低照度点灯手段とを有する。

【０００５】制御部に高照度点灯手段と低照度点灯手段とを設けることにより、夜間時に常時発光ダイオードを点灯させても低電力消費化を図ることが可能となる。また、昼夜判別センサー、人体検知センサー、点灯用タイマー、及び温度センサーの各出力信号を組み合わせることで、高照度点灯と低照度点灯の必要性を判別し、不必要な高照度点灯を防止することにより低電力消費化を図ることができる。特に、温度センサーを設けることにより発光ダイオード近傍の温度を検出して、発光ダイオードの温度が所定値以上の場合は、低照度点灯条件にすることで、発光ダイオードに過剰な電流が流れないようにすることが可能となる。

【０００６】本発明に係る照明装置において、前記照明部には放熱器が設けられ、前記発光ダイオードが点灯中に発生する熱を外部に放散することができる。放熱器を設けることにより発光ダイオードの点灯中に発生した熱を、外部に効率的に放散させることが可能となり、発光ダイオードの点灯中の温度を安定化させることができる。

【０００７】本発明に係る照明装置において、前記電源部は太陽電池と蓄電池の組み合わせとすることができる。また、前記制御部には前記昼夜判別センサーが夜を検知した後の時間をカウントする照明装置用タイマーと、前記蓄電池の残量が所定値より減少した場合は前記発光ダイオードの点灯を停止する電源停止手段とが設けられていることが好ましい。照明の不要な昼間時に太陽電池により発電を行い、発生した電気を蓄電池に充電し、照明装置の維持電源や夜間時等の照明電源に使用することにより、照明装置の省エネルギー化が達成できる。また、照明装置用タイマーを設けることにより不要な深夜の照明を停止して、低電力消費化を図ることができる。更に、蓄電池内の蓄電残量が低下すると点灯を停止することで、蓄電池の過放電を防止することにより、蓄電池のサイクル寿命を長くすることができる。

【０００８】本発明に係る照明装置において、前記照明部には前記白色光を発する発光ダイオードが選択使用され、更に該白色光を発する発光ダイオードの他に赤色光を発する発光ダイオードが少数混在し、前記照明部からの光を温かみのある電球色に近い照明とすることが好ましい。白色光を発する発光ダイオードに赤色光を発する発光ダイオードを組み合わせることで、照明光としての色温度を低下させることができて、照明部からの光を温かみのある電球色に近い照明とすることができる。

【０００９】更に、本発明に係る照明装置において、前記昼夜判別センサーに、前記照明部の発光ダイオードの何れか１又は２以上を使用し、前記発光ダイオードが外部光によって生ずる起電力を検知して、昼夜を検知することができる。発光ダイオードには光を照射すると起電力が生じる特性があるので、照明部に使用されている発光ダイオードに外部光が入射すると、照明部に使用されている発光ダイオードに起電力が生じる。発生する起電力は外部光の強さ（周囲の明るさ）に比例するため、周囲の明るさと起電力の関係を予め求めておくと、発生する起電力を検出することにより、昼夜の判別を行なうことができる。

【００１０】

【発明の実施の形態】続いて、添付した図面を参照しつつ、本発明を具体化した実施の形態につき説明し、本発明の理解に供する。ここに、図１は本発明の一実施の形態に係る照明装置における機器構成を示したブロック図、図２は同照明装置の照明部の部分断面図、図３は同照明装置の発光ダイオードの配置を示す平面図、図４は同照明装置の外観図、図５は同照明装置の動作内容を示したフロー図である。

【００１１】図１に示すように、本発明の一実施の形態に係る照明装置１０は、照明部２３と、電源部２２と、電源部２２から供給する電力を制御する制御部１８と、照明部２３内の温度を検知する温度センサー２５と、照明部２３の近傍に配置された人体検知センサー２４と、昼夜の区別を検知する昼夜判別センサー２３ａとを有している。以下、これらについて詳細に説明する。

【００１２】図２に示すように、照明部２３の光源には、低消費電力で高照度な発光ダイオード２９、すなわち白色光を発する発光ダイオード（以下、白色発光ダイオードという）、橙色光を発する発光ダイオード（橙色発光ダイオードという）及び黄色光を発する発光ダイオード（黄色発光ダイオード）をそれぞれ単独、若しくはこれらを組み合わせて使用する。橙色発光ダイオード及び黄色発光ダイオードは、白色発光ダイオードに比較して照度が著しく高い（例えば、５～１５倍）ものが得られるので、橙色発光ダイオード及び黄色発光ダイオードを使用することで、同一電力でも広範囲の照明を効率よく行なうことが可能となる。しかし、橙色光、黄色光による照明では、被照明体の色を正確に識別することが困難となる。このため、橙色発光ダイオード、黄色発光ダイオード、又は橙色発光ダイオード及び黄色発光ダイオードを光源とする場合に、白色発光ダイオードを組み合

わせることで橙色光、黄色光の演色性を向上させて、色の識別性を向上させることが可能となる。

【００１３】図２に示すように、照明部２３は、所定個数（例えば、１００～１０００個）の発光ダイオード２９と、各発光ダイオード２９を整列固定して電力を供給する基板２８と、基板２８を収納する収納容器の一例であるアルミニウム製箱３１と、発光ダイオード２９の発光面を保護するためにアルミニウム製箱３１に取付けられる保護具の一例である透光性を有するプラスチックカバー３２とを有している。

【００１４】基板２８は、基板裏面（発光ダイオード２９を整列固定した面の反対側面）３３とアルミニウム製箱内底３４の間に空間部２７が生じるようにアルミニウム製箱３１内に取付けられている。また空間部２７には、熱電対や抵抗測温体等が使用できる温度センサー２５の温度検出部が基板裏面３３に当接するように設けられている。発光ダイオード２９は点灯中に熱を発生するため、発生した熱は基板２８に伝わり、基板２８の温度を上昇させる。この温度上昇は基板裏面３３に設けられた温度センサー２５により測定することができる。従って、基板裏面３３の温度を測定することにより、間接的に発光ダイオード２９の温度を測定することができる。

【００１５】空間部２７には絶縁性で熱伝導率の高い物質の一例であるシリコン樹脂が充填されている。アルミニウム製箱外底３５には放熱器の一例であるアルミニウム製フィン２６が設けられている。発光ダイオード２９の点灯中に発生した熱は基板２８に伝わり、基板２８内を伝導して基板裏面３３に到達する。熱は基板裏面３３からシリコン樹脂を介してアルミニウム製箱内底３４へ伝達され、アルミニウム製箱内底３４からアルミニウム製箱外底３５、更にアルミニウム製フィン２６まで伝導し、アルミニウム製フィン２６で外気と熱交換して空気中に放散される。上記のような放熱機能を設けることにより発光ダイオード２９の点灯中に発生した熱を、外部に効率的に放散させることが可能となり、発光ダイオード２９の点灯中の温度を安定化させることができる。

【００１６】図３に照明装置１０の発光ダイオード２９に、例えば白色発光ダイオード２９ａを選択使用し、更に照明光の色温度を低下させるために赤色発光ダイオード３０を組み合わせた場合を示している。図３に示すように、白色発光ダイオード２９ａと赤色発光ダイオード３０を基板２８上に所定個数、所定位置に整列固定する。白色発光ダイオード２９ａの総数に対して組み合わせる赤色発光ダイオード３０の個数と配置状態を調整することにより、照明光の色温度を任意に調整させることができる。白色発光ダイオード２９ａでは色温度が高い青白い照明光しか得られなかったのに対して、赤色発光ダイオード３０を組み合わせることにより、照明光を温かみのある電球色に近い照明とすることが可能となる。

【００１７】発光ダイオードは、電力を負荷することにより発光する特性を有する素子であるが、光の照射により起電力が生じるという逆の特性も有する。発生する起電力は外部光の強さ（周囲の明るさ）に比例するので、周囲の明るさと起電力の関係を予め求めておくと、発生する起電力を検出することにより昼夜の判別を行なうことができる。すなわち、図３に示すように複数の発光ダイオード２９（２９ａ、３０）に発光用電力を供給する発光用電力供給回路４０とは別に、直列に配列された複数の発光ダイオード２９（２９ａ、３０）に外部光が入射したときに生じる起電力を検出する起電力検出回路４１を、回路切替え手段４２を介して発光用電力を供給する回路と並列に接続することにより昼夜判別センサー２３ａを構成する。回路切替え手段４２を制御することにより、発光ダイオード２９を照明用の光源として使用することも、昼夜判別センサー２３ａとして使用することもできる。超音波センサー、焦電センサー等が利用できる人体検知センサー２４は、照明部２３の近傍に配置されており、人が照明装置１０を中心として一定距離以内に存在しているかどうかを検知するためのものである。

【００１８】図１に示すように、電源部２２は太陽電池２１と、充放電器２０と、蓄電池１９とを有している。昼間時に太陽電池２１で発電した電気を充放電器２０を介して蓄電池１９に充電して蓄え、照明装置１０の維持用電力及び夜間時等の発光ダイオード２９の発光用電力として使用する。なお、充放電器２０は蓄電池１９が過充電されることを防止する機能を有し、蓄電池１９の充電量を検知して、蓄電池１９の充電量が所定量に達した場合は、太陽電池２１で発電した電気を放電により消費している。

【００１９】図１に示すように、制御部１８は、ＣＰＵ１２、ＲＡＭ１１、ＲＯＭ１３及びＩ／Ｏポート１５を有するマイクロコンピューターと、ドライバー１７と、タイマー１４と、蓄電池残量検知器１６とを有している。タイマー１４は、後述する照明装置用タイマー及び点灯用タイマーから構成されている。ＲＯＭ１３にはＣＰＵ１２を制御するプログラムが書き込まれており、マイクロコンピューターは、このプログラムに従ってＩ／Ｏポート１５より昼夜判別センサー２３ａからの信号と、照明装置１０を中心とした所定の範囲内に人の存在を検知するする人体検知センサー２４からの信号と、発光ダイオード２９の温度を示す温度センサー２５からの信号と、昼夜判別センサー２３ａが夜を検知してか発光ダイオード２９が点灯している時間をカウントする照明装置用タイマーからの信号と、人体検知センサー２４が人を検知した後の時間をカウントして高照度点灯手段から低照度点灯手段への切替え時間をカウントする点灯用タイマーからの信号と、蓄電池の電圧変化から蓄電池１９の蓄電残量を測定する蓄電池残量検知器１６の信号とを取り込み、演算処理を行い、必要に応じて処理したデータをＩ／Ｏポート１５から出力する。Ｉ／Ｏポート１

5から出力された信号をドライバー17に入力して、内部に配置されたスイッチ（接点スイッチ及び／又はスイッチング素子等を含む）の切替えを行い、電源部22に対しては蓄電池19の出力制御を行い、更に照明部23に対しては多数ある発光ダイオード29に供給する発光用電力の制御を行なう。

【0020】マイクロコンピューター詳細にはROM13内のプログラムに、高照度点灯手段が設けられ、この高照度点灯手段によってマイクロコンピューター（以下、単に「CPU」という場合もある）が次の処理を行う。即ち、昼夜判別センサー23aが夜を検知し、人体検知センサー24が人を検知し、照明装置用タイマーと点灯用タイマーがカウントオン（作動中）で、温度センサー25による発光ダイオード29の温度が所定温度未満であると判断した場合、マイクロコンピューターからの出力は、I／Oポート15よりドライバイー17に伝えられ、ドライバイー17のスイッチを切り替えて発光ダイオード29を高照度に点灯する制御を行う。

【0021】一方、マイクロコンピューター詳細にはROM13内のプログラムに、低照度点灯手段が別に設けられ、この低照度点灯手段によって次の処理を行う。即ち、昼夜判別センサー23aが夜を検知したことを条件として、人体検知センサー24が人を検知していないこと、照明装置用タイマーがカウントオンあること、点灯用タイマーがカウントオフであること、発光ダイオード29の温度が所定温度以上であることの少なくとも1つを検出した場合、I／Oポート15を介してドライバイー17に伝えられ、ドライバイー17のスイッチを切り替えて発光ダイオード29を低照度に点灯する制御を行う。

【0022】更に、マイクロコンピューター詳細にはROM13内のプログラムに、電源停止手段が別に設けられている。この電源停止手段は、蓄電池残量検知器16の信号から、蓄電池19の電圧が所定値より下がる、即ち蓄電池19に蓄えられている電気量が所定量より減少したことを検知すると、高照度点灯手段あるいは低照度点灯手段が動作する条件が整っていても、全ての発光ダイオード29の電源供給が遮断する制御を行う。更に、昼夜判別センサー23aが夜を検知した後、発光ダイオード29が夜間に点灯している時間をカウントする照明装置用タイマーが、設定値（例えば、5～7時間）を超えてカウントオフ（即ち、照明装置用タイマーが前記設定時間をカウントアップすること）すると、マイクロコンピューターが、夜間であっても発光ダイオード29の点灯を停止するように制御する。各照明装置10の設置場所、季節等の状況により照明装置用タイマーの設定値を調整して、深夜の不要照明を防止するようにする。照明装置用タイマーのカウント値は、昼夜判別センサー23aが昼（周囲が明るくなったこと）を検知した時点でリセットされ、照明装置用タイマーは初期状態に復帰する。また、点灯用タイマーのカウント値は人体検知センサー24が人を検知していない状態となった時点でリセットされ、点灯用タイマーは初期状態に復帰する。

【0023】図4に本発明の一実施の形態に係る照明装置10の外観図を示す。照明装置10では、照明装置10のステンレス製支柱38に、固定具の一例であるステンレス製腕36を介してアルミニウム製フィン26が取付けられた照明部23が2個取付けられている。また、太陽光を効率よく受光できる方向となるように、太陽電池21が固定具の一例であるステンレス製腕37を介してステンレス製支柱38に取付けられ、照明部23近傍のステンレス製支柱38には人体検知センサー24として焦電センサーが取付けられている。更に、電源部22と制御部18が収納されている例えばステンレス製の機器収納箱39とステンレス製支柱38とは、図示してない地下埋設ケーブルにより接続されている。照明部23に使用している発光ダイオード29の個数は700個であり、5直列、140並列に接続されている。主光源として使用しているのは白色発光ダイオード29aで、色温度調整用に使用している赤色発光ダイオード30の個数は70個である。また、太陽電池21の発電容量は晴天時で最高109W／時であり、蓄電池19の総蓄電量は97Ahである。照明部23では高照度点灯時に発光ダイオード1個に10mAの電流が流れるので、高照度点灯の条件で毎日連続3時間点灯しても（照明装置用タイマーを3時間に設定した場合）、6～7日間は無充電の状態で使用することができる。

【0024】制御部18のROM13に書き込まれているプログラムをフロー図で示すと、図5のようになる。以下、プログラムフロー図に基づいて、本発明の照明装置10の動作について詳しく説明する。プログラムがスタートすると、昼夜判別センサー23aからの起電力を検出し（ステップS1）、起電力が設定値を超える場合は昼と判断し、起電力が設定値未満の場合は夜と判断する（ステップS2）。昼と判断した場合は、電源部22から発光用電力を供給しない照明消灯の状態となる（ステップS15）。

【0025】夜と判断した場合は、照明装置用タイマーがカウントオンとなり、発光ダイオード29の夜間点灯経過時間のカウントを開始する（ステップS3）。夜間点灯経過時間と設定値（照明装置10が夜間に点灯する総時間）とを比較して（ステップS4）、夜間点灯経過時間が設定値を超える場合は、電源部22から発光用電力を供給しない照明消灯の状態となる（ステップS15）。なお、昼夜判別センサー23aによる昼夜の判別精度を高めるため、昼夜判別センサー23aのサンプリングは予め設定した所定時間の間連続して行い、得られた連続測定値が昼夜を区別する設定値を全て超えている場合は昼、測定値が全て設定値を超えない場合は夜と判定するようにしている。昼夜判別センサー23aのサン

プリング設定時間と昼夜判定用の設定値は、各照明装置１０の設置場所の状況により調整する。

【００２６】夜間点灯経過時間が照明装置用タイマーの設定値未満の場合は、蓄電池残量検知器１６により測定した蓄電池電圧を検出し（ステップＳ５）、蓄電池電圧が設定値未満の場合は蓄電池１９の残量が設定値より減少していると判断し、蓄電池電圧が設定値を超える場合は蓄電池１９の残量が設定値を超えていると判断する（ステップＳ６）。蓄電池１９の残量が設定値より減少していると判断した場合は、電源停止手段によって電源部２２から発光用電力を供給しない照明消灯の状態となる（ステップＳ１５）。

【００２７】蓄電池１９の残量が設定値を超えていると判断した場合は、人体検出センサー２４の信号を検知し（ステップＳ７）、照明装置１０を中心とした所定の範囲内に人が存在するか確認する（ステップＳ８）。人体を検出しない場合は、低照度点灯手段によって低照度点灯となる（ステップＳ１４）。

【００２８】人体検出センサー２４が人体を検出した場合は、温度センサー２５からの信号を検知し（ステップＳ９）、発光ダイオード２９の温度と設定値を比較して（ステップＳ１０）、発光ダイオード２９の温度が設定値を超えると判断した場合は、低照度点灯手段によって低照度点灯となる（ステップＳ１４）。発光ダイオード２９の温度が設定値未満と判断した場合は、人体検知センサー２４が人を検知した後の経過時間を高照度点灯手段から低照度点灯手段への切替え時間としてカウントする点灯用タイマーのカウント値と高照度点灯手段から低照度点灯手段への切替え時間の設定値とを比較する（ステップＳ１１）。点灯用タイマーのカウント値（切替え時間）が設定値を超えると低照度点灯手段によって低照度点灯となる（ステップＳ１４）。点灯用タイマーのカウント値が設定時間未満であると、高照度点灯手段によって高照度点灯となる（ステップＳ１３）。

【００２９】高照度点灯（ステップＳ１３）及び低照度点灯（ステップＳ１４）を行なった後は、いずれも照明消灯（ステップＳ１５）の状態を経てステップＳ１の昼夜判別センサー２３ａからの起電力検出に戻り、再度一連の流れを繰り返す。発光ダイオード２９の点灯、消灯の応答性は非常に高いので、照明消灯（ステップＳ１５）の状態が高照度点灯あるいは低照度点灯を行なう一連の流れの中に存在しても、照明装置１０の運転状態には何ら支障はない。

【００３０】次に、本発明の照明装置１０の動作内容を実際の状況に則して説明する。昼間時は、ステップＳ１、Ｓ２、及びステップＳ１５の流れを繰り返す。夜になり、人が照明装置１０を中心とした所定の範囲内に存在しているとステップＳ１～Ｓ１３及びステップＳ１５の流れを繰り返し、人が照明装置１０を中心とした所定の範囲外に立ち去った場合は、ステップＳ１～Ｓ８、Ｓ１４及びステップＳ１５の流れを繰り返す。照明装置１０の夜間点灯経過時間が照明装置用タイマーの設定値を超えると、ステップＳ１～Ｓ４及びステップＳ１５の流れを繰り返すことになり、夜であっても点灯しない。この状態は昼夜判別センサー２３ａが昼を検知するまで継続し、昼が検知された時点で照明装置用タイマーのカウント値は初期状態に復帰し、ステップＳ１～Ｓ４及びステップＳ１５の流れが停止して、ステップＳ１、Ｓ２、及びステップＳ１５の流れに変わり、照明装置１０では照明消灯の状態が継続することになる。

【００３１】なお、蓄電池電圧の検出から蓄電池残量が所定値より減少している場合は、ステップＳ１～Ｓ６及びステップＳ１５の流れを繰り返すことになり、夜であっても点灯しない。また、高照度点灯が長時間継続して、発光ダイオード２９の温度が所定温度以上となると、ステップＳ１～Ｓ１０、Ｓ１４及びステップＳ１５の流れを繰り返すことになり、夜であって人を検出しても低照度点灯しか行なわない。更に、人体検出センサー２４が人を検出してから設定時間経過すると、ステップＳ１～Ｓ１２、Ｓ１４及びステップＳ１５の流れを繰り返すことになり、夜であって人を検出しても低照度点灯しか行なわない。人体検出センサー２４が人を検出しなくなると、点灯用タイマーのカウント値は初期状態に復帰し、ステップＳ１～Ｓ１２、Ｓ１４及びステップＳ１５の流れが停止して、ステップＳ１～Ｓ８、Ｓ１４及びステップＳ１５の流れに変わり、照明装置１０では低照度照明の状態が継続することになる。

【００３２】以上、本発明の実施の形態を説明したが、本発明は、この実施の形態に限定されるものではない。例えば、白色発光ダイオードの総数に対して組み合わせる赤色発光ダイオードの個数と配置状態を調整するとしたが、設定した色温度を再現するのに必要な赤色発光ダイオードの個数よりも多くの赤色発光ダイオードを配置するようにして、季節により赤色発光ダイオードの点灯個数を変化させるようにすることも可能である。季節により照明光の色温度を変化させて、夏季は涼しげな照明を、冬季は温かみのある照明を行なうことができる。また、放熱器に熱電素子を利用することで、発光ダイオードの温度を厳密に制御することが可能となり、照明装置をより安定的に使用することができる。更に、この実施の形態においては、昼夜判別センサーとして照明装置を構成する発光ダイオードを使用したが、例えば、ＣＤＳ、フォトダイオード、フォトトランジスタ等の素子を使用することもできる。

【００３３】

【発明の効果】請求項１～６記載の照明装置においては、低消費電力で高照度な白色光を発する発光ダイオード、橙色光を発する発光ダイオード、及び黄色光を発する発光ダイオードの何れか１又は２以上を組み合わせて光源として使用する照明部と、照明部に電源部から供給

する電力を制御する制御部と、昼夜の区別を検知する昼夜判別センサーと、照明部の発光ダイオードの温度を検知する温度センサーと、照明部の近傍に配置された人体検知センサーとを有する照明装置において、制御部には人体検知センサーが人体を検知した後の時間をカウントする点灯用タイマーと、昼夜判別センサーが夜を検知したこと、人体検知センサーが人を検知したこと、点灯用タイマーがカウントオンであること、及び温度センサーによる発光ダイオードの温度が所定温度未満であることを条件にして、発光ダイオードを高照度に点灯する高照度点灯手段と、昼夜判別センサーが夜を検知したことを条件として、人体検知センサーが人を検知していないこと、点灯用タイマーがカウントオフであること、及び温度センサーによる発光ダイオードの温度が所定温度以上であることの少なくとも1つを更なる条件にして、発光ダイオードを低照度で点灯する低照度点灯手段とを有するので、従来の照明装置では必須作業となるランプの寿命切れの確認や寿命切れランプの交換の作業が不要となり、照明装置の運用経費が節約できる。また、発光ダイオードは点灯、消灯の応答性が非常に速く、頻繁に点灯、消灯を行なっても発光ダイオードの寿命が短くなることはないので、低消費電力化をさらに進めることが可能となる。

【0034】特に、請求項2記載の照明装置においては、照明部には放熱器が設けられ、発光ダイオードが点灯中に発生する熱を外部に放散しているので、高照度点灯が必要な場合に高照度点灯できる状態に発光ダイオードを保つことができる。請求項3記載の照明装置においては、電源部は太陽電池と蓄電池を組み合わせているので、天候の関係で発電できない期間が存在しても、夜間時に照明することができる。また、照明用の電力線の設置が不要となるため、照明装置の設置が容易かつ安価となる。

【0035】請求項4記載の照明装置においては、制御部には昼夜判別センサーが夜を検知した後の時間をカウントする照明装置用タイマーと、蓄電池の残量が所定値より減少した場合は発光ダイオードの点灯を停止する電源停止手段とが設けられているので、不要な深夜の照明を停止して蓄電池内の電気量消費を抑えると共に蓄電池の過放電を防止して蓄電池の寿命の低下を防止することができる。請求項5記載の照明装置においては、白色光を発する白色発光ダイオードを使用した場合、赤色光を発する赤色発光ダイオードを少数混在させて、照明部からの光を温かみのある電球色に近い照明とするので、発光ダイオードの種類を増加させないで、照明の状態を人の目の感覚に合わせて任意に調整することが容易かつ安価にできる。

【0036】請求項6記載の照明装置においては、昼夜判別センサーに、照明部の発光ダイオードの何れか1又は2以上を使用し、発光ダイオードが昼間に発する起電力を検知して、昼夜を検知するので、昼夜判別センサーを特別に設ける必要がなく、装置より簡単に構成することが可能となり、装置を安価に製作することができる。

【図面の簡単な説明】

【図1】本発明の一実施の形態に係る照明装置における機器構成を示したブロック図である。

【図2】同照明装置の照明部の部分断面図である。

【図3】同照明装置の発光ダイオードの配置を示す平面図である。

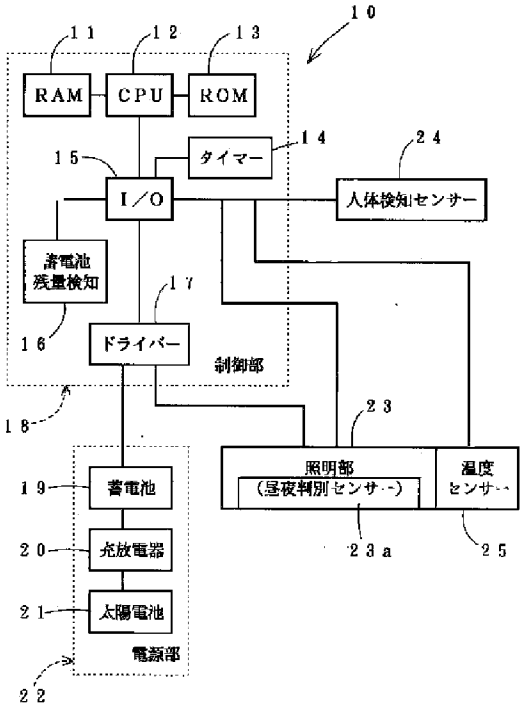
【図4】同照明装置の外観図である。

【図5】同照明装置の動作内容を示したフロー図である。

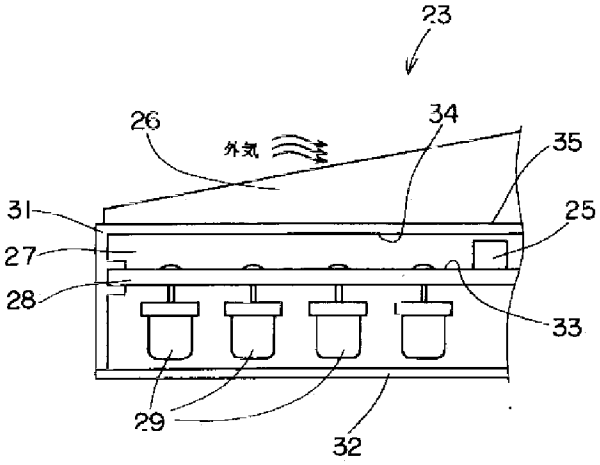
【符号の説明】

10：照明装置、11：RAM、12：CPU、13：ROM、14：タイマー、15：I／Oポート、16：蓄電池残量検知器、17：ドライバー、18：制御部、19：蓄電池、20：充放電器、21：太陽電池、22：電源部、23：照明部，23a：昼夜判別センサー、24：人体検知センサー、25：温度センサー、26：アルミニウム製フィン、27：空間部（シリコン樹脂）、28：基板、29：発光ダイオード、29a：白色発光ダイオード、30：赤色発光ダイオード、31：アルミニウム製箱、32：プラスチックカバー、33：基板裏面、34：アルミニウム製箱内底、35：アルミニウム製箱外底、36、37：ステンレス製腕、38：ステンレス製支柱、39：機器収納箱、40：発光用電力供給回路、41：超電力検出回路、42：回路切替え手段

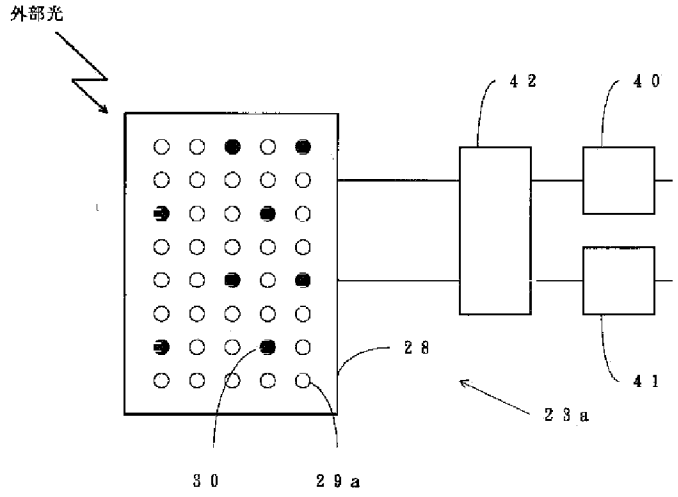
【図1】


10
11
12
13
RAM
CPU
ROM
14
タイマー
24
15
I/O
人体検知センサー
蓄電池
残量検知
16
17
ドライバー
制御部
18
23
照明部
(昼夜判別センサー)
温度
センサー
23a
25
19
蓄電池
20
充放電器
21
太陽電池
電源部
22

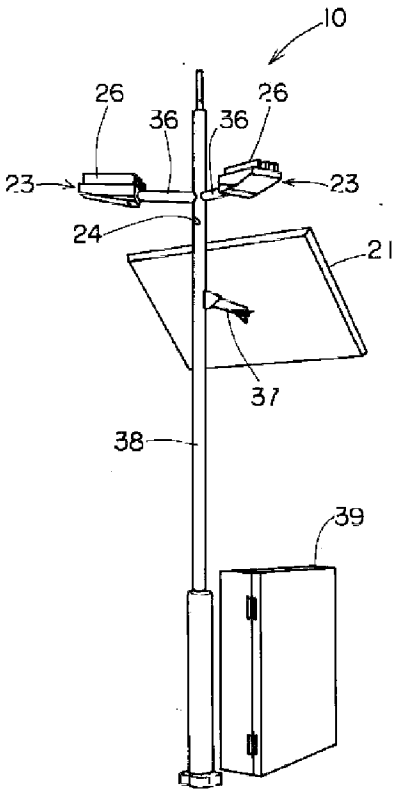
【図2】


23
26
外気
34
35
31
25
27
28
33
29
32

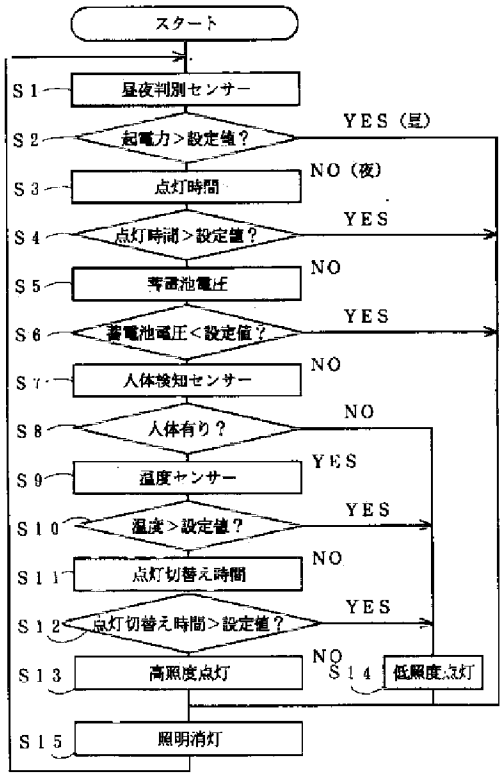
【図3】


外部光
42
40
28
41
23a
30
29a

【図4】


10
26
36
36
26
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23
24
21
37
38
39

【図5】



フロントページの続き

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LIGHTING SYSTEM

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Classification: **- international:** ***H01L33/00; H05B37/02;*** (IPC1-7): H01L33/00; H05B37/02

- cooperative:

Application number: JP19980200951 19980715

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Abstract of JP2000030877 (A)

PROBLEM TO BE SOLVED: To dim the light output in steps with an easily miniaturizable structure at a low cost in a lighting system using light emission diodes as a light source. SOLUTION: This lighting system is provided with multiple LED arrays 1, 2,..., m connected with one or multiple light emission diodes and current limiting elements Z1, Z2,..., Zm in series. One-side ends of the LED arrays 1, 2,..., m are connected in common to one DC output terminal of a full-wave rectifying circuit DB full-wave-rectifying an AC power source AC. A switch means SW is provided for selectively connecting the other ends of the LED arrays 1, 2,..., m to the other DC output terminal of the full-wave rectifying circuit DB or to one end of the AC power source AC.

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H01L 33/00 (2006.01)　H01L 33/00　L

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(54)【発明の名称】照明装置

(57)【特許請求の範囲】

【請求項1】

１個あるいは複数個の発光ダイオードと限流要素とを直列に接続して成るＬＥＤアレイを複数列備え、交流電源を全波整流する全波整流回路の一方の直流出力端子に各ＬＥＤアレイの各一端を共通接続し、各ＬＥＤアレイの各他端をそれぞれ前記全波整流回路の他方の直流出力端子又は前記交流電源の一端のいずれかに選択的に切り替え接続するスイッチ手段を設けたことを特徴とする照明装置。

【請求項2】

前記全波整流回路の直流出力端子間に接続されて前記一方の直流出力端子を基準電位として任意の電圧波形を発生させる任意波形発生回路を備え、前記スイッチ手段は、各ＬＥＤアレイの各他端をそれぞれ前記全波整流回路の他方の直流出力端子又は前記交流電源の一端、又は前記任意波形発生回路の出力端子のいずれかに選択的に切り替え接続する手段であることを特徴とする請求項１記載の照明装置。

【請求項3】

前記任意波形発生回路は各ＬＥＤアレイの順方向降下電圧よりも高い電圧ピーク値を有する１つ又は複数の電圧波形を発生させる回路であることを特徴とする請求項２記載の照明装置。

【請求項4】

前記各ＬＥＤアレイを構成する発光ダイオードの個数はアレイ毎にそれぞれ異なる個数に設定されていることを特徴とする請求項１乃至３のいずれかに記載の照明装置。

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【請求項5】
前記各ＬＥＤアレイを構成する発光ダイオードの発光色はアレイ毎にそれぞれ異なる発光色が選択されていることを特徴とする請求項１乃至３のいずれかに記載の照明装置。
【請求項6】
前記各限流要素は、各発光ダイオードに流れる電流を制限する限流素子であることを特徴とする請求項１乃至３のいずれかに記載の照明装置。
【請求項7】
　前記各限流要素は、各発光ダイオードに流れる電流を制御する定電流回路であることを特徴とする請求項1記載の照明装置。

【発明の詳細な説明】
【０００１】
【発明の属する技術分野】
本発明は発光ダイオードを光源とする照明装置に関するものであり、特に、その段調光回路に関するものである。
【０００２】
【従来の技術】
従来、発光ダイオードを光源とする照明装置において、光出力を可変とするために幾つかの回路が提案されている。図５の従来例は、複数のＬＥＤを直列接続して成る複数列のＬＥＤアレイ１，…，ｍ（ｍは２以上の整数）と、各ＬＥＤアレイ１，…，ｍの一端に一方の電極を接続された電源Ｅと、電源Ｅの他方の電極に各一端を接続された限流用の抵抗Ｒ１，Ｒ２と、これらの抵抗Ｒ１，Ｒ２の各他端とＬＥＤアレイ１，…，ｍの各他端を任意に切り替え接続するスイッチ手段ＳＷとから成り、抵抗値の異なる２つの抵抗Ｒ１，Ｒ２のいずれかを限流用の抵抗として選択することにより、各ＬＥＤアレイ１，…，ｍは各々２種類の電流値を選択することができ、ｍ＝２の照明装置では、４段階の調光が可能となる。
【０００３】
図６の従来例は、トランジスタを用いた定電流回路によりＬＥＤに流れる電流を切り替えるものであり、複数のＬＥＤを直列接続して成る複数列のＬＥＤアレイ１，…，ｍ（ｍは２以上の整数）と、各ＬＥＤアレイ１，…，ｍの一端に一方の電極を接続された電源Ｅと、電源Ｅの他方の電極に各一端を接続された限流用の抵抗Ｒ１，…，Ｒｍと、これらの抵抗Ｒ１，…，Ｒｍの各他端にエミッタを接続され、ＬＥＤアレイ１，…，ｍの各他端にコレクタを接続されたトランジスタＱ１，…，Ｑｍと、各トランジスタＱ１，…，Ｑｍにベース電位を与える直流電源Ｅ１，Ｅ２と、各トランジスタＱ１，…，Ｑｍのベースと直流電源Ｅ１，Ｅ２の接続を個別に選択するスイッチ手段ＳＷとから成り、電圧値の異なる２つの直流電源Ｅ１，Ｅ２のいずれかを各トランジスタＱ１，…，Ｑｍのベースに接続することにより、各ＬＥＤアレイ１，…，ｍは各々２種類の電流値を選択することができ、ｍ＝２の照明装置では、４段階の調光が可能となる。
【０００４】
図７の従来例は、図６と同様の回路構成の定電流回路であるが、トランジスタＱ１，…，Ｑｍのベースに接続される直流電源Ｅ１，Ｅ２に代えて、矩形波状のパルス波形を出力するパルス電源Ｐ１，Ｐ２を用いたものであり、パルス状の電圧によりトランジスタＱ１，…，Ｑｍに流れる電流を断続させ、パルス幅制御（ＰＷＭ制御）によりＬＥＤに流れる平均電流を切り替えている。すなわち、パルス幅（デューティ）の異なる２つの矩形波状のパルス波形を出力するパルス電源Ｐ１，Ｐ２のいずれかを各トランジスタＱ１，…，Ｑｍのベースに接続することにより、各ＬＥＤアレイ１，…，ｍは各々２種類の平均電流値を選択することができ、ｍ＝２の照明装置では、４段階の調光が可能となる。
【０００５】
【発明が解決しようとする課題】
これらの電流制御方式では、同一電源Ｅを用いて段調光を行っており、図５の抵抗切り替え方式では、抵抗Ｒ１，Ｒ２の消費電力を設定する際、抵抗Ｒ１，Ｒ２に流れる最大電流

を想定しなければならない。また、流れる電流は、接続されるＬＥＤアレイの最大数とＬＥＤに流す最大電流を考慮せねばならない。したがって、消費電力の大きい抵抗Ｒ１，Ｒ２を採用しなければならず、コスト、サイズとも大きい抵抗となる。また、図６、図７の方式でも、同様にＬＥＤアレイの最大接続数を考慮した設計が必要となるため、制御部のコスト、サイズとも大きくなる。

【０００６】

本発明は上述のような点に鑑みてなされたものであり、その目的とするところは、発光ダイオードを光源とする照明装置において、安価で小型化も容易な構成で光出力を段調光可能とすることにある。

【０００７】

【課題を解決するための手段】

本発明の照明装置によれば、上記の課題を解決するために、図１に示すように、１個あるいは複数個の発光ダイオードと限流要素Ｚ１，Ｚ２，…，Ｚｍとを直列に接続して成るＬＥＤアレイ１，２，…，ｍを複数列備え、交流電源ＡＣを全波整流する全波整流回路ＤＢの一方の直流出力端子に各ＬＥＤアレイ１，２，…，ｍの各一端を共通接続し、各ＬＥＤアレイ１，２，…，ｍの各他端をそれぞれ前記全波整流回路ＤＢの他方の直流出力端子又は前記交流電源ＡＣの一端のいずれかに選択的に切り替え接続するスイッチ手段ＳＷを設けたことを特徴とするものである。

【０００８】

【発明の実施の形態】

（実施例１）

図１に本発明の実施例１の回路図を示す。本実施例の回路は、交流電源ＡＣと、この交流電源ＡＣに接続された全波整流回路ＤＢと、複数のＬＥＤを直列接続して成る複数列のＬＥＤアレイ１，…，ｍ（ｍは２以上の整数）と、各ＬＥＤアレイ１，…，ｍのカソード側に各一端を接続され、全波整流回路ＤＢの負出力端子に各他端を共通接続された抵抗等の限流素子Ｚ１，…，Ｚｍと、各ＬＥＤアレイ１，…，ｍのアノード側を全波整流回路ＤＢの正出力端子又は交流電源ＡＣの一端に選択的に切り替え接続するスイッチ手段ＳＷとから成り、全波通電又は半波通電のいずれかを選択することにより、各ＬＥＤアレイ１，…，ｍは各々２種類の電流値を選択することができ、ｍ＝２の照明装置では、４段階の調光が可能となる。

【０００９】

例えば、限流素子Ｚ１に直列に複数のＬＥＤを接続したＬＥＤアレイ１のアノード側端子Ａ１を交流電源ＡＣの一端Ｓ１に接続すると、図２（ａ）に示すように、ＬＥＤの順方向降下電圧によって決まる所定電圧Ｖｔを越えると限流素子Ｚ１により制限された電流Ｉｚ１がＬＥＤに流れ、ＬＥＤが点灯発光する。このとき、ＬＥＤの整流作用により、半波整流された電源電圧でＬＥＤが点灯されたのと同じ状態となっている。

【００１０】

次に、例えば、限流素子Ｚ２に直列に複数のＬＥＤを接続したＬＥＤアレイ２のアノード側端子Ａ２を全波整流回路ＤＢの正出力端子Ｓ２に接続すると、図２（ｂ）に示すように、ＬＥＤの順方向降下電圧によって決まる所定電圧Ｖｔを越えると限流素子Ｚ２により制限された電流Ｉｚ２がＬＥＤに流れ、ＬＥＤが点灯発光する。このとき、ＬＥＤアレイ１とＬＥＤアレイ２が、同一仕様で構成されているとすると、ＬＥＤアレイ２の各ＬＥＤに流れる電流の平均値は、ＬＥＤアレイ１の各ＬＥＤに流れる電流の平均値の２倍となる。したがって、端子Ｓ１、Ｓ２と端子Ａ１、Ａ２の接続の組み合わせにより、段調光が可能となる。

【００１１】

（実施例２）

図３に本発明の実施例２の回路図を示す。本実施例の回路は、実施例１の全波整流回路ＤＢの出力電圧を入力として、任意の電圧波形を発生させる任意波形発生回路Ｗを設けて、その出力端子Ｓ３，…，Ｓｎ（ｎは３以上の整数）をスイッチ手段ＳＷにより各ＬＥＤア

レイ１，…，ｍのアノード側端子Ａ１，…，Ａｍに選択的に切り替え接続可能としている。この任意波形発生回路Ｗからは、例えば図２（ｃ）に示すような三角波、図２（ｄ）に示すようなＬＥＤアレイの順方向降下電圧の和より小さくならない脈流波形、図２（ｅ）に示すような脈流の無い波形の直流電圧などを出力する。これらの波形は、そのピーク値がＬＥＤアレイの順方向降下電圧の和より大きければ、図示された例だけに限られるものではない。選択された任意の電圧波形Ｖｓの場合に流れるＬＥＤ電流Ｉｚは、（任意波形電圧－ＬＥＤの順方向降下電圧）／限流用抵抗で表される。

【００１２】

（実施例３）

図４は本発明の実施例３の動作波形図である。本実施例では、図３の回路において、限流素子Ｚ１，…，Ｚｍとして、図６に示すような定電流回路を用いた場合に、ＬＥＤに流れる電流波形を示している。この場合、ＬＥＤに流れる電流は定電流となる。図中、（ａ）はＬＥＤアレイのアノード側端子を交流電源ＡＣの一端Ｓ１に接続した場合、（ｂ）は全波整流回路ＤＢの正出力端子Ｓ２に接続した場合、（ｃ）は脈流の無い波形の直流電圧に接続した場合の動作をそれぞれ示している。

【００１３】

（実施例４）

また、特に図示しないが、各ＬＥＤアレイ１，２，…，ｍの発光色、個数を任意に設定することにより、任意の発光色または調光段数の設定が可能となる。

【００１４】

【発明の効果】

請求項１の発明によれば、複数列のＬＥＤアレイのそれぞれについて、交流電源による半波通電又は全波整流回路による全波通電のいずれかを選択できるので、簡単な回路構成で段調光が可能となる。

請求項２又は３の発明によれば、任意波形発生回路を設けたことにより、各ＬＥＤアレイについて、全波通電と半波通電による２段階の調光に比べてさらに多段階の調光が可能となる。

【００１５】

請求項４又は５の発明によれば、発光ダイオードの個数や発光色を任意に選択することにより調光／調色が可能となる。

請求項６又は７の発明によれば、各発光ダイオードに流れる電流のピーク値を制限することができる。

【図面の簡単な説明】

【図１】本発明の実施例１の回路図である。

【図２】本発明の実施例１の動作説明のための波形図である。

【図３】本発明の実施例２の回路図である。

【図４】本発明の実施例３の動作説明のための波形図である。

【図５】従来例１の回路図である。

【図６】従来例２の回路図である。

【図７】従来例３の回路図である。

【符号の説明】

１，２，…，ｍ　　ＬＥＤアレイ

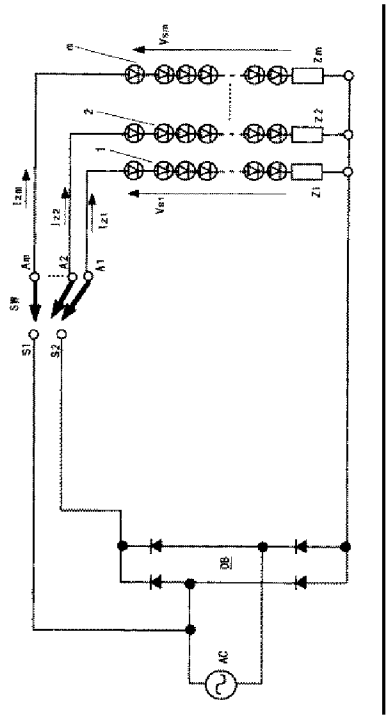
ＳＷ　　スイッチ手段

ＡＣ　　交流電源

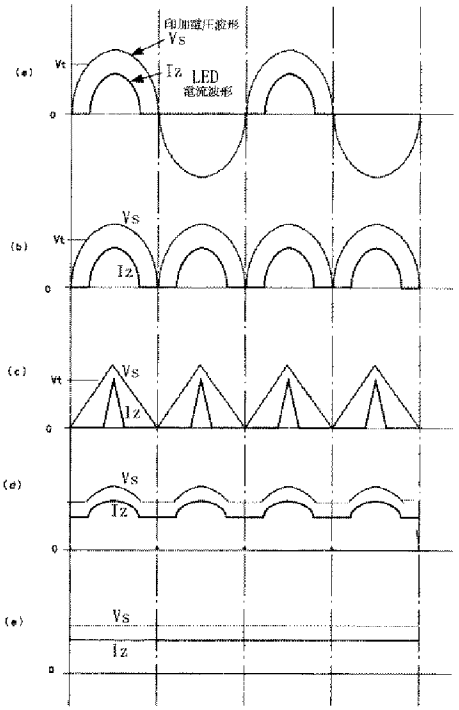
ＤＢ　　全波整流回路

Ｚ１，…，Ｚｍ　　限流要素

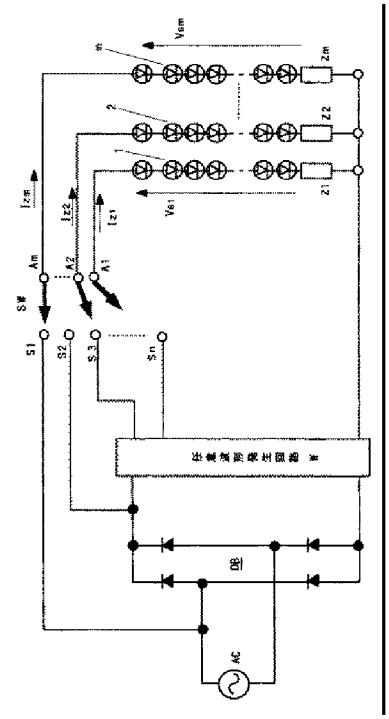
【図1】


n
Vsn
Zn
2
Z2
1
Z1
Vs1
Izn
Iz2
Iz1
An
A2
A1
SW
S1
S2
整流回路
AC

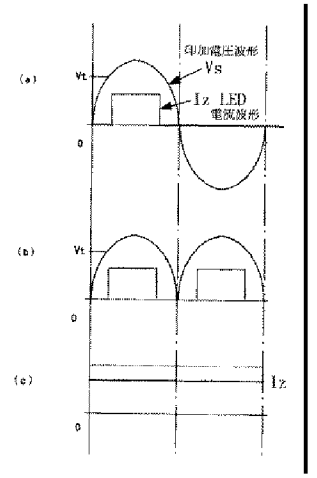
【図2】


印加電圧波形
Vs
(a)
Vt
Iz
LED
電流波形
0
(b)
Vs
Iz
(c)
(d)
(e)

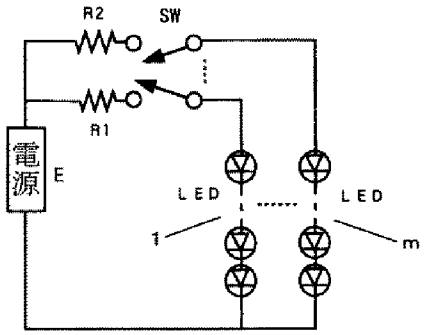
【図3】


n
Vsn
Zn
2
Z2
1
Z1
Vs1
Izn
Iz2
Iz1
An
A2
A1
SW
S1
S2
S3
Sn
整流回路
AC

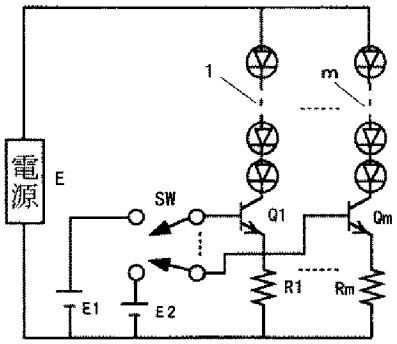
【図4】


印加電圧波形
Vs
(a)
Vt
Iz
LED
電流波形
0
(b)
(c)

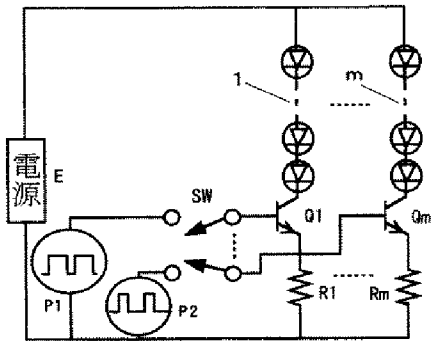
【図5】


R2
SW
R1
電源
E
LED
LED
1
m

【図6】



【図7】



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審査官　永田　和彦

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特開平０６－０４５０７５（ＪＰ，Ａ）
特開昭４９－０７９４９２（ＪＰ，Ａ）
実開平０３－１１６６９８（ＪＰ，Ｕ）
実開昭４９－１４５５８０（ＪＰ，Ｕ）
実開昭５５－１３８７９７（ＪＰ，Ｕ）

(58)調査した分野(Int.Cl.，ＤＢ名)
H05B 37/00-37/04,
H01L 33/00,
G09F 13/00-13/20

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Bibliographic data: JP2001284065 (A) — 2001-10-12

ILLUMINATOR

Inventor(s): FUJIMOTO KOJI; KATAYAMA NAOTAKE; ICHIDA SHINICHI ± (FUJIMOTO KOJI, ; KATAYAMA NAOTAKE, ; ICHIDA SHINICHI)

Applicant(s): MATSUSHITA ELECTRIC WORKS LTD; ASAHI NAT LIGHTING CO LTD ± (MATSUSHITA ELECTRIC WORKS LTD, ; ASAHI NATIONAL LIGHTING CO LTD)

Classification: **- international:** ***H05B37/02;*** (IPC1-7): H05B37/02
- cooperative: Y02B20/40 (EP)

Application number: JP20000099349 20000331

Priority number (s): JP20000099349 20000331

Abstract of JP2001284065 (A)

PROBLEM TO BE SOLVED: To provide an illuminator making a sleeping user wake up comfortably by stimulation of light without giving any feeling of uneasiness and unpleasantness. SOLUTION: The illuminator has a remote-controlling transmitter 11, a plurality of incandescent lamps 131 as the first luminous part 13, a fluorescent lamp 141 as the second luminous part 14, and a lighting device 10 which is composed of a light control part 101, a lighting part 102, a receiving part 103, a switch 11, a switch 12, and a control part 100. The control part 100 controls the lighting of the first luminous part 13 through the light control part 101 so as to make the output power of the first luminous part 13 increase continuously or stepwise from that of low brightness side and reach that of high brightness at the time set beforehand. Toward the time set beforehand, the second luminous part 14 is controlled to turn on and the first luminous part 13 is controlled to turn off through the lighting part 102 so as to change the luminous part from the first luminous part 13 to the second luminous part 14 by turning on the second luminous part 14 while the first luminous part 13 is lighting.

(19)日本国特許庁（ＪＰ）　(12) **公開特許公報**（Ａ）　(11)特許出願公開番号
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Ｈ０５Ｂ　37/02		Ｈ０５Ｂ　37/02	Ｆ　３Ｋ０７３
			Ｈ
			Ｌ

審査請求　未請求　請求項の数13　ＯＬ　（全 14 頁）

(21)出願番号　特願2000－99349(P2000－99349)

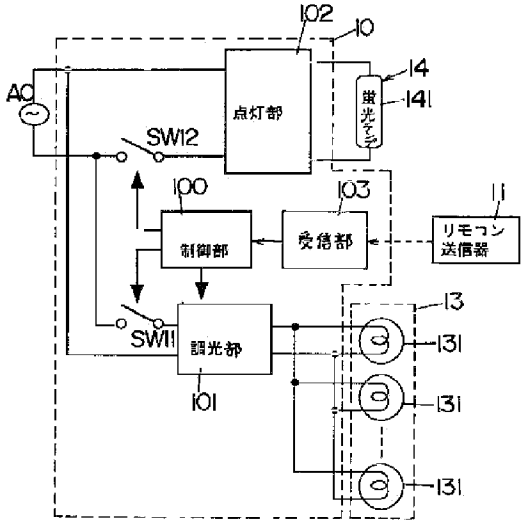
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最終頁に続く

(54)【発明の名称】　照明装置

(57)【要約】
【課題】　光刺激によって就寝者を心地よく目覚めさせ、不安感や不快感を与えないようにする。
【解決手段】　リモコン送信器１１と、第１発光部１３としての複数の白熱ランプ１３１と、第２発光部１４としての蛍光ランプ１４１と、点灯装置１０とを設け、この点灯装置１０を、調光部１０１、点灯部１０２、受信部１０３、スイッチＳＷ１１，ＳＷ１２および制御部１００で構成した。この制御部１００は、第１発光部１３の光出力が低照度側から連続的または段階的に上昇してセット時刻に高照度になるように、調光部１０１を通じて第１発光部１３の調光制御を行い、セット時刻頃に、第１発光部１３が点灯しているうちに第２発光部１４が点灯して第１発光部１３から第２発光部１４に照明が切り替わるように、点灯部１０２を通じて第２発光部１４の点灯制御を行うとともに、第１発光部１３の消灯制御を行う。



１０　点灯装置
１１　リモコン送信器
１３　第１発光部
１４　第２発光部
１００　制御部
１０１　調光部
１０２　点灯部
１０３　受信部

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【特許請求の範囲】
【請求項１】　照明用の第１発光手段と、
照明用の第２発光手段と、
前記第１発光手段の調光を行う調光手段と、
前記第２発光手段の点灯を行う点灯手段と、
前記第１発光手段の光出力が低照度側から連続的または段階的に上昇してセット時刻に高照度になるように、前記調光手段を通じて前記第１発光手段の調光制御を行い、前記セット時刻頃に、前記第１発光手段が点灯しているうちに前記第２発光手段が点灯して前記第１発光手段から前記第２発光手段に照明が切り替わるように、前記点灯手段を通じて前記第２発光手段の点灯制御を行うとともに、前記第１発光手段の消灯制御を行う制御手段とを備えることを特徴とする照明装置。
【請求項２】　前記制御手段は、前記セット時刻頃に、前記第２発光手段が点灯するように前記点灯手段を通じて前記第２発光手段の点灯制御を行い、この後、前記第１発光手段がフェードアウトで消灯するように、前記調光手段を通じて前記第１発光手段の調光制御を行って、前記第１発光手段の消灯制御を行うことを特徴とする請求項１記載の照明装置。
【請求項３】　前記第２発光手段は蛍光ランプであり、前記点灯手段は前記第２発光手段の先行予熱、始動および点灯を行い、前記制御手段は、前記調光手段を通じて前記第１発光手段のフィードアウトを開始するほぼ１秒前に、前記点灯手段を通じて前記蛍光ランプの先行予熱を開始することを特徴とする請求項２記載の照明装置。
【請求項４】　前記第２発光手段は蛍光ランプであり、前記点灯手段は前記第２発光手段の先行予熱、始動および点灯を行い、前記制御手段は、前記セット時刻頃に、前記第１発光手段が点灯しているうちに前記第２発光手段が点灯するように、前記点灯手段を通じて前記第２発光手段の先行予熱、始動および点灯制御を行う場合、点灯操作に応じて前記第２発光手段の先行予熱、始動および点灯制御を行う場合よりも、先行予熱電流を小さくしかつ先行予熱時間を長くして前記蛍光ランプの先行予熱を行い、この先行予熱の終了と同時に前記第１発光手段の消灯制御を行うことを特徴とする請求項１または２記載の照明装置。
【請求項５】　前記制御手段は、前記セット時刻頃に、前記第１発光手段がフェードアウトで消灯するように、前記調光手段を通じて前記第１発光手段の調光制御を行って、消灯制御を行い、前記フェードアウト中に前記第２発光手段が点灯するように、前記点灯手段を通じて前記第２発光手段の点灯制御を行うことを特徴とする請求項１記載の照明装置。
【請求項６】　前記第１および第２発光手段の各々は少なくとも１つの光源により成り、前記制御手段は、前記第１発光手段がフェードアウトで消灯するように、前記調光手段を通じて前記第１発光手段の調光制御を行って、消灯制御を行うとともに、前記第２発光手段がフェードインで点灯するように、前記点灯手段を通じて前記第２発光手段の点灯制御を行って、前記第１発光手段から前記第２発光手段に照明が切り替わる間、前記複数の光源の少なくとも１つを点灯させることを特徴とする請求項１記載の照明装置。
【請求項７】　前記フェードアウトで前記第１発光手段の光出力が５０％になるとき、前記フェードインで前記第２発光手段の光出力が略５０％になることを特徴とする請求項６記載の照明装置。
【請求項８】　前記第１発光手段の低照度時の色温度は３０００Ｋ以下であることを特徴とする請求項１～７のいずれかに記載の照明装置。
【請求項９】　前記セット時刻以降の照明の色温度は４０００Ｋ～６０００Ｋであることを特徴とする請求項８記載の照明装置。
【請求項１０】　前記第１および第２発光手段は複数のランプにより成り、前記第１発光手段を構成する複数のランプのうち、所望のランプに対する前記調光手段による調光を許容ないし禁止することを特徴とする請求項１～９のいずれかに記載の照明装置。
【請求項１１】　前記第１および第２発光手段は複数の照明器具により成り、前記第１発光手段を構成する複数の照明器具のうち、所望の照明器具のランプに対する前記調光手段による調光を許容ないし禁止することを特徴とする請求項１～９のいずれかに記載の照明装置。
【請求項１２】　複数のランプを備え、セット時刻に対して低照度から高照度へ連続的または段階的に光出力を上げる目覚まし機能を有する照明装置であって、低照度から高照度へ光出力が上昇するランプを選択できることを特徴とする照明装置。
【請求項１３】　連動する照明器具を複数備え、セット時刻に対して低照度から高照度へ連続的または段階的に光出力を上げる目覚まし機能を有する照明装置であって、低照度から高照度へ光出力が上昇する前記照明器具のランプを選択できることを特徴とする照明装置。
【発明の詳細な説明】
【０００１】
【発明の属する技術分野】本発明は、光刺激によって就寝者を目覚めさせる目覚まし機能付きの照明装置に関するものである。
【０００２】
【従来の技術】従来、この種の装置として、セット時刻に応じて低照度から高照度に連続的または段階的に照度を変化させることにより、就寝者の睡眠を深い状態から浅い状態に導いて、より心地よい目覚めを促すものが知られている。
【０００３】例えば、特開平７－３１８６７０号公報には、設定された起床希望時刻に応じて光発生手段を動作させて光発生手段が発生する光の照度を低照度、中照

度、高照度の順に変化させるとともに低照度から中照度への照度変化を穏やかに、中照度から高照度への照度変化を急速に行う目覚まし装置が開示されている。

【0004】

【発明が解決しようとする課題】また、放電ランプと電球とを備え、第1の所定時刻になると、少なくとも電球の光出力を変化させる照明装置が提案されている（特願平11-152957号）。この照明装置では、図18（a）に示すように、セット時刻の一定時間前に光源Aが点灯を開始し、この後、所定の上昇カーブ（このカーブについては、特開平7-318670号公報で説明されている。）で光源Aの照度が徐々に上昇し、セット時刻になると、光源Aが消灯して光源Bが点灯する。

【0005】このような照明装置の場合、光源Aと光源Bとの切替制御が重要となる。つまり、図18（b）に示すように、セット時刻に光源が切り替わる時、それぞれの光源が同時に消灯している状態ができると、明るくなった後にその消灯により暗くなり、そして別の光源の点灯によりまた明るくなるので、心地よい目覚めを促すという本来の目的を達成することができず、かえってユーザに不安感や不快感を与えてしまう恐れがある。

【0006】また、比較的広い部屋に1人で寝ている場合に部屋全体を明るくしてしまうと省エネルギーの面から見て問題が有るのは明らかである。

【0007】さらに、同じ部屋で寝ている複数の人の起床時刻が必ずしも一致しているとは限らない。

【0008】本発明は、上記事情に鑑みてなされたものであり、光刺激によって就寝者を心地よく目覚めさせることができるとともに、不安感や不快感を与えることのない照明装置を提供することを目的とする。

【0009】

【課題を解決するための手段】上記課題を解決するために、請求項1記載の発明の照明装置は、照明用の第1発光手段と、照明用の第2発光手段と、前記第1発光手段の調光を行う調光手段と、前記第2発光手段の点灯を行う点灯手段と、前記第1発光手段の光出力が低照度側から連続的または段階的に上昇してセット時刻に高照度になるように、前記調光手段を通じて前記第1発光手段の調光制御を行い、前記セット時刻頃に、前記第1発光手段が点灯しているうちに前記第2発光手段が点灯して前記第1発光手段から前記第2発光手段に照明が切り替わるように、前記点灯手段を通じて前記第2発光手段の点灯制御を行うとともに、前記第1発光手段の消灯制御を行う制御手段とを備えるのである。

【0010】請求項2記載の発明は、請求項1記載の照明装置において、前記制御手段は、前記セット時刻頃に、前記第2発光手段が点灯するように前記点灯手段を通じて前記第2発光手段の点灯制御を行い、この後、前記第1発光手段がフェードアウトで消灯するように、前記調光手段を通じて前記第1発光手段の調光制御を行って、前記第1発光手段の消灯制御を行うことを特徴とする。

【0011】請求項3記載の発明は、請求項2記載の照明装置において、前記第2発光手段は蛍光ランプであり、前記点灯手段は前記第2発光手段の先行予熱、始動および点灯を行い、前記制御手段は、前記調光手段を通じて前記第1発光手段のフィードアウトを開始するほぼ1秒前に、前記点灯手段を通じて前記蛍光ランプの先行予熱を開始することを特徴とする。

【0012】請求項4記載の発明は、請求項1または2記載の照明装置において、前記第2発光手段は蛍光ランプであり、前記点灯手段は前記第2発光手段の先行予熱、始動および点灯を行い、前記制御手段は、前記セット時刻頃に、前記第1発光手段が点灯しているうちに前記第2発光手段が点灯するように、前記点灯手段を通じて前記第2発光手段の先行予熱、始動および点灯制御を行う場合、点灯操作に応じて前記第2発光手段の先行予熱、始動および点灯制御を行う場合よりも、先行予熱電流を小さくしかつ先行予熱時間を長くして前記蛍光ランプの先行予熱を行い、この先行予熱の終了と同時に前記第1発光手段の消灯制御を行うことを特徴とする。

【0013】請求項5記載の発明は、請求項1記載の照明装置において、前記制御手段は、前記セット時刻頃に、前記第1発光手段がフェードアウトで消灯するように、前記調光手段を通じて前記第1発光手段の調光制御を行って、消灯制御を行い、前記フェードアウト中に前記第2発光手段が点灯するように、前記点灯手段を通じて前記第2発光手段の点灯制御を行うことを特徴とする。

【0014】請求項6記載の発明は、請求項1記載の照明装置において、前記第1および第2発光手段の各々は少なくとも1つの光源により成り、前記制御手段は、前記第1発光手段がフェードアウトで消灯するように、前記調光手段を通じて前記第1発光手段の調光制御を行って、消灯制御を行うとともに、前記第2発光手段がフェードインで点灯するように、前記点灯手段を通じて前記第2発光手段の点灯制御を行って、前記第1発光手段から前記第2発光手段に照明が切り替わる間、前記複数の光源の少なくとも1つを点灯させることを特徴とする。

【0015】請求項7記載の発明は、請求項6記載の照明装置において、前記フェードアウトで前記第1発光手段の光出力が50%になるとき、前記フェードインで前記第2発光手段の光出力が略50%になることを特徴とする。

【0016】請求項8記載の発明は、請求項1～7のいずれかに記載の照明装置において、前記第1発光手段の低照度時の色温度は3000K以下であることを特徴とする。

【0017】請求項9記載の発明は、請求項8記載の照明装置において、前記セット時刻以降の照明の色温度は

４０００Ｋ～６０００Ｋであることを特徴とする。

【００１８】請求項１０記載の発明は、請求項１～９のいずれかに記載の照明装置において、前記第１および第２発光手段は複数のランプにより成り、前記第１発光手段を構成する複数のランプのうち、所望のランプに対する前記調光手段による調光を許容ないし禁止することを特徴とする。

【００１９】請求項１１記載の発明は、請求項１～９のいずれかに記載の照明装置において、前記第１および第２発光手段は複数の照明器具により成り、前記第１発光手段を構成する複数の照明器具のうち、所望の照明器具のランプに対する前記調光手段による調光を許容ないし禁止することを特徴とする。

【００２０】請求項１２記載の発明は、複数のランプを備え、セット時刻に対して低照度から高照度へ連続的または段階的に光出力を上げる目覚まし機能を有する照明装置であって、低照度から高照度へ光出力が上昇するランプを選択できることを特徴とする。

【００２１】請求項１３記載の発明は、連動する照明器具を複数備え、セット時刻に対して低照度から高照度へ連続的または段階的に光出力を上げる目覚まし機能を有する照明装置であって、低照度から高照度へ光出力が上昇する前記照明器具のランプを選択できることを特徴とする。

【００２２】

【発明の実施の形態】図１は本発明に係る第１実施形態の照明装置の構成図、図２は図１の照明装置の外観図、図３，図４は図１の照明装置の動作説明図で、これらの図を用いて以下に第１実施形態の説明を行う。

【００２３】本照明装置は、図２に示すように、リモコン送信器１１付きの照明器具であって、天井面に取り付けられる本体１２と、この本体１２に取り付けられる第１発光部１３としての複数の白熱ランプ（ミニクリプトン電球）１３１と、本体１２に取り付けられる第２発光部１４としての蛍光ランプ１４１と、本体１２内に収納される点灯装置１０（図２では図示省略）とを備えている。

【００２４】リモコン送信器１１は、操作キー、送信部（例えば赤外線送信部）、タイマおよびマイコンなどにより成り、このマイコンによって、例えば、第１発光部１３および第２発光部１４の少なくとも一方を点灯／消灯させるための信号を、操作キーの操作に応じて送信部から送信する制御などが行われるほか、目覚まし機能を動作させるべく、操作キーでセット時刻として起床時刻が設定されると、そのセット時刻の所定時間前に送信部から目覚まし機能動作用の信号を送信する制御が行われる。

【００２５】点灯装置１０は、図１に示すように、第１発光部１３の調光を行う調光部１０１と、電源が投入されると第２発光部１４の先行予熱、始動および点灯を行う点灯部１０２と、リモコン送信器１１からの信号受信用の受信部（例えば赤外線受信用の受光モジュール）１０３と、調光部１０１に対する商用電源ＡＣのオン／オフ用のスイッチＳＷ１１と、点灯部１０２に対する商用電源ＡＣのオン／オフ用のスイッチＳＷ１２とを備えているとともに、制御部１００を備えている。

【００２６】この制御部１００は、マイコンなどにより成り、点灯装置１０全般の制御などの処理をリモコン送信器１１と協調して行うもので、例えば、リモコン送信器１１から受信部１０３を介して、第１発光部１３および第２発光部１４の少なくとも一方を点灯／消灯させるための、点灯／消灯操作に応じた通常動作用の信号を受信すると、調光部１０１、点灯部１０２およびスイッチＳＷ１１，ＳＷ１２の全部または一部を通じて、第１発光部１３および第２発光部１４の少なくとも一方を点灯／消灯する制御を行う。

【００２７】また、制御部１００は、リモコン送信器１１から受信部１０３を介して、目覚まし機能動作用の信号を受信すると、スイッチＳＷ１１をオンにし、この後、上記所定時間かけて第１発光部１３の光出力が低照度側から連続的または段階的に上昇してセット時刻に高照度になるように、調光部１０１を通じて第１発光部１３の調光制御を行い、そして、セット時刻頃に、第１発光部１３が点灯しているうちに第２発光部１４が点灯して第１発光部１３から第２発光部１４に照明が切り替わるように、スイッチＳＷ１２をオンにして点灯部１０２通じて第２発光部１４の点灯制御を行うとともに、スイッチＳＷ１１をオフにして第１発光部１３の消灯制御を行う。

【００２８】第１実施形態では、セット時刻頃に、第２発光部１４が点灯するようにスイッチＳＷ１２をオンにし、この後、第１発光部１３が消灯するように、スイッチＳＷ１１をオフにする処理がなされる。

【００２９】また、複数の白熱ランプ１３１のうち所望の白熱ランプ１３１を目覚まし機能動作用に予め設定することができるようになっている。例えば、リモコン送信器１１の操作キーで、目覚まし機能動作用として所望の白熱ランプ１３１が選択されると、選択された白熱ランプ１３１を示す信号がリモコン送信器１１から送信され、その信号を受けた制御部１００は、目覚まし機能動作時、図２（ｂ）に示すように、選択された白熱ランプ１３１に対して上述の調光制御を行う。図２（ｂ）の例では、６個の白熱ランプ１３１のうち右半分の３個が、所望の白熱ランプ１３１として選択され、動作している。これにより、図３に示すように、就寝者のいる方向の白熱ランプのみを点灯させ、他の白熱ランプは点灯しないので、従来に比べ省エネルギーを達成しつつ、より心地よい目覚めを促すという効果が得られる。また、一つの部屋で複数人が就寝しており、起床時刻が皆同じとは限らないといった場合にも対応することができる。な

お、この場合、例えば調光部１０１の出力と各白熱ランプ１３１との間に制御部１００によってオン／オフされるスイッチを設ける構成にしてもよい。

【００３０】次に、本照明装置の一動作例を説明する。図４（ａ）に示すように、セット時刻ｔ１１の所定時間前の時刻ｔ１０になると、リモコン送信器１１から目覚まし機能動作用の信号が送信される。そして、その信号が受信部１０３を介して制御部１００により受信されると、スイッチＳＷ１１がオンになり、この後、上記所定時間かけて第１発光部１３の光出力が低照度側から連続的または段階的（図４の例では連続的）に上昇してセット時刻ｔ１１に高照度になる。

【００３１】またこのｔ１１時点、図４（ｂ）に示すように、スイッチＳＷ１２がオンになり、この後、スイッチＳＷ１１がオフになる（ｔ１３）。ここで、第２発光部１４が蛍光ランプ１４１であるので、先行予熱時間によってセット時刻ｔ１１から少し遅れた時点ｔ１２に第２発光部１４が始動して点灯し、この後、第１発光部１３が消灯する（ｔ１３）。

【００３２】このように、照明（光源）が切り替わる間、第１発光部１３の複数の白熱ランプ１３１のうち少なくとも１つが点灯状態にあるので、睡眠状態から目覚めたユーザに対して、第１発光部１３および第２発光部１４の双方の急な消灯による不安感や不快感を与えることがなくなる。また、照明が切り替わる時にフェードインやフェードアウトを組み合わせると、全体としての照度変化を抑えることができ、またユーザに不快感を与えないようにすることができる。

【００３３】また、複数の白熱ランプ１３１のうち所望の白熱ランプ１３１を目覚まし機能動作用に予め設定することができるので、比較的広い部屋に１人で寝ている場合に部屋全体を明るくしてしまう問題を解決することができるとともに、省エネルギーの面でも効果がある。また、起床時刻が異なる複数の人（夫婦でも起床時刻が一緒とは限らない）が同じ部屋で寝ていても、起床しない人に対する照明を和らげることができる。

【００３４】なお、第１実施形態では、リモコン送信器が使用される構成になっているが、これに限らず、例えば壁取付形の操作スイッチが使用される構成でもよい。

【００３５】図５は本発明に係る第２実施形態の照明装置における点灯装置の構成図で、この図を用いて以下に第２実施形態の説明を行う。

【００３６】本照明装置は、リモコン送信器１１と、本体１２と、第１発光部１３と、第２発光部１４とを第１実施形態と同様に備えているほか、第１実施形態との相違点として点灯装置２０を備えている。

【００３７】この点灯装置２０は、点灯部１０２と、受信部１０３とを第１実施形態と同様に備えているほか、図５に示すように、マイコン２００と、トライアックＴＲ１およびＦＥＴＱ１などにより成り第１発光部１３の調光を行う調光部２０１と、トライアックＴＲ２およびＦＥＴＱ２などにより成り第１実施形態のスイッチＳＷ１２として機能するスイッチ部ＳＷ２２と、降圧トランスＴ２０４、整流器ＤＢ２０４、ダイオードＤ２０４および平滑コンデンサＣ２０４により成りマイコン２００の直流電源となる電源部２０４とを備えている。

【００３８】マイコン２００は、点灯装置２０全般の制御などの処理をリモコン送信器１１と協調して行うもので、例えば、リモコン送信器１１から受信部１０３を介して、第１発光部１３および第２発光部１４の少なくとも一方を点灯／消灯させるための、点灯／消灯操作に応じた通常動作用の信号を受信すると、調光部２０１、点灯部１０２およびスイッチ部ＳＷ２２の全部または一部を通じて、第１発光部１３および第２発光部１４の少なくとも一方を点灯／消灯する制御を行う。

【００３９】また、マイコン２００は、リモコン送信器１１から受信部１０３を介して、目覚まし機能動作用の信号を受信すると、第１発光部１３の光出力が低照度側から連続的に上昇してセット時刻に高照度になるように、調光部２０１を通じて第１発光部１３の調光制御を位相制御で行い、そして、セット時刻頃に、第２発光部１４が点灯するようにスイッチ部ＳＷ２２をオンにして点灯部１０２を通じて第２発光部１４の点灯制御を行い、この後、第１発光部１３がフェードアウトで消灯するように、調光部２０１を通じて第１発光部１３の調光制御を行って、第１発光部１３の消灯制御を行う。

【００４０】つまり、マイコン２００は、第１発光部１３がフェードアウトで消灯するように制御を行う以外は第１実施形態の制御部１００とほぼ同様に構成されるのであり、したがって、本照明装置の動作は、第１発光部１３がフェードアウトで消灯する以外は第１実施形態とほぼ同様となる。

【００４１】以上、第１発光部１３をフェードアウトで消灯するので、急激な照度変化を抑えることができるので、ユーザの受ける不安感を和らげることができる。

【００４２】なお、第２実施形態において、マイコン２００が、図６に示すように、調光部２０１を通じて第１発光部１３のフィードアウトを開始するほぼ１秒前に、点灯部１０２を通じて蛍光ランプ１４１の先行予熱を開始する構成にしてもよい。通常、蛍光ランプは点灯前にフィラメントを予熱する必要があるので、その先行予熱の時間を考え、スイッチ部ＳＷ２２をオンしてから第１発光部１３のフェードアウトを開始するまで、ほぼ１秒の時間を設けるようにする。これにより、第１発光部１３および第２発光部１４の双方の急な消灯をほぼ確実に防止することができる。また、この場合も、第１発光部１３がフェードアウトで消灯するので、全体の照度変化が図６の下段に示すような特性となり、照度変化が滑らかになるから、ユーザの受ける不安感を和らげることができる。

【００４３】図７は本発明に係る第３実施形態の照明装置の構成図、図８は図７のマイコンによる蛍光ランプに対する先行予熱制御の説明図、図９は図７の照明装置の動作説明図で、これらの図を用いて以下に第３実施形態の説明を行う。

【００４４】本照明装置は、リモコン送信器１１と、本体１２と、第１発光部１３と、第２発光部１４とを第１実施形態と同様に備えているほか、第１実施形態との相違点として点灯装置３０を備えている。

【００４５】この点灯装置３０は、受信部１０３を第１実施形態と同様に備えているほか、図７に示すように、フォトトライアックＰＴ１およびトライアックＴＲ２などにより成り第１発光部１３の調光を行う調光部３０１と、ＦＥＴＱ１１，Ｑ１２などにより成るハーフブリッジ型のインバータ３０２ａおよびＦＥＴＱ１１，Ｑ１２駆動用のドライバＩＣ３０２ｂにより構成され第２発光部１４の先行予熱、始動および点灯を行う点灯部３０２と、整流器ＤＢ３０４および平滑コンデンサＣ３０４などにより成りインバータ３０２ａに直流電力を供給する直流電源部３０４と、この直流電源部３０４から分圧した電圧を得て後述のマイコン３００に供給する分圧部３０５とを備えているとともに、マイコン３００を備えている。

【００４６】このマイコン３００は、点灯装置３０全般の制御などの処理をリモコン送信器１１と協調して行うもので、例えば、リモコン送信器１１から受信部１０３を介して、第１発光部１３および第２発光部１４の少なくとも一方を点灯／消灯させるための、点灯／消灯操作に応じた通常動作用の信号を受信すると、調光部３０１および点灯部３０２の全部または一部を通じて、第１発光部１３および第２発光部１４の少なくとも一方を点灯／消灯する制御を行う。

【００４７】また、マイコン３００は、リモコン送信器１１から受信部１０３を介して、目覚まし機能動作用の信号を受信すると、第１発光部１３の光出力が低照度側から連続的に上昇してセット時刻に高照度になるように、調光部３０１を通じて第１発光部１３の調光制御を位相制御で行い、そして、セット時刻頃に、第２発光部１４が点灯するように点灯部３０２を通じて第２発光部１４の先行予熱、始動および点灯制御を行うとともに、第１発光部１３が消灯するように、調光部３０１を通じて第１発光部１３の消灯制御を行う。

【００４８】さらに、マイコン３００は、点灯部３０２を通じて第２発光部１４に対して、目覚まし機能動作用の先行予熱、始動および点灯制御を行う場合、通常動作用の先行予熱、始動および点灯制御を行う場合よりも、先行予熱電流を小さくしかつ先行予熱時間を長くして蛍光ランプ１４１の先行予熱を行い、この先行予熱の終了と同時に調光部３０１を通じて第１発光部１３の消灯制御を行う。つまり、図８に示すように、始動周波数および点灯周波数は同じであるが、通常動作用の予熱周波数および先行予熱時間をそれぞれｆ１およびＴ１とし、目覚まし機能動作用の予熱周波数および先行予熱時間をそれぞれｆ２およびＴ２としたとき、ｆ１＜ｆ２、Ｔ１＜Ｔ２の関係が成り立つようになっている。ここに、目覚まし機能動作用の先行予熱電流を小さくするために、予熱周波数ｆ２が予熱周波数ｆ１よりも高めに設定される。

【００４９】次に、本照明装置の一動作例を説明する。図９に示すように、セット時刻ｔ３２の所定時間前の時刻ｔ３０になると、リモコン送信器１１から目覚まし機能動作用の信号が送信される。そして、その信号が受信部１０３を介してマイコン３００により受信されると、このマイコン３００の制御によって、第１発光部１３の光出力が低照度側から連続的に上昇してセット時刻ｔ３２に高照度になる。そして、このセット時刻ｔ３２頃に、つまり先行予熱時間Ｔ２前の時点ｔ３１に第２発光部１４の先行予熱が開始し、セット時刻ｔ３２になると、先行予熱が終了して第２発光部１４が始動（放電を開始）するとともに、第１発光部１３が消灯する。この後、発振周波数が始動周波数から点灯周波数に移行し、第２発光部１４が安定に点灯する。なお、上記タイミングに限らず、第２発光部１４が始動周波数で動作中に第１発光部１３が消灯するタイミングでもよい。

【００５０】以上のように、目覚まし機能動作用の先行予熱電流を小さくしかつ先行予熱時間を長くすれば、先行予熱の途中に放電が開始するのを防止することができるので、蛍光ランプ１４１を所望の時刻に合わせて放電させることができる。すなわち、通常動作用の先行予熱電流および先行予熱時間では、周囲温度をはじめ様々な要因によって先行予熱の途中に放電を開始してしまうことがあり、この場合、全体の照度が放電を開始した分だけ高くなるのであるが、第３実施形態では、先行予熱電流が小さいので、先行予熱の途中に放電を開始することがなくなり、しかも先行予熱時間が長いので、先行予熱が十分となり、この結果、蛍光ランプ１４１を所望の時刻に確実に始動させることができ、照度の変化を抑制し、ユーザに不快感を与えないようにすることができる。

【００５１】図１０は本発明に係る第４実施形態の照明装置の構成図、図１１は図１０の照明装置の動作説明図で、これらの図を用いて以下に第４実施形態の説明を行う。

【００５２】本照明装置は、リモコン送信器１１と、本体１２と、第２発光部１４とを第１実施形態と同様に備えているほか、第１発光部４３として色温度が３０００Ｋ以下の複数の白熱ランプ４３１と、点灯装置４０とを備えている。

【００５３】この点灯装置４０は、調光部１０１と、点灯部１０２と、受信部１０３と、スイッチＳＷ１１，Ｓ

Ｗ１２とを第１実施形態と同様に備えているとともに、目覚まし機能動作時において、図１１に示すように、セット時刻頃に、第１発光部４３がフェードアウトで消灯するように、調光部１０１を通じて第１発光部４３の調光制御を行って、消灯制御を行い、その調光制御中に第２発光部１４が点灯するように、スイッチＳＷ１２および点灯部１０２を通じて第２発光部１４の先行予熱、始動および点灯制御を行う以外は第１実施形態の制御部１００と同様に構成される制御部４００を備えている。なお、スイッチＳＷ１１は、第１発光部４３がフェードアウトの調光制御によって消灯状態になった時点以降にオフにされる。また、例えばセット時刻に、第１発光部４３がフェードアウトを開始するようにまたは第２発光部１４が始動して点灯するように構成してもよい。

【００５４】ここで、白熱ランプには、色温度３０００Ｋ以上のハロゲン電球などもあるが、通常、人が起床するのは朝であり、日の出の色温度は時間と共に高くなっていき、日の出４０分後の色温度は２７５０～３１００Ｋといわれている。したがって、覚まし機能をもつ照明装置で起床時に照度を上昇させていく負荷として、３０００Ｋ以下の色温度となる白熱ランプ４３１を使用するのが望ましい。

【００５５】以上、色温度が３０００Ｋ以下の白熱ランプ４３１を使用することで、目覚まし機能動作時における照明の変化を朝陽が昇る感じに近づけることができる。

【００５６】図１２は本発明に係る第５実施形態の照明装置の構成図、図１３は図１２の照明装置の動作説明図で、これらの図を用いて以下に第５実施形態の説明を行う。

【００５７】本照明装置は、リモコン送信器１１と、本体１２と、第１発光部４３とを第４実施形態と同様に備えているほか、第２発光部５４として色温度が５０００Ｋ程度の蛍光ランプ５４１と、点灯装置５０とを備えている。ここで、色温度が５０００Ｋ程度の蛍光ランプ５４１を使用するのは、正午の太陽の色温度が５０００～６０００Ｋといわれていることによる。

【００５８】この点灯装置５０は、調光部１０１と、受信部１０３と、スイッチＳＷ１１，ＳＷ１２とを第４実施形態と同様に備えているとともに、調光機能を有する点灯部５０２と、目覚まし機能動作時において、図１３に示すように、セット時刻頃に、第１発光部４３がフェードアウトで消灯するように、調光部１０１を通じて第１発光部４３の調光制御を行って、消灯制御を行い、フェードアウト中に第２発光部５４がフェードインで点灯するように、点灯部５０２を通じて第２発光部５４の点灯制御を行う以外は第１実施形態の制御部１００と同様に構成される制御部５００とを備えている。ただし、図１３に示すように、上記フェードアウトで第１発光部４３の光出力が５０％になるとき、フェードインで第２発光部５４の光出力が略５０％になるように設定されている。なお、例えばセット時刻に、第１発光部４３がフェードアウトを開始するように、第１発光部４３および第２発光部５４の光出力が略５０％になるように、あるいは第２発光部５４の光出力が１００％になるように構成してもよい。

【００５９】以上、目覚まし機能動作時において、フェードアウトで第１発光部４３の光出力が５０％になるとき、フェードインで第２発光部５４の光出力が略５０％になるので、照明の切替え時に、全体の照度が大きく変化することがないので、ユーザに不快感を与えることを抑制できる。

【００６０】図１４は本発明に係る第６実施形態の照明装置の構成図で、この図を用いて以下に第６実施形態の説明を行う。

【００６１】本照明装置は、リモコン送信器１１と、本体１２と、第１発光部４３とを第５実施形態と同様に備えているほか、第２発光部６４としての複数の白熱ランプ６４１と、点灯装置６０とを備えている。

【００６２】この点灯装置６０は、調光部１０１と、受信部１０３と、スイッチＳＷ１１，ＳＷ１２とを第５実施形態と同様に備えているとともに、調光部１０１と同様の調光部６０２と、調光部１０１，６０２およびスイッチＳＷ１１，ＳＷ１２を通じて第１発光部４３および第２発光部６４に対する制御を、第５実施形態の制御部５００と同様に行う制御部６００とを備えている。

【００６３】ここで、上記第５実施形態では、蛍光ランプ５４１を調光制御する構成になっているが、蛍光ランプの場合、特に出力の低い調光状態で蛍光ランプの放電を維持させようとすると、点灯装置が複雑となり高価なものとなってしまう。そこで、第６実施形態では、安価な回路構成で第５実施形態と同様の効果を得るべく、蛍光ランプに代えて白熱ランプを使用するのである。

【００６４】図１５は本発明に係る第７実施形態の照明装置の構成図で、この図を用いて以下に第７実施形態の説明を行う。

【００６５】本照明装置は、第３実施形態と同様のリモコン送信器１１および第２発光部１４に加えて、第１発光部７３としての複数のＬＥＤ７３１と、点灯装置７０とを備えている。

【００６６】この点灯装置７０は、第１発光部７３に対する回路構成以外は第３実施形態の点灯装置３０とほぼ同様に構成される。すなわち、マイコン７００は、ＬＥＤ７３１の点灯数を増大することで、あるいはＬＥＤ７３１に流れる電流を増大することで照度を上昇させる調光制御を行うように構成される。前者の場合、第１発光部７３の調光を行う調光手段はマイコン７００の処理機能により実現されることになる。また、後者の場合、調光手段はＬＥＤ７３１に流れる電流をマイコン７００からの信号に従って増減する回路（図示せず）により実現

されることになる。図１５の例は、トランジスタのオン／オフで複数のＬＥＤ７３１を点灯／消灯する前者の回路構成になっている。

【００６７】このような構成でも第３実施形態と同様の効果を奏することが可能になる。なお、ＬＥＤを使用する構成では、例えば何色かのＬＥＤを組み合わせることで、時間と共に全体の色温度を変化させることも可能である。

【００６８】図１６は本発明に係る第８実施形態の照明装置の構成図で、この図を用いて以下に第８実施形態の説明を行う。

【００６９】本照明装置は、第３実施形態と同様のリモコン送信器１１に加えて、第１発光部８３としての複数のＬＥＤ８３１と、第２発光部８４としての複数のＬＥＤ８４１と、点灯装置８０とを備えている。

【００７０】この点灯装置８０は、複数のＬＥＤ８３１駆動用のトランジスタＱ８３と、複数のＬＥＤ８４１駆動用のトランジスタＱ８４と、第５実施形態の制御部５００が第１発光部４３および第２発光部５４に対して行う制御とほぼ同様の制御を、第１発光部８３および第２発光部８４に対して行うマイコン８００と、降圧トランスＴ８０４、整流器ＤＢ８０４および平滑コンデンサＣ８０４により成りマイコン８００などの直流電源となる電源部８０４とを備えている。

【００７１】この構成では、第５実施形態と同様に、全体の照度としては、照明の切替え時に大きな変化が生じることなく、ユーザに不快感を与えることを抑制できるという効果が得られる。

【００７２】なお、上記各実施形態では、照明装置は、照明器具になっているが、連動する複数の照明器具により成る構成でもよい。この構成の説明図を図１７に示す。この図１７に示すように、壁に備え付けられた白熱ランプを負荷とする複数のブラケットと、蛍光ランプを負荷とする天井照明とが連動して目覚まし動作を行うように構成される。図示しないリモコン送信器に入力されたセット時刻の一定時間前に予め設定されたブラケットが点灯を開始し、時間とともにブラケットの負荷である白熱ランプの出力が増大する。そして、セット時刻に天井照明が点灯し、ブラケットの白熱ランプがフェードアウトする。これにより、図３と同様、就寝者のいる方向の白熱ランプのみを点灯動作させ、他の白熱ランプは点灯動作しないので、従来に比べ省エネルギーを達成しつつ、より心地よい目覚めを促すという効果が得られる。また、一つの部屋で複数人が就寝しており、起床時刻が皆同じとは限らないといった場合にも対応することができる。

【００７３】

【発明の効果】以上のことから明らかなように、請求項１記載の発明によれば、照明用の第１発光手段と、照明用の第２発光手段と、前記第１発光手段の調光を行う調光手段と、前記第２発光手段の点灯を行う点灯手段と、前記第１発光手段の光出力が低照度側から連続的または段階的に上昇してセット時刻に高照度になるように、前記調光手段を通じて前記第１発光手段の調光制御を行い、前記セット時刻頃に、前記第１発光手段が点灯しているうちに前記第２発光手段が点灯して前記第１発光手段から前記第２発光手段に照明が切り替わるように、前記点灯手段を通じて前記第２発光手段の点灯制御を行うとともに、前記第１発光手段の消灯制御を行う制御手段とを備えるので、光刺激によって就寝者を心地よく目覚めさせることができるとともに、不安感や不快感を与えることがなくなる。

【００７４】請求項２記載の発明によれば、請求項１記載の照明装置において、前記制御手段は、前記セット時刻頃に、前記第２発光手段が点灯するように前記点灯手段を通じて前記第２発光手段の点灯制御を行い、この後、前記第１発光手段がフェードアウトで消灯するように、前記調光手段を通じて前記第１発光手段の調光制御を行って、前記第１発光手段の消灯制御を行うので、例えば起床時刻に光源を切り替える際に照度変化を抑えることができ、ユーザに不快感を与えることを抑制することができる。

【００７５】請求項３記載の発明によれば、請求項２記載の照明装置において、前記第２発光手段は蛍光ランプであり、前記点灯手段は前記第２発光手段の先行予熱、始動および点灯を行い、前記制御手段は、前記調光手段を通じて前記第１発光手段のフィードアウトを開始するほぼ１秒前に、前記点灯手段を通じて前記蛍光ランプの先行予熱を開始するので、例えば起床時刻に光源を切り替える際に照度変化を抑えることができ、ユーザに不快感を与えることを抑制することができる。

【００７６】請求項４記載の発明によれば、請求項１または２記載の照明装置において、前記第２発光手段は蛍光ランプであり、前記点灯手段は前記第２発光手段の先行予熱、始動および点灯を行い、前記制御手段は、前記セット時刻頃に、前記第１発光手段が点灯しているうちに前記第２発光手段が点灯するように、前記点灯手段を通じて前記第２発光手段の先行予熱、始動および点灯制御を行う場合、点灯操作に応じて前記第２発光手段の先行予熱、始動および点灯制御を行う場合よりも、先行予熱電流を小さくしかつ先行予熱時間を長くして前記蛍光ランプの先行予熱を行い、この先行予熱の終了と同時に前記第１発光手段の消灯制御を行うので、例えば起床時刻に光源を切り替える際に照度変化を抑えることができ、ユーザに不快感を与えることを抑制することができる。

【００７７】請求項５記載の発明によれば、請求項１記載の照明装置において、前記制御手段は、前記セット時刻頃に、前記第１発光手段がフェードアウトで消灯するように、前記調光手段を通じて前記第１発光手段の調光

制御を行って、消灯制御を行い、前記フェードアウト中に前記第２発光手段が点灯するように、前記点灯手段を通じて前記第２発光手段の点灯制御を行うので、例えば起床時刻に光源を切り替える際に照度変化を抑えることができ、ユーザに不快感を与えることを抑制することができる。

【００７８】請求項６記載の発明によれば、請求項１記載の照明装置において、前記第１および第２発光手段の各々は少なくとも１つの光源により成り、前記制御手段は、前記第１発光手段がフェードアウトで消灯するように、前記調光手段を通じて前記第１発光手段の調光制御を行って、消灯制御を行うとともに、前記第２発光手段がフェードインで点灯するように、前記点灯手段を通じて前記第２発光手段の点灯制御を行って、前記第１発光手段から前記第２発光手段に照明が切り替わる間、前記複数の光源の少なくとも１つを点灯させるので、例えば起床時刻に光源を切り替える際に照度変化を抑えることができ、ユーザに不快感を与えることを抑制することができる。

【００７９】請求項７記載の発明によれば、請求項６記載の照明装置において、前記フェードアウトで前記第１発光手段の光出力が５０％になるとき、前記フェードインで前記第２発光手段の光出力が略５０％になるので、例えば起床時刻に光源を切り替える際に照度変化を抑えることができ、ユーザに不快感を与えることを抑制することができる。

【００８０】請求項８記載の発明によれば、請求項１～７のいずれかに記載の照明装置において、前記第１発光手段の低照度時の色温度は３０００Ｋ以下であるので、目覚まし機能動作時における照明の変化を朝陽が昇る感じに近づけることができる。

【００８１】請求項９記載の発明によれば、請求項８記載の照明装置において、前記セット時刻以降の照明の色温度は４０００Ｋ～６０００Ｋであるので、目覚まし機能動作時における照明の変化を朝陽が昇る感じに近づけることができる。

【００８２】請求項１０記載の発明によれば、請求項１～９のいずれかに記載の照明装置において、前記第１および第２発光手段は複数のランプにより成り、前記第１発光手段を構成する複数のランプのうち、所望のランプに対する前記調光手段による調光を許容ないし禁止するので、従来に比べ省エネルギーで優れた目覚まし機能付きの照明装置を提供することができ、起床時刻の異なる複数の人が同じ部屋で寝ていたとしても他の人に及ぼす影響を少なくすることができる。

【００８３】請求項１１記載の発明によれば、請求項１～９のいずれかに記載の照明装置において、前記第１および第２発光手段は複数の照明器具により成り、前記第１発光手段を構成する複数の照明器具のうち、所望の照明器具のランプに対する前記調光手段による調光を許容ないし禁止するので、従来に比べ省エネルギーで優れた目覚まし機能付きの照明装置を提供することができ、起床時刻の異なる複数の人が同じ部屋で寝ていたとしても他の人に及ぼす影響を少なくすることができる。

【００８４】請求項１２記載の発明によれば、複数のランプを備え、セット時刻に対して低照度から高照度へ連続的または段階的に光出力を上げる目覚まし機能を有する照明装置であって、低照度から高照度へ光出力が上昇するランプを選択できるので、従来に比べ省エネルギーで優れた目覚まし機能付きの照明装置を提供することができ、起床時刻の異なる複数の人が同じ部屋で寝ていたとしても他の人に及ぼす影響を少なくすることができる。

【００８５】請求項１３記載の発明によれば、連動する照明器具を複数備え、セット時刻に対して低照度から高照度へ連続的または段階的に光出力を上げる目覚まし機能を有する照明装置であって、低照度から高照度へ光出力が上昇する前記照明器具のランプを選択できるので、従来に比べ省エネルギーで優れた目覚まし機能付きの照明装置を提供することができ、起床時刻の異なる複数の人が同じ部屋で寝ていたとしても他の人に及ぼす影響を少なくすることができる。

【図面の簡単な説明】

【図１】本発明に係る第１実施形態の照明装置の構成図である。

【図２】図１の照明装置の外観図である。

【図３】図１の照明装置の動作説明図である。

【図４】図１の照明装置の動作説明図である。

【図５】本発明に係る第２実施形態の照明装置における点灯装置の構成図である。

【図６】第２実施形態に適用可能な動作説明図である。

【図７】本発明に係る第３実施形態の照明装置の構成図である。

【図８】図７のマイコンによる蛍光ランプに対する先行予熱制御の説明図である。

【図９】図７の照明装置の動作説明図である。

【図１０】本発明に係る第４実施形態の照明装置の構成図である。

【図１１】図１０の照明装置の動作説明図である。

【図１２】本発明に係る第５実施形態の照明装置の構成図である。

【図１３】図１２の照明装置の動作説明図である。

【図１４】本発明に係る第６実施形態の照明装置の構成図である。

【図１５】本発明に係る第７実施形態の照明装置の構成図である。

【図１６】本発明に係る第８実施形態の照明装置の構成図である。

【図１７】連動する複数の照明器具で構成される照明装置の説明図である。

【図１８】課題となる照明装置の動作説明図である。

【符号の説明】

１０，２０，３０，４０，５０，６０，７０，８０　点灯装置

１１　リモコン送信器

１２　本体

１３，４３，７３，８３　第１発光部（第１発光手段）

１４，５４，６４，８４　第２発光部（第２発光手段）

１００，４００，５００，６００　制御部（制御手段）

２００，３００，７００，８００　マイコン（制御手段）

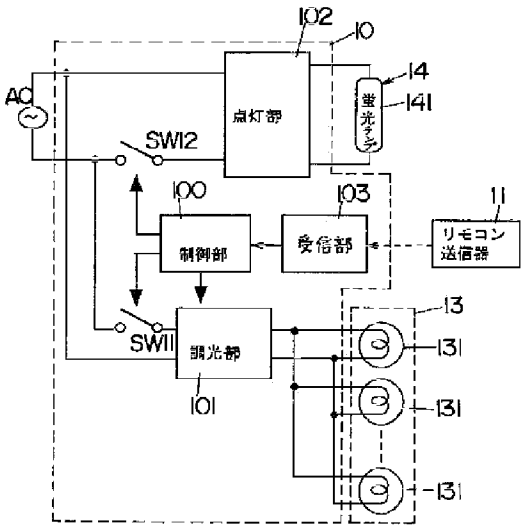
１０１，２０１，３０１　調光部（調光手段）

１０２，３０２，５０２　点灯部（点灯手段）

６０２　調光部

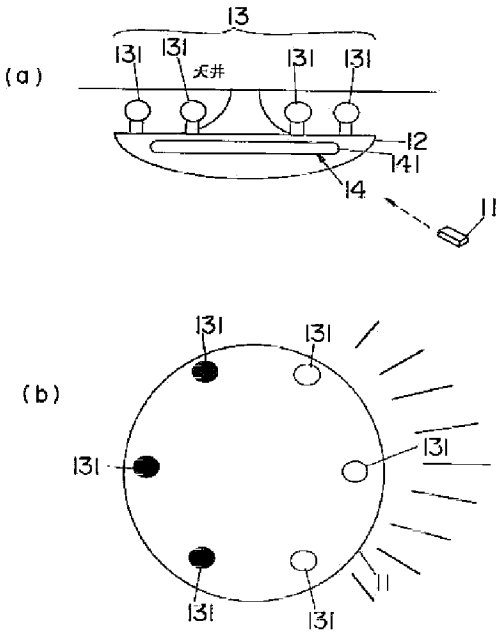
１０３　受信部

【図１】

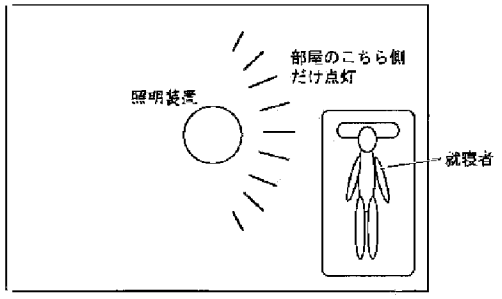


１０　点灯装置
１１　リモコン送信器
１３　第１発光部
１４　第２発光部
１００　制御部
１０１　調光部
１０２　点灯部
１０３　受信部

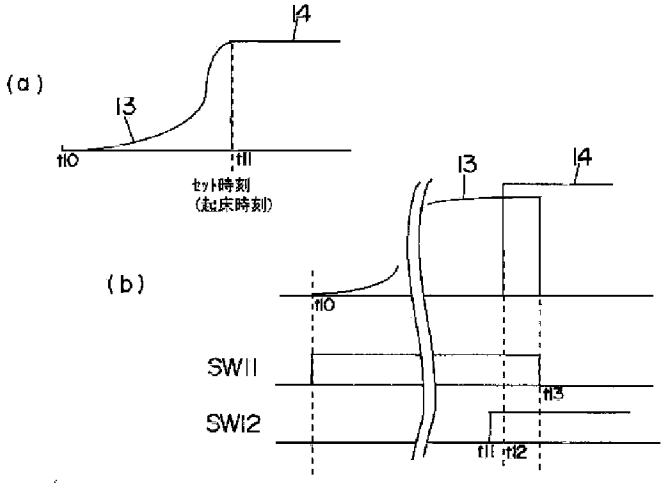
【図２】



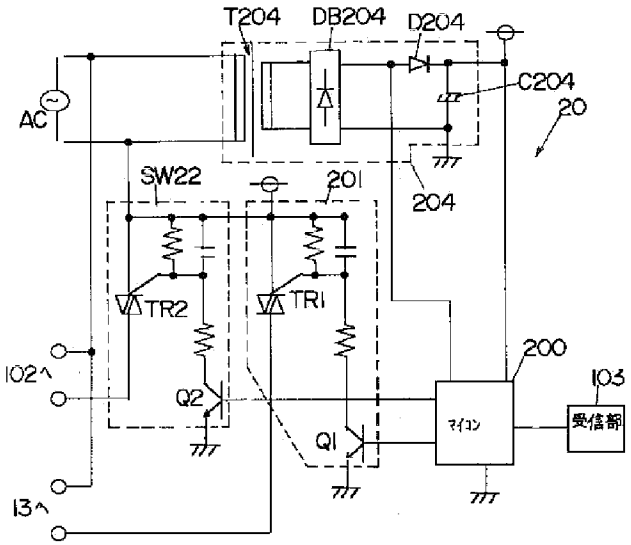
【図３】



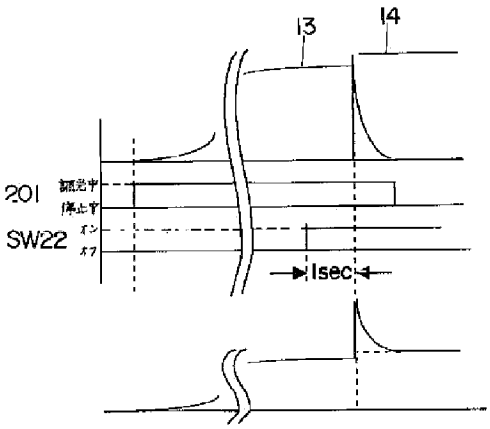
【図４】



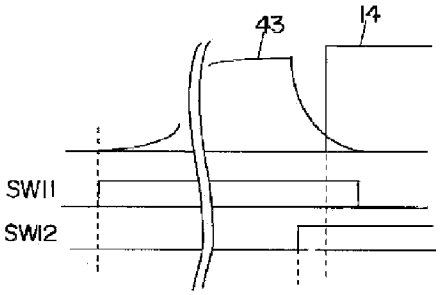
【図5】



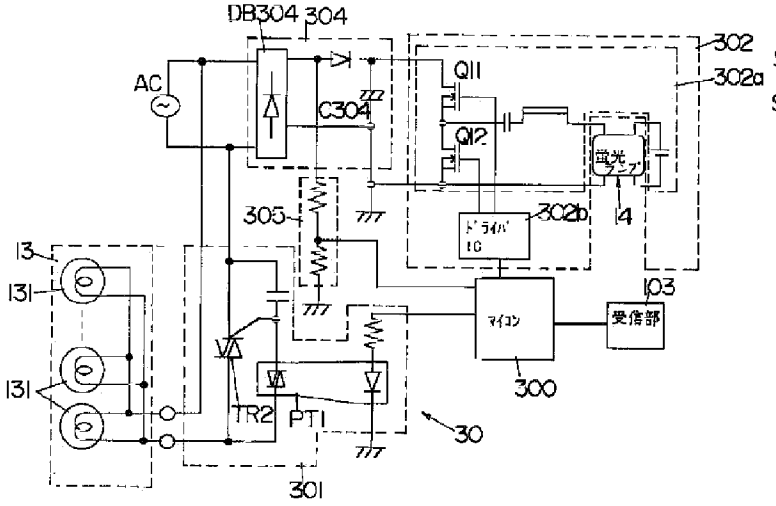
【図6】



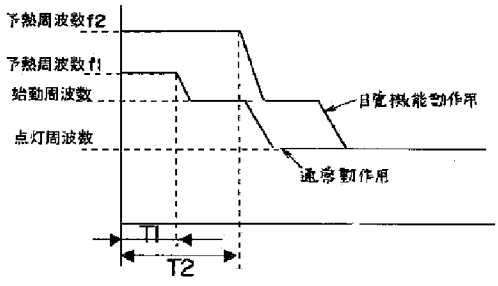
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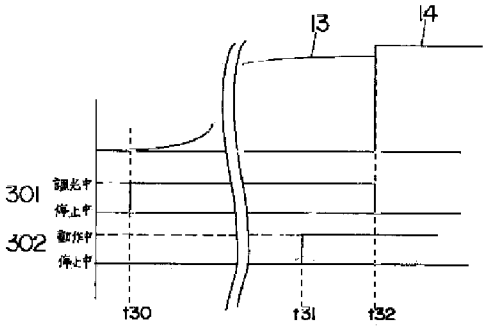
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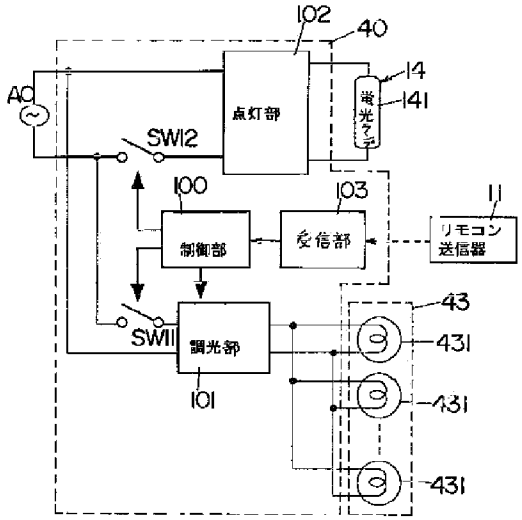
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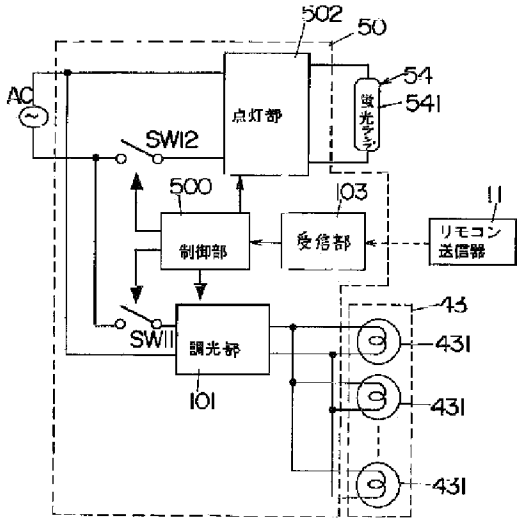
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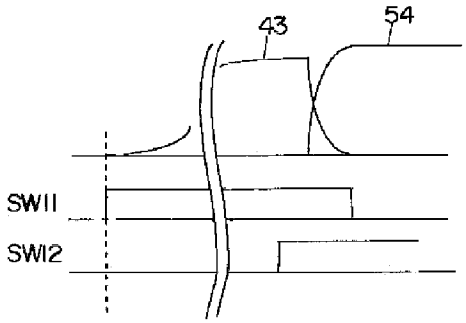
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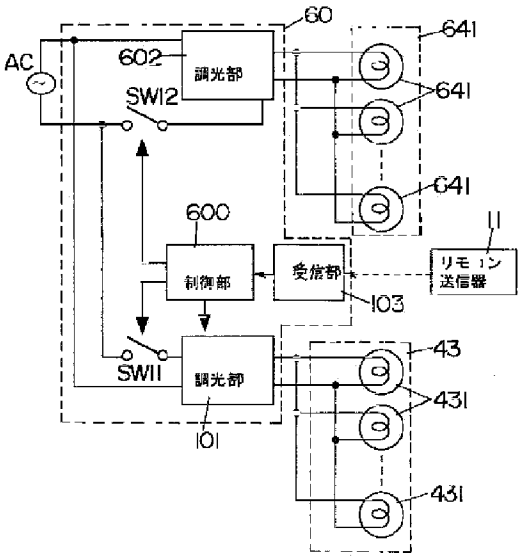
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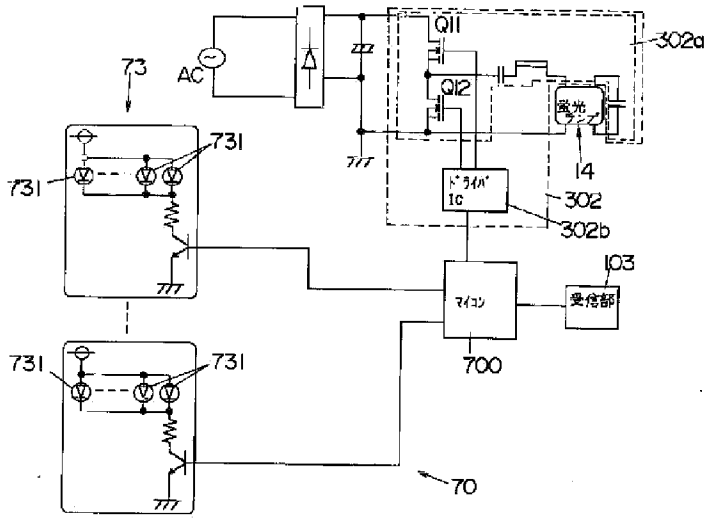
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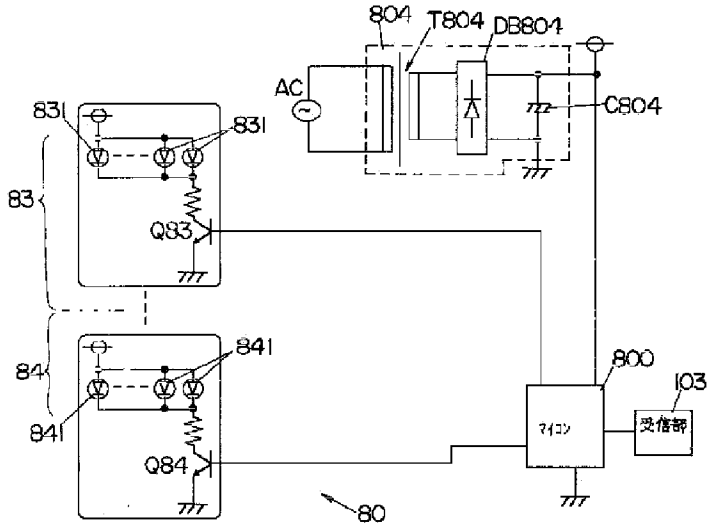
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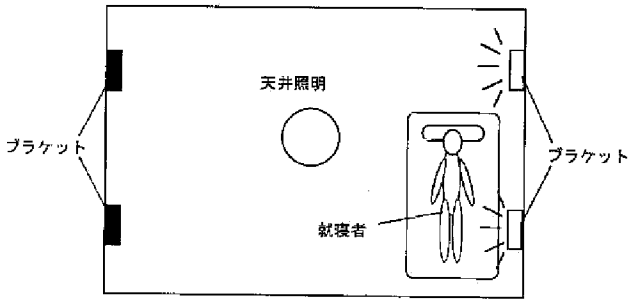
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73
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Q12
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302
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731
731
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103
受信部
700
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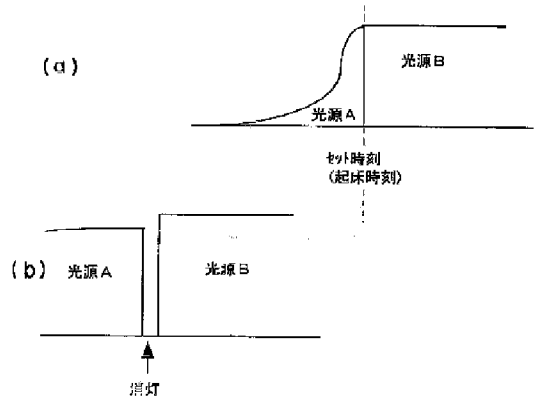
【図１６】


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DB804
AC
C804
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831
83
Q83
841
841
84
Q84
800
103
受信部
80

【図１７】


天井照明
ブラケット
ブラケット
就寝者

【図１８】



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Espacenet

JP2001004753A OXIDE PHOSPHOR AND RADIATION DETECTOR USING IT AS WELL AS X-RAY CT APPARATUS

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OXIDE PHOSPHOR AND RADIATION DETECTOR USING IT AS WELL AS X-RAY CT APPARATUS

Abstract

PROBLEM TO BE SOLVED: To obtain an oxide phosphor whose luminous efficiency with reference to X-rays is increased, whose afterglow is reduced extremely and which can acquire a high-resolution and high-quality tomogram by forming a garnet structure which is constituted of at least elements as Gd, Ce, Al, Ga and O. SOLUTION: In this oxide phosphor which is used for an X-ray CT apparatus or the like, a garnet structure in which Gd at a site (c) is substituted for Ga and/or holes and in which Ga and Al at a site (a) and a site (d) are substituted mutually and substituted for Gd and/or holes is used as a mother crystal, and Ce is used as a luminous component. When the atomic ratio of Ga/(A+Ga+Gd) is at 0.33 to 0.42, a good characteristic is obtained, Ge is set at a molecular ratio of 0.05 to 2.0% with reference to Gd. However, a case in which (Gd+ Ce)/(Al+Ga+Gd+Ce) is at 0.375 is excluded. A heterogeneous amount other than in the garnet structure is less than 20 wt.%, a relative density is 99.0% or higher, a luminous main peak is near 550 nm, and an afterglow attenuation rate after 30 ms of an excitation stop is 10-3 or lower.

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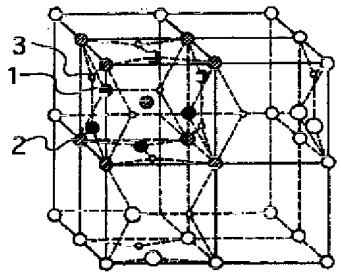
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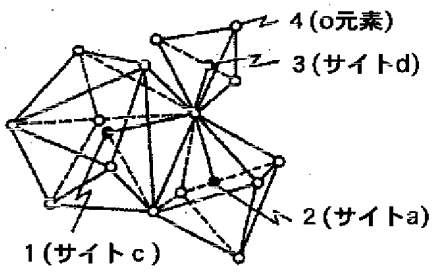
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(54)【発明の名称】　酸化物蛍光体及びそれを用いた放射線検出器、並びにＸ線ＣＴ装置

(57)【要約】
【課題】　Ｘ線に対する発効効率が高く、残光が極めて少ない蛍光体を提供する。また、この蛍光体を、光検出器を備えた放射線検出器のシンチレータとして用いることにより、光出力が大きな低残光放射線検出器が得られ、この検出器をＸ線CT装置に適用することによって、高解像度、高品質の断層像を提供する。
【解決手段】　少なくともGd、Ce、Al、Ga及びO元素から構成されたガーネット構造で、ガーネット構造以外の異相量が2.0wt%未満、相対密度が99.0%以上、拡散透過率が50.0%以上の酸化物とする。該酸化物は、発光スペクトルのメインピークが550nm近傍に存在し、励起光を絶ってから30ms後における残光の減衰率が10^{-3}以下となり、発効効率が高く、残光の低い蛍光体が得られる。



（ａ）



（ｂ）

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【特許請求の範囲】
【請求項１】　少なくともGd、Ce、Al、Ga、O元素から構成された酸化物において、該酸化物の結晶構造がガーネット構造であることを特徴とする酸化物蛍光体。
【請求項２】　請求項１の酸化物蛍光体において、ガーネット構造以外の異相量が2.0wt％未満で、相対密度が99.0％以上、拡散透過率が50.0％以上であることを特徴とする酸化物蛍光体。
【請求項３】　請求項１及び請求項２の酸化物蛍光体において、発光スペクトルのメインピークが550nm近傍に存在し、励起光を絶ってから30ms後における残光の減衰率が10^{-3}以下であることを特徴とする酸化物蛍光体。
【請求項４】　請求項１から請求項３の酸化物蛍光体において、Gd/(Al+Ga+Gd)の原子比が0.33以上、0.42以下であることを特徴とする酸化物蛍光体。但し、CeはGdに対して原子比で0.05 %以上、2.00 %以下であり、(Gd+Ce)/(Al+Ga+Gd+Ce)の原子比が0.375の組成を除く。
【請求項５】　請求項１から請求項４の酸化物蛍光体において、Ga/Alの原子比が0.20以上、4.0以下であることを特徴とする酸化物蛍光体。
【請求項６】　セラミックスシンチレータと、このシンチレータの発光を検出するための光検出器を備えた放射線検出器において、該セラミックスシンチレータとして請求項１から請求項５に記載の酸化物蛍光体を用いたことを特徴とする放射線検出器。
【請求項７】　Ｘ線源と、このＸ線源に対向して置かれたＸ線検出器と、これらＸ線源及びＸ線源検出器を保持し、被検体の周りを回転駆動される回転円板と、前記Ｘ線検出器で検出されたＸ線の強度に基づき該被検体の断層像を画像再構成する画像再構成手段とを備えたＸ線ＣＴ装置において、該Ｘ線検出器として請求項６に記載の放射線検出器を用いたことを特徴とするＸ線ＣＴ装置。
【発明の詳細な説明】
【０００１】
【発明の属する技術分野】本発明は、Ｘ線、γ線などを検出する放射線検出器、特にＸ線ＣＴ装置やポジトロンカメラなどの放射線検出器に好適な酸化物蛍光体、及びそれを用いた放射線検出器、並びにＸ線ＣＴ装置に関する。
【０００２】
【従来の技術】従来、Ｘ線ＣＴ装置などに用いる放射線検出器としては、キセノンのガスチェンバー、ゲルマニウム酸ビスマス（BGO単結晶）と光電子増倍管を組み合わせたもの、CsI：Tl単結晶または$CdWO_4$単結晶とフォトダイオードを組み合わせたものが用いられてきた。また、近年では、放射線から光への変換効率の高い希土類系蛍光体が開発され、このような蛍光体とフォトダイオードを組み合わせた放射線検出器が実用化されている。希土類蛍光体は、希土類酸化物或いは希土類酸硫化物を母材とした発光成分である付活剤を添加したもので、希土類酸化物蛍光体として、特開平3－50991号等に記載されている酸化イットリウムと酸化ガドリニウムを母材としたものなどが提案されている。
【０００３】
【発明が解決しようとする課題】一般に、放射線検出器に用いられるシンチレータ材料に要求される特性としては、高い発光効率、短い残光、大きいＸ線阻止能などが挙げられる。上記蛍光体の中には、発光効率の高いものもあるが、残光時間は比較的長い。Ｘ線ＣＴ装置の用途では、Ｘ線検出器に用いられるシンチレータの残光が大きいと、得られた情報が時間軸方向に対して不鮮明になる。上記の従来材料においてはシンチレータ材料の特性として残光が比較的大きい。
【０００４】本発明の目的は、Ｘ線に対する発光効率が高く、残光が極めて少ない蛍光体を提供することにある。また、この蛍光体を光検出器を備えた放射線検出器のシンチレータとして用いることにより、光出力が大きな低残光放射線検出器が得られ、このＸ線検出器をＸ線ＣＴ装置に適用することによって、高解像度、高品質の断層像を提供することにある。
【０００５】
【課題を解決するための手段】本発明にかかわる蛍光体は、少なくともGd、Ce、Al、Ga及びO元素から構成されたガーネット構造で、ガーネット構造以外の異相量が2.0wt％未満、相対密度が99.0％以上、拡散透過率が50.0％以上の酸化物である。該酸化物は、発光スペクトルのメインピークが550nm近傍に存在し、励起光を絶ってから30ms後における残光の減衰率が10^{-3}以下となり、発光効率が高く、残光の少ない蛍光体が得られることを見出し、本発明に至った。
【０００６】本発明のガーネット構造の金属イオン配置を図１に示す。ガーネット構造の金属イオンには３種類のc、a、dサイトがある。サイトの大きさはc>a>dで、イオンの大きさだけから言えば、Ce^{3+}=1.07Å、Gd^{3+}=0.97Å、Ga^{3+}=0.62Å、Al^{3+}=0.51Åであるから、cサイトはCe^{3+}とGd^{3+}が、aサイトはGa^{3+}が、dサイトはAl^{3+}がそれぞれ優先的に占め、この場合の化学組成は$Gd_3(Ga_2Al_3)O_{12}$で表される。Gd、Ce、Al、Ga、O元素からなる種々の組成のガーネット構造について、Ｘ線回折法に基づく結晶学的な検討をリートベルト解析手法を用いて行った。
【０００７】この結果、これら構成元素からなるガーネット構造においては、化学量論組成である$(Gd,Ce)_3(Ga,Al)_5O_{12}$組成からずれ、ｃサイトのGdはGa及び／又は空孔で置換され、ａ、ｄサイトのGa及びAlは相互に置換するばかりでなく、Gd及び／又は空孔でも置換され、更に酸素のサイトも欠損が生じていることが明らかとなった。従って、このGd、Ce、Al、Ga、O元素から構成された現実の酸化物は、厳密には化学量論組成式$(Gd,Ce)_3(Ga_2Al_3)O_{12}$であらわすことはできない。
【０００８】これらの結果をもとに、Gd、Al、Ga、O元

素からなるガーネット構造を母結晶とし、Ceを発光成分とする酸化物蛍光体の種々の組成について検討した結果、Gd/(Al+Ga+Gd)の原子比が、0.33以上、0.42以下で良好なＸ線感度と残光特性が得られた。CeはGdに対して原子比で0.05 %以上、2.0%以下であり、この組成の範囲外であると、十分な発光強度は得られない。但し、(Gd+Ce)/(Al+Ga+Gd+Ce)が0.375の場合を除く。

【００００９】本発明の組成が必須の理由としては、Gd/(Al+Ga+Gd)の原子比が0.33未満であると、ガーネット組成に比してGd量が少なすぎ、ガーネット構造のマトリックス中にGa_2O_3などの異相が生成し、一方、Gd量が0.42を越えると、ペロブスカイト結晶構造の$Gd(Ga,Al)O_3$や$Gd_4(Ga,Al)_2O_9$相がガーネットマトリックス中に生成する。これらいずれの場合も、相対密度を99.0%以上としても異相量は2.0 wt%以上、拡散透過率は50.0%未満となってしまうためである。また、Ga/Alの原子比が0.20未満であると、結晶構造としてはガーネット構造単相になるが、Ceドープによっても十分な発光強度は得られず、また、Ga/Alの原子比が4.0を越えても十分な発光強度は得られないためである。

【００１０】本発明の蛍光体は、結晶形態には特に限定されず、単結晶であっても多結晶であっても良いが、製造の容易さ、特性ばらつきの少ない点から多結晶体が望ましい。多結晶体は、１）シンチレーの原料となる粉末の合成プロセスと、２）この粉末を用いた焼結プロセスを経て蛍光体材料を得ることができる。所望のガーネット構造単相の酸化物を得るには、合成粉末の結晶粒径はできるだけ小さいほうが良く、1.0μm以下が望ましい。

【００１１】粉末の合成方法としては、１）通常の酸化物混合法を主体とした方法、２）共沈法、ゾルゲル法といった液相を介する方法、３）更には酸化物混合法を主体として合成した粉末を再度機械的に微細化する方法、がある。

【００１２】通常の酸化物混合法では、例えば次のようにして製造できる。原料粉末としてGd_2O_3、Ce_2O_3、Al_2O_3、及びGa_2O_3を所定量秤量した後、例えば自動乳鉢等によって30分程度、湿式混合する。この混合粉末を1400℃～1700℃の大気中で数時間焼成してシンチレータ合成粉末を作製する。必要によっては、フラックスとしてK_2SO_4等のカリウム化合物、BaF_2等の弗化物等を用いて、Gd-Ce-Al-Ga-O系ガーネット構造の生成を促進させることもできる。

【００１３】共沈法を用いたプロセスでは、例えば一例として次のように合成できる。硝酸ガドリニウム、硝酸アルミナ、硝酸ガリウム、硝酸セリウムを所定量秤量して複合硝酸塩水溶液とし、金属イオン濃度の合計量の15倍相当の尿素を硫酸イオンと共存させる。この水溶液を70～100℃に加熱して尿素を加水分解し、Gd-Ce-Al-Ga-O前駆体を沈殿させる。沈殿物の洗浄を繰り返し、沈殿物中の無関係陰イオン濃度を1000ppm未満に低下させた後、120℃程度での乾燥、1200℃程度での仮焼成を行いシンチレータ粉末とする。乾燥温度は、水分が蒸発する90℃以上であれば良く、仮焼温度はガーネット構造が生成される900℃以上であれば良い。生成したガーネット構造の結晶粒が成長するような高温での熱処理は避けなければならない。

【００１４】共沈法の原料としては、硝酸塩に限らず、各種金属の塩酸塩、硫酸塩、蓚酸塩等も用いることができる。また、場合によってこれら金属塩を数種類混合して用いることもできる。また、尿素の代わりに炭酸水素アンモニウムを用いることもできる。

【００１５】更に、別の方法としては、複合金属溶液中に、１）尿素と乳酸アンモニウム、２）炭酸水素アンモニウムとアンモニア水、或いは３）硫酸アンモニウムとアンモニア水、４）マスキング剤としての過酸化水素水と、アンモニア水と硫酸アンモニウム、等の添加によってもGd-Ce-Al-Ga-O前駆体を沈殿できる。

【００１６】また、原料粉末を機械的に微細化することも、焼結によってガーネット構造を得るのに適した手法である。即ち、前述の酸化物混合法と同様に、構成金属成分の酸化物を所定量秤量した後、自動乳鉢で30分程度混合する。この混合粉末を1500℃前後の温度で仮焼成したのち、機械的な粉砕を行う。ボールミル、より好ましくは遊星ボールミルなど、より粉砕エネルギーの高い粉砕手法がよい。これにより、粉末粒径が約0.01～0.5μm程度の粉末を容易に得ることができる。

【００１７】このようにして合成した粉末の焼結は、ホットプレス法、HIP法、常圧焼結法、更には常圧焼結法とHIP法との併用法、等で行うことができる。ホットプレス法では、前述の合成粉末を600kgf/cm²程度の圧力で金型成型して成型体とした後、ホットプレス型にセットし、真空中、大気中、或いは酸素中の雰囲気下で、1400℃から1700℃の焼結温度で数時間、300kgf/cm²程度の加圧力で焼結する。これによって相対密度99.0%以上の蛍光体を容易に得ることができる。一方、HIP法では、鉄、或いはW、Mo等の金属製カプセル中に合成粉末を入れ、真空封止して、1400℃前後の温度で2000atm程度の圧力で焼結を行う。

【００１８】また、常圧焼結法では、合成粉末を600kgf/cm²程度の圧力で金型成型した後、3000kgf/cm²程度の圧力で静水圧プレス（CIP）を行った後、1600～1700℃前後の大気中、或いは純酸素中で数～数十時間の焼結を行う。1700℃を越えると試料が溶解し、1600℃未満であると焼結密度は90%程度となり十分ではない。雰囲気は大気中、或いは純酸素中が望ましく、Ar、N_2などの不活性雰囲気中或いは真空雰囲気では、焼結体中のボイドを少なくできない。

【００１９】常圧焼結法によって、相対密度が99.0%以上の焼結体を得るには、合成粉末として、１）焼結助剤を添加した粉末を用いる、２）サブミクロンサイズの微

細粉を用いる。また、常圧焼結によって93.0%程度以上の相対密度のものができれば閉気孔となるため、必要に応じて金属製カプセルが不要なカプセルフリーHIP法を追加することによって、相対密度が99.0%以上の蛍光体を容易に得ることができる。

【００２０】本発明によって、マトリックスがガーネット構造を有し、これ以外の結晶相が2.0wt%未満、相対密度が99.0%以上、拡散透過率が50.0%以上の酸化物蛍光体を得ることができる。この蛍光体は、発光出力が高く、残光が極めて小さいので、X線などを検出する放射線検出器、特にX線ＣＴ装置やポジトロンカメラなどの放射線検出器に好適である。

【００２１】本発明の放射線検出器は、セラミックスシンチレータと、このシンチレータの発光を検知するための光検出器とを備え、セラミックスシンチレータとして上述の蛍光体を用いたものである。光検出器としてはPIN型ダイオードを用いる。このフォトダイオードは感度が高く、応答時間が速く、かつ波長感度が可視光から近赤外領域にあるので、本発明の蛍光体の発光波長とのマッチングがよい。

【００２２】また、本発明のX線ＣＴ装置は、X線源と、このX線源に対向して配置されたX線検出器と、これらX線源及びX線検出器を保持し被検体の周りで回転駆動させる回転体と、X線検出器で検出されたX線の強度に基づき被検体の断層像を画像構成する画像再構成手段とを備えたX線ＣＴ装置において、X線検出器として上述した蛍光体とフォトダイオードを組み合わせた放射線検出器を用いる。このX線検出器を用いることにより、X線を高い検出効率で検出できるので、従来のシンチレータ（例えば$CdWO_4$）を用いたX線ＣＴ装置に比べ感度を約２倍向上でき、又残光が極めて少ないため、高画質、高分解能の画像を得ることができる。

【００２３】

【発明の実施の形態】以下、本発明の実施例について説明する。

【００２４】（実施例１）原料粉末として、Gd_2O_3、Ce_2O_3、Al_2O_3、及びGa_2O_3を用いて、試料No.１～６を製造した。粉末を原子量比で表１のように秤量して、自動乳鉢等によって30分、エタノールを用いて湿式混合した。この混合粉末に、フラックス成分としてK_2SO_4を加え、これらの混合物をアルミナるつぼに充填し、1650℃の大気中で３時間焼成した。

【００２５】フラックス成分を除去するため、純水中で６回水洗いしてシンチレータ用合成粉末を得た。この合成粉末を、600kgf/cm²の圧力で金型成型して成型体とした後、ホットプレスダイス型にセットして、真空中雰囲気下で、1550℃で３時間、300kgf/cm²の圧力でホットプレス焼結を行った。相対密度はいずれも99.9%以上であった。これら焼結体を、大気中、1300℃での３時間のアニールを施した後、厚さ1.8mmに機械加工してセラミックスシンチレータを作製した。この試料の異相量と拡散透過率とを、X線回折装置、並びに分光光度計を用いて測定した。また、これら試料とフォトダイオードとを組み合わせて検出器を作り、X線源(120kV、150mA)から110cm離れたところに検出器を置き、発光強度、並びに残光を評価した。発光強度は$CdWO_4$の値を１としたときの相対値で、残光はX線を遮断してから30ms後の減衰率で示した。実施例１の組成からなるシンチレータは発光強度が高く、しかも残光の小さい優れたシンチレータ特性を有することが分かる。

【表１】

表１

No.		Gd	Al	Ga	Gdに対するCeの原子割合(%)	原子比 Gd/(Al+Ga+Gd)	原子比 Ga/Al	異相量（%）	拡散透過率（%）	発光強度（対$CdWO_4$）	残光(30ms)
1	実験例	35.0	38.0	27.0	0.20	0.35	0.71	0.0	73	1.9	$4x10^{-5}$
2	実験例	38.0	36.0	26.0	0.20	0.38	0.72	0.0	68	2.3	$2x10^{-5}$
3	実験例	42.0	34.0	24.0	0.20	0.42	0.71	0.3	62	2.2	$2x10^{-5}$
4	実験例	33.0	39.0	28.0	0.20	0.33	0.72	0.7	70	2.1	$3x10^{-5}$
5	比較例	30.0	41.0	29.0	0.20	0.30	0.71	2.1	25	0.5	$5x10^{-2}$
6	比較例	46.0	31.0	23.0	0.20	0.46	0.74	3.5	20	0.4	$4x10^{-2}$

【００２６】（実施例２）原料粉末として硝酸ガドリニウム、硝酸アルミニウム、硝酸ガリウム、硝酸セリウムを用いて、表２に示す試料No.7～19を作製した。各粉末を秤量して、500ccの複合硝酸塩水溶液とした。金属イオン濃度の合計量の14.5倍相当の尿素を添加し、更に濃硫酸を用いて1.2倍量の硫酸イオンを共存させて、90℃に加熱して撹拌しながら６時間反応させた後、室温まで冷却した。このようにして沈殿させたGd-Ce-Al-Ga-O前駆体を、ろ過と水洗のサイクルを６回繰り返した後に150℃で12時間乾燥させた。得られた沈殿物中の硫酸イオン濃度は、いずれの試料においても900ppm以下であった。この沈殿を、大気中、1200℃で３時間仮焼して、合成粉末を製造した。SEMで観察したところ、いずれの試料においても平均一次粒子径は0.1μm前後の値であった。これら合成粉末を、φ60の金型を用いて600kgf/cm²の圧力で成型した後、3000kgf/cm²の圧力で静水圧プレス（CIP）を行った後、純酸素中、1650℃で３時間の常圧焼結を行った。実施例１と同様の方法で、機械加工を行いシンチレータウェハーとした後、異相量、拡散透過率といった材料特性、並びに発光強度、残光といったシ

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ンチレータとしての特性を評価した。　　【表２】

表２

No.		Gd	Al	Ga	Gdに対するCeの原子割合(%)	原子比 Gd/(Al+Ga+Gd)	原子比 Ga/Al	異相量（%）	拡散透過率（%）	発光強度（対$CdWO_4$）	残光(30ms)
7	実験例	35.0	59.0	6.0	0.20	0.35	0.10	4.0	13	0.4	$5x10^{-2}$
8	実験例	40.0	54.0	6.0	0.20	0.40	0.11	7.5	5	0.3	$4x10^{-2}$
9	実験例	35.0	50.0	15.0	0.20	0.35	0.30	0.3	61	2.0	$3x10^{-5}$
10	実験例	40.0	45.0	15.0	0.20	0.40	0.33	0.1	70	2.2	$2x10^{-5}$
11	実験例	35.0	40.0	25.0	0.05	0.35	0.63	0.0	75	2.1	$2x10^{-5}$
12	実験例	40.0	35.0	25.0	2.00	0.40	0.71	0.0	79	2.2	$1x10^{-5}$
13	実験例	35.0	29.0	36.0	0.20	0.35	1.24	0.2	71	2.1	$2x10^{-5}$
14	実験例	40.0	24.0	36.0	0.20	0.40	1.50	0.0	70	2.3	$2x10^{-5}$
15	実験例	35.0	19.0	46.0	0.20	0.35	2.42	0.8	65	2.0	$3x10^{-5}$
16	実験例	40.0	14.0	46.0	0.20	0.40	3.29	1.0	61	2.0	$3x10^{-5}$
17	比較例	35.0	10.0	55.0	0.20	0.35	5.50	2.0	35	0.2	$2x10^{-2}$
18	比較例	40.0	5.0	55.0	0.20	0.40	11.0	3.2	39	0.3	$4x10^{-2}$
19	比較例	33.0	67.0	0.0	0.20	0.33	0.00	2.8	25	0.0	——

【００２７】実施例１と同様に、実施例２の材料組成においては、発光強度、残光ともに優れた特性を示すことが分かる。なお、尿素の代わりに炭酸水素アンモニウムを用いて沈殿させた前駆体を使用しても同様の結果が得られた。また、複合金属溶液中に、１）尿素と乳酸アンモニウム、２）炭酸水素アンモニウムとアンモニア水、或いは３）硫酸アンモニウムとアンモニア水、４）マスキング剤としての過酸化水素水にアンモニア水と硫酸アンモニウム、等の添加、によって合成した粉末でも、いずれもサブミクロンサイズの粉末が得られ、良好なシンチレータ特性を示した。

【００２８】（実施例３）実施例１と同様の構成金属成分の酸化物粉末を用いて、試料No.20～31を製造した。粉末を秤量した後、自動乳鉢で30分程度混合した。この混合粉末を大気中、1500℃、３時間、仮焼成した。この仮焼粉をアルミナ製自動乳鉢を用いて、30分間乾式粉砕して0.5mm以下の粉末とした。この粉末を、さらに遠心ボールミルを用いて機械的な粉砕を行った。粉砕媒体としてはZrO_2ボールを用いた。粉砕後の粉末の平均粒子径は、いずれの試料もほぼ同じで約0.08μmであった。この粉末中へのZrO_2の混入が懸念されるため、No.22の試料の化学分析を行った結果、Zrの含有量は0.002wt％で、不純物の混入量としては極めて僅かな値であった。これら合成粉末を用いて、実施例２と同様の方法で成型体を作製し、常圧焼結によってシンチレータ材料を製造した。その結果を表３に示す。実施例３の組成範囲の材料では、いずれも良好なシンチレータ特性を示した。

【表３】

表３

No.		Gd	Al	Ga	Gdに対するCeの原子割合(%)	原子比 Gd/(Al+Ga:Gd)	原子比 Ga/Al	異相量（%）	拡散透過率（%）	発光強度（対$CdWO_4$）	残光(30ms)
20	比較例	42.0	58.0	0.0	0.20	0.42	0.00	5.0	26	0.0	——
21	比較例	42.0	48.0	10.0	0.20	0.42	0.21	4.3	30	0.4	$3x10^{-2}$
22	実験例	33.0	47.0	20.0	0.20	0.33	0.43	0.3	75	2.2	$3x10^{-5}$
23	実験例	42.0	28.0	30.0	0.20	0.42	1.07	0.1	62	2.1	$2x10^{-5}$
24	実験例	33.0	17.0	50.0	0.20	0.33	2.94	0.8	53	2.1	$2x10^{-5}$
25	比較例	42.0	8.0	50.0	0.20	0.42	6.25	3.0	40	0.3	$4x10^{-2}$
26	比較例	42.0	0.0	58.0	0.20	0.42	∞	2.5	38	0.0	——
27	比較例	33.0	0.0	67.0	0.20	0.33	∞	2.2	45	0.0	——
28	比較例	30.0	50.0	20.0	0.20	0.30	0.40	5.3	50	0.3	$1x10^{-2}$
29	比較例	45.0	41.0	14.0	2.10	0.45	0.34	7.5	36	0.4	$4x10^{-2}$
30	比較例	45.0	15.0	40.0	0.04	0.45	2.67	6.6	44	0.2	$2x10^{-2}$
31	比較例	30.0	10.0	60.0	0.20	0.30	6.0	9.8	28	0.3	$4x10^{-2}$

【００２９】（実施例４）図２に本発明のシンチレータを用いたＸ線検出器の一例を示す。シンチレータ11はフォトダイオード13と接着し、更にシンチレータの発光を外部に逃がさないための遮蔽12で覆う。遮蔽12はＸ線を透過し、光を反射する材料であるアルミニウム等を用いる。本発明のシンチレータ11がＸ線を吸収すると、従来のシンチレータに比較して高い発光出力を有し、Siフォトダイオードの感度波長に比較的近い波長である550nm

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近傍に発光ピークを有するので、高い効率でフォトダイオードによって光電変換された。また、残光も従来シンチレータに比して極めて少なく、Ｘ線検出器として優れた特性を示した。

【００３０】（実施例５）図３に本発明のＸ線ＣＴ装置の概略を示す。この装置はガントリ部18と画像再構成部22とを備え、ガントリ部18には、被検体が搬入される開口部20を備えた回転円板19と、この回転円板に搭載されたＸ線管16と、Ｘ線管に取りつけられＸ線の放射方向を制御するコリメータ17と、Ｘ線管に対向して回転円板に搭載されたＸ線検出器15と、Ｘ線検出器15で検出されたＸ線を特定の信号に変換する検出器回路21と、回転円板の回転及びＸ線束の幅を制御するスキャン制御回路24とを備えている。開口部20に設置された寝台に被検者を寝かせた状態で、Ｘ線管からＸ線が照射される。このＸ線はコリメータによって指向性を得て、Ｘ線検出器によって前記被検体の透過Ｘ線を検出する。回転円板を被検体の周りを回転させることによって、Ｘ線の照射方向を変えながらＸ線を検出し、画像再構成部22で断層像を作成し、モニター23に表示する。

【００３１】

【発明の効果】本発明によれば、Ｘ線に対する発光効率が高く、残光が極めて少ない蛍光体を提供できる。また、この蛍光体を光検出器を備えた放射線検出器のシンチレータとして用いることにより光出力が大きな低残光放射線検出器が得られ、このＸ線検出器をＸ線ＣＴ装置に適用することによって、高解像度、高品質の断層像が得られる。

【図面の簡単な説明】

【図１】（ａ）はガーネット構造の金属イオンの配置図、（ｂ）はガーネット構造の金属イオン周囲の酸素の配置図。

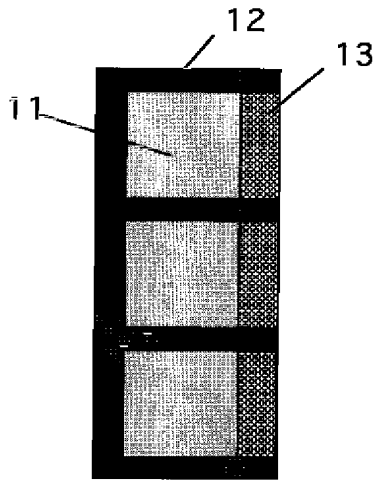
【図２】本発明のシンチレータを用いたＸ線検出器の概略図。

【図３】本発明のＸ線ＣＴ装置の概略図。

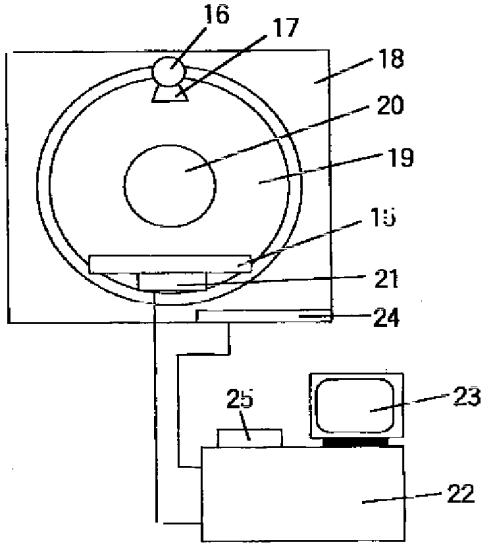
【符号の説明】

1…ガーネット構造におけるｃサイト
2…ガーネット構造におけるａサイト
3…ガーネット構造におけるｄサイト
4…酸素イオン
11…シンチレータ
12…遮蔽板
13…フォトダイオード
16…Ｘ線管
17…コリメータ
18…ガントリ
19…回転円板
20…開口部
21…検出器回路
22…画像再構成部
23…モニタ
24…スキャン制御回路

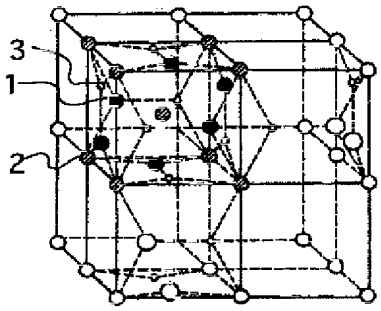
【図２】



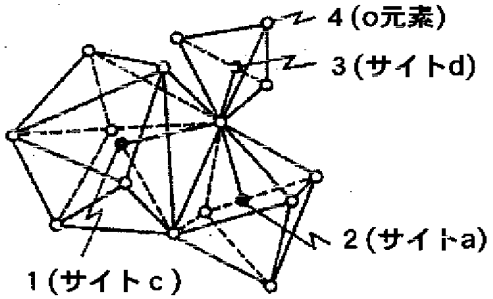
【図３】



【図１】



（ａ）



（ｂ）

フロントページの続き

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4H001 CA08 XA08 XA13 XA31 XA58 XA64

Espacenet

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Inventors: YASUDA TAKEO

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SOLID LIGHT SOURCE

Abstract

PROBLEM TO BE SOLVED: To provide a solid light source that has a light distribution property suitable for using for general illumination and has little sense of incompatibility with the appearance, and also has relatively small mass. SOLUTION: The light source device comprises many light-emitting diodes 13' of white color emission type of chip shape which are dispersed on the outside face of at least the bulb main part 2a1 of a hollow base substrate 2 having a bulb part 2a and a neck part 2b of which neck part 2b is mounted on the screw base 1, and of which bottom face nearly contacts the outside face of the hollow base substrate 2, and comprises also a circuit means 4' that wires the light-emitting diodes 13' as required and is connected to the base. The circuit means 4' comprises a first printed-circuit board 4a' that is formed on the outside face of the hollow base substrate 2 and can mount the light-emitting diodes 13' on the top. If required, a translucent insulating coating 5 can be coated on top of the light-emitting diodes 13'.

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8/04		Ｆ２１Ｙ 101:02		
Ｈ０１Ｌ　33/00		Ｆ２１Ｓ　5/00		Ａ
// Ｆ２１Ｙ 101:02		1/02		Ｃ

審査請求　未請求　請求項の数６　ＯＬ　（全 10 頁）

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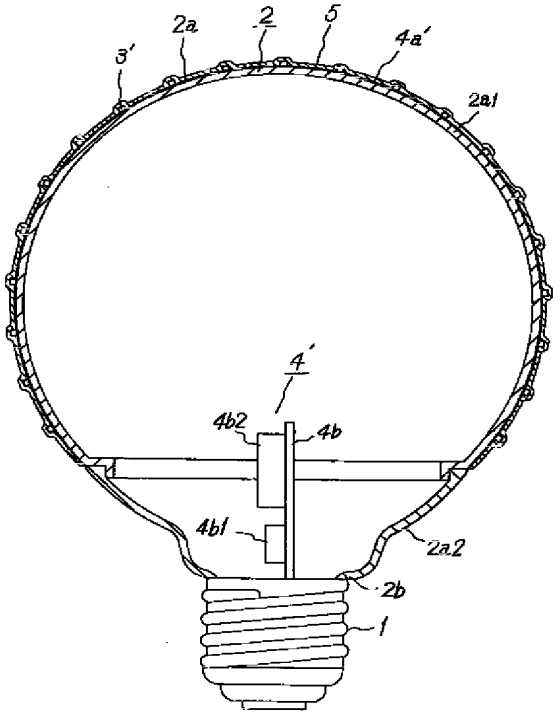
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Ｆターム(参考)　5F041 AA11 BB09 BB21 DA01 DA07 DA75 DC08 FF11

(54)【発明の名称】　固体形光源装置

(57)【要約】
【課題】一般照明に用いるのに好適な配光特性を有し、外観に違和感が少なく、しかも比較的質量が小さい固体光源装置を提供することを目的とする。
【解決手段】バルブ部２ａおよびネック部２ｂを備え、ネック部２ｂがねじ口金１に装着されている中空基体２の少なくともバルブ主要部２ａ１の外面に分散し、かつ、底面が中空基体２の外面にほぼ当接して多数のチップ状で白色発光タイプの発光ダイオード１３´を配設するとともに、発光ダイオード１３´を所要に配線し、かつ、口金に接続する回路手段４´を具備している。回路手段４´は、中空基体２の外面に形成した第１のプリント配線基板４ａ´を備え、発光ダイオード１３´を表面実装することができる。また、所要により、発光ダイオード１３´の上から透光性絶縁被覆５を被着することができる。



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【特許請求の範囲】
【請求項１】ねじ口金と；バルブ部およびネック部を備え、ネック部がねじ口金に装着されている中空基体と；中空基体のバルブ部の少なくとも主要部の外面に分散し、かつ、底面が中空基体の外面にほぼ当接して配設されたそれぞれが白色発光タイプである多数のチップ状の発光ダイオードと；発光ダイオードを所要に配線するとともに口金に接続する回路手段と；を具備していることを特徴とする固体形光源装置。
【請求項２】回路手段は、中空基体の少なくともバルブ部に形成した第１のプリント配線基板を備えており；発光ダイオードは、第１のプリント配線に実装されることにより配設されている；ことを特徴とする請求項１記載の固体形光源装置。
【請求項３】回路手段は、中空基体の内部に収納された第２のプリント配線基板および第２のプリント配線基板に実装された電流制限要素または定電流回路を備えていることを特徴とする請求項１または２記載の固体形光源装置。
【請求項４】中空基体は、バルブ部がほぼ真球状をなしていることを特徴とする請求項１ないし３のいずれか一記載の固体形光源装置。
【請求項５】ねじ口金と；バルブ部およびネック部を備え、ネック部がねじ口金に装着されている中空基体と；中空基体の少なくとも主要部の外面に分散して配設されていて、それぞれが白色発光タイプであるとともに、定格光束の総和が１５０１ｍ以上となる多数のチップ状の発光ダイオードと；発光ダイオードを所要に配線するとともに口金に接続する回路手段と；を具備していることを特徴とする固体形光源装置。
【請求項６】発光ダイオードの上から中空基体の外面に被着した透光性絶縁被覆を具備していることを特徴とする請求項１ないし５のいずれか一記載の固体形光源装置。
【発明の詳細な説明】
【０００１】
【発明の属する技術分野】本発明は、発光ダイオードを用いた固体形光源装置に関する。
【０００２】
【従来の技術】特開平１０－８３７０９号公報には、角筒状の側面発光部と、側面発光部の前面に配設された前面発光部と、側面発光部の背面側に配設されたバヨネット形の口金とを具備した発光ユニットが開示されている。この発光ユニットは、交通信号灯などの信号灯器用として白熱電球に代替させることを目的としている。信号灯器は、発光ユニットごとに赤色、黄色または青色（緑色）の信号光を発生させる。そして、反射体と組み合わせて効率よく前方へ投光するように特別な配置により構成されている。すなわち、側面発光部に配設される発光ダイオードは、専ら反射鏡の軸に対して直角な方向へ光を出射する。また、前面発光部に配設される発光ダイオードは、専ら反射鏡の軸方向へ光を出射する。さらに、発光ダイオードは、レンズ形でその配光特性が狭角である。
【０００３】
【発明が解決しようとする課題】上記の発光ユニットを一般照明用として流用することが考えられるとしても、その場合には以下に示す問題がある。
【０００４】１　配光特性の問題
一般照明用の白熱電球は、真球状のバルブ部を備えたガラスバルブの内面に光拡散膜を形成したボール形すなわちＧ形の形状を備えたガラスバルブの場合、水平配光特性が真円形であり、鉛直配光特性が口金側すなわち１８０°で光度が０になるが、その他の多くの角度範囲では円形に近い。このため、種々の一般照明用の照明器具に適合する。また、一般照明用として最も多く使用されているＰＳ形のガラスバルブを備えた白熱電球もＧ形におけるとの類似した配光特性を有している。
【０００５】これに対して、従来技術においては、上記の発光部の構成のために、鉛直配光特性が左右９０°および０°の３方向にシャープに突出した特異なものとなり、一般照明用の各種照明器具に用いても、照明器具としての所望の配光特性を得ることができない。このことは、従来技術を一般照明に用いたとしても、快適な照明を行う目的に対して使い物にならないことを意味する。
【０００６】２　重量が大きすぎる問題
レンズ形の発光ダイオードが用いられているために、全体として一般照明用の白熱電球に比較すると、著しく重くなり、取り扱いにくくなる。
【０００７】３　外観に違和感がある問題
基本形状が角筒状をなしているとともに、レンズ形の発光ダイオードが露出しているため、外観が特異であり、一般照明用として違和感が大きすぎる。
【０００８】４　一般照明用電球のランプソケットに装着できない問題
従来技術に用いられている口金は、バヨネット形であるのに対して、一般照明用電球の口金はＥ２６形ねじ口金であるから、一般照明用電球のランプソケットに適合しない。
【０００９】本発明は、一般照明に用いるのに好適な配光特性を有する固体光源装置を提供することを目的とする。
【００１０】また、本発明は、外観に違和感が少ない固体光源装置を提供することを他の目的とする。
【００１１】さらに、本発明は、比較的質量が小さい固体光源装置を提供することを他の目的とする。
【００１２】
【課題を達成するための手段】請求項１の発明の固体形光源装置は、ねじ口金と；バルブ部およびネック部を備え、ネック部がねじ口金に装着されている中空基体と；

中空基体のバルブ部の少なくとも主要部の外面に分散し、かつ、底面が中空基体のほぼ当接して配設されたそれぞれが白色発光タイプである多数のチップ状の発光ダイオードと；発光ダイオードを所要に配線するとともに口金に接続する回路手段と；を具備していることを特徴としている。

【００１３】本発明および以下の各発明において、特に指定しない限り用語の定義および技術的意味は次による。

【００１４】＜ねじ口金について＞ねじ口金は、Ｅ２６形またはＥ１７形のねじ口金を用いるのがよい。これらの口金は、一般照明用の白熱電球に用いられているから、そのランプソケットに装着して使用することが可能になる。上記のねじ口金は、一般に１００Ｖまたは１２０Ｖの低圧商用交流電源に接続するように用いられるのが一般的である。

【００１５】＜中空基体について＞中空基体は、バルブ部およびネック部を備えている。

【００１６】バルブ部は、一般照明用の白熱電球のガラスバルブや電球形蛍光ランプのグローブの形状またはそれらに類似した形状および大きさであることが好ましいが、要すればたとえばサッカーボールのように六角形の平面部を繋ぎ合せたような多面体形状であってもよい。なお、多面体形状の場合には、一般照明用の白熱電球のガラスバルブや電球形蛍光ランプのグローブの輪郭形状にほぼ内接する形状および大きさであることが好ましい。一般照明用の白熱電球におけるガラスバルブの形状としては、Ｇ形およびＰＳ形が主に用いられている。また、電球形蛍光ランプのグローブの形状としては、Ｇ形、Ａ形およびＴ形が主に用いられている。これらの形状は、一般照明用光源の業界においては、周知である。さらに、バルブ部は、口金から露出している部分の中空基体の軸方向に沿った長さの１／２の位置を中心としてバルブの先端から軸の周囲に１３５°をなす部位までを主要部という。なお、これは一般照明においては、バルブ部の上記により定義される主要部から放射される光が主に有効に利用される、換言すれば効率よく照明を行えることから規定している。また、中空基体のバルブ部の主要部とその他の部分とを分離可能に形成してもよい。

【００１７】ネック部は、中空基体とねじ口金とを結合する部分であるから、バルブ部に比べると細くなっている。ネック部の先端をねじ口金の内部に挿入してねじ口金を加締めたり、接着したりすることによって両者を結合するように構成することができる。

【００１８】また、中空基体は、絶縁性材料たとえばポリブチレンテレフタレート（ＰＢＴ）樹脂、ポリカーボネート樹脂、プリント配線基板材料たとえばガラス繊維強化エポキシ樹脂などの合成樹脂やセラミックス、ガラスなどを用いて形成することができる。中空基体の外面の色は、材料固有色および塗装色のいずれでもよいが、所望により任意に選択すればよく、たとえば白色系や外面を鏡面にして反射性を付与したり、透明にして内部が透視できるスケルトン仕様にしたりすることができる。

【００１９】さらに、中空基体には、発光ダイオードを回路手段に接続する態様に応じてプリント配線およびまたはリード線挿入孔が形成される。これらについては後述する。

【００２０】さらにまた、中空基体は、その成形、組み立て、プリント配線の形成または発光ダイオードの実装を容易にするために、必要に応じて複数に分割された部品を組み立てて形成することができる。分割は、縦割り、横割りなど適当に構成することができる。組み立ては、接着、嵌合など既知の結合手段を適宜採用することができる。

【００２１】さらにまた、中空基体の適所に内部に発生した熱を外部へ放散させる放熱手段たとえば放熱孔、放熱フィンなどを配設することができる。

【００２２】＜発光ダイオードについて＞発光ダイオードは、一般に発光部およびリード部から構成されている。

【００２３】発光部は、本発明において、その形状を大別してレンズ形およびチップ形に分類する。なお、「レンズ形」とは、発光部の高さが幅および奥行きのいずれかに対して大きいものをいい、その多くは発光ダイオードの配光を所望に制御するために、全体または多くの部分がレンズ作用を呈するように形成されている。これに対して、「チップ形」とは、発光部が薄形で、高さが幅および奥行きのいずれか大きい方に対して同等以下のものをいう。なお、「幅」とは、リード部が左右に見える位置における発光部のリード部方向の寸法である。また、「奥行き」とは、薄形を構成している発光部の平面内において、幅と直交する部分の寸法である。

【００２４】また、発光部の構造は、一般的にはレンズ形とチップ形とで異なるが、しかし、これは決定的なものではない。レンズ形は、リードフレーム、リードフレームにボンディングした発光ダイオードチップ、ボンディングワイヤおよびこれらの部品を埋設してレンズ状に成形した透光性樹脂シール部からなるものが多い。これに対して、チップ形は、一般的にはセラミックス基板、セラミックス基板上に配設したリードフレーム、リードフレームにボンディングした発光ダイオードチップ、ボンディングワイヤおよびこれらの部品を埋設してセラミックス基板上に成形した透光性樹脂シール部によって構成することができる。また、セラミックス基板上に形成した一対の導電膜、一方の導電膜に配設した発光ダイオードチップ、発光ダイオードチップと他方の導電膜の間を接続するボンディングワイヤおよびこれらの部品を埋設してセラミックス基板上に成形した透光性樹脂シール部によって構成することもできる。

【００２５】次に、リード部は、発光ダイオードチップ

から導出した外部接続部であり、細長い金属線、細長いリードフレームまたはチップ形発光部のセラミックス基板の主として底面に形成した導電膜や発光部から側方へ突出した舌片状のリードフレームなどからなる。レンズ形においては、発光部の底面から軸方向に一対の金属線またはリードフレームが平行に延在する構成である。これに対して、チップ形においては、発光部から側方へ細長い金属線、細長いリードフレームまたは舌片状のリードフレームが延在するか、あるいはセラミックス基板の底面およびまたは側面に導電膜が被着している構成が多い。しかし、本発明においてはリード部の構成は特に限定されない。

【００２６】さらに、発光ダイオードの発光色は、一般に赤系、橙系、黄系、緑系、青系および白系に別れる。白系は、青系の発光ダイオードチップと黄色発光蛍光体とを組み合わせた構成、３原色発光または２色発光となるそれぞれの発光色の発光ダイオードチップを集合して白色発光を行うようにした構成などでもよい。

【００２７】本発明において用いる発光ダイオードは、発光部がチップ形であるとともに、その幅寸法が４ｍｍ以下のものをいい、また、発光色は白色発光タイプである。

【００２８】さらにまた、発光ダイオードは、その多数が中空基体のバルブ部の少なくとも主要部の外面に分散し、かつ、発光部の底面が中空基体の外面にほぼ当接して配設される。なお、「多数の発光ダイオード」とは、少なくとも５０個以上であることを意味し、好ましくは１５０個以上である。「分散し」とは、均一に分散している態様および不均一に分散している態様を含む意味である。不均一の場合、たとえばバルブ部の先端側の配置密度を相対的に高くし、ネック側を相対的に疎に配置することで配光特性を所望に補正することもできる。「ほぼ当接」するとは、当接しているように見える程度であればよく、多少浮いていてもよい。

【００２９】さらにまた、発光ダイオードのリード部の一部またはプリント基板およびはんだなどの充電部が中空基体の外面に露出する場合には、当該充電部のみを絶縁被覆するか、中空基体の全体を発光ダイオードの上から透光性合成樹脂で絶縁被覆すれば、充電部は隠蔽される。

【００３０】さらにまた、発光ダイオードの発光の色温度は、２０００～１００００Ｋの範囲であることを許容する。

【００３１】＜回路接続手段について＞回路接続手段は、発光ダイオードと口金との間を所要に接続して、発光ダイオードを点灯するための手段であり、発光ダイオードの駆動方式を決定するとともに、発光ダイオードの配線手段を含む。

【００３２】まず、駆動方式について説明する。発光ダイオードは、その順方向に電流すなわち順電流を流すことにより発光すなわち点灯する。発光ダイオードを点灯するには、交流電流をそのまま２個以上の発光ダイオードに通流する交流駆動方式と、直流電流を通流する直流駆動方式と、パルス電流を通流して点灯するパルス駆動方式とがあり、本発明においてはそのいずれであってもよい。

【００３３】交流駆動方式は、交流電圧が正の半波のときに順電流が流れる発光ダイオードと、負の半波のときに順電流が流れる発光ダイオードとを並列すなわち対の発光ダイオードを逆並列に接続すればよい。所与の交流電圧に適合させるために、または所望の光量を得るために、複数の発光ダイオードを直列接続する場合、複数の発光ダイオードを直列接続したものを逆並列接続してもよいし、一対の発光ダイオードを逆並列接続したものを複数組直列接続してもよい。要するに、交流駆動とは、電源側から見た場合のことであって、発光ダイオード側から見れば直流駆動であるが、商用交流電源のように正弦波電圧をそのまま発光ダイオードに印加すれば、順電流も正弦波状に変化する。

【００３４】直流駆動方式は、駆動電源が直流であり、したがって発光ダイオードのアノードが直流電源の正極側に、カソードが負極側に、それぞれ接続される。このため、口金が低圧交流電源に接続する場合には、整流手段またはおよび平滑コンデンサを発光ダイオードの前段に介在させる。この場合の整流手段またはおよび平滑コンデンサは、回路手段の一部をなす。

【００３５】パルス駆動方式は、パルス電流を発光ダイオードに通流してパルス点灯する方式である。電流依存性の強い発光ダイオードを用い、かつ、ピーク値の大きなパルス電流を通量すれば、人の目の残像現象を利用して直流駆動のときよりも明るくすることができる。したがって、残像現象を生じるようにパルス電流の繰り返し周波数を比較的高く設定する。この方式におけるパルス駆動回路は、回路手段の一部をなす。

【００３６】上記のいずれの駆動方式においても所定の順電流を流すために、電流制限要素を発光ダイオードと直列に接続したり、定電流回路を用いたりすることができる。この場合の電流制限要素や定電流回路は、回路手段の一部をなす。なお、「電流制限要素」とは、抵抗器およびリアクタンス素子をいい、後者はコンデンサおよびインダクタを含み、交流回路において用いられる。また、逆耐圧の問題が生じないように発光ダイオードと同極性にダイオードを直列接続したり、発光ダイオードにツ ナーダイオードを並列接続したりすることができる。

【００３７】次に、配線手段について説明する。以下、配線手段を、多数の発光ダイオードを中空基体に実装して所要に接続する第１の配線手段と、電流制限要素や定電流回路あるいはおよび整流回路などを実装する第２の配線手段と、所要に接続された多数の発光ダイオードを

電流制限抵抗器や定電流回路あるいはおよび整流回路などに接続するとともに、これらを口金に接続する第３の配線手段とに分けて説明する。

【００３８】第１の配線手段は、中空基体の内面または外面にプリント配線を形成することによって配設することができる。中空基体の内面にプリント配線を形成する場合は、中空基体に発光ダイオードに細長いリード線を備えたものを用いて、そのリード線を挿通する透孔をプリント配線に合わせて形成する。そして、中空基体の内面側でリード線をプリント配線にはんだ付けする。これに対して、中空基体の外面にプリント配線を形成する場合は、発光ダイオードにセラミックス基板の底面に導電膜を備えるか、発光部の左右に舌片状のリードフレームを突出したものを用いて、それらを中基体の外面側ではんだ付け、または導電性接着剤を用いて接続する。しかし、本発明は、中空基体にプリント配線を形成しないで、中空基体にリード線挿通孔を形成して発光ダイオードのリード線を外側から挿通し、中空基体の内部でリード線同士を接続して所要の接続を得てもよい。

【００３９】第２の配線手段は、特に限定されないが、たとえば中空基体の外面に加えて内面にもプリント配線を形成するか、中空基体とは別にプリント配線基板を設けて実装し、かつ中空基体の内部に配設して実装することができる。

【００４０】第３の配線手段は、特に限定されないが、たとえば適当な導体を用いることにより構成することができる。

【００４１】＜本発明の作用について＞本発明においては、中空基体の外面に多数のチップ形の発光ダイオードを分散して配設しているので、中空基体のバルブ部の少なくとも主要部の全体から白色光が均一に放射され、その結果、一般照明用の白熱電球に近い配光特性が得られる。

【００４２】また、チップ形の発光ダイオードは、発光部が薄いので、中空基体からの突出高さを小さくでき、したがって固体形光源装置の発光部分の外形が中空基体の形状により支配的に決定される。このため、固体形光源装置の外観が一般照明用の白熱電球の光拡散形ガラスバルブか電球形蛍光ランプのグローブに近い形状になり、外観に違和感がない。

【００４３】さらに、チップ形の発光ダイオードは、発光部が相対的に小さいので、固体形光源装置の質量が小さくなる。

【００４４】請求項２の発明の固体形光源装置は、請求項１記載の固体形光源装置において、回路手段は、中空基体の少なくともバルブ部に形成した第１のプリント配線基板を備えており；発光ダイオードは、第１のプリント配線に実装されることにより配設されている；ことを特徴としている。

【００４５】本発明は、第１のプリント配線は、中空基体の内外両面のいずれであってもよい。外面に第１のプリント配線を形成すれば、発光ダイオードを表面実装することができる。

【００４６】そうして、本発明においては、発光ダイオードの配設が容易になる。

【００４７】請求項３の発明の固体形光源装置は、請求項１または２記載の固体形光源装置において、回路手段は、中空基体の内部に収納された第２のプリント配線基板および第２のプリント配線基板に実装された電流制限要素または定電流回路を備えていることを特徴としている。

【００４８】電流制限要素は、抵抗器だけでなく、リアクタンス素子たとえばコンデンサまたはインダクタなどであってもよい。なお、リアクタンス素子は、交流回路部分に挿入されることにより、電流制限作用を呈する。

【００４９】定電流回路は、どのような構成であってもよい。

【００５０】また、直流駆動の場合、交流を整流して得た直流を電流源として用いる場合、整流回路を第２のプリント配線基板に実装することができる。

【００５１】第２のプリント配線基板は、どのような構成であってもよく、たとえばリード線を配線孔に挿通してはんだ付けする汎用の配線基板、表面実装配線基板、フレキシブル配線基板などを用いることができる。また、第２のプリント配線基板は、中空基体の内部に収納されていれば、その支持手段を問わない。たとえば、中空基体の内面に接着したり、ねじ口金に固定したりしてもよい。中空基体の内面に第１のプリント配線を形成する場合、第２のプリント配線基板に端子片を突出して設け、この端子片を第１のプリント配線の所定の位置にはんだ付けすることによって、所要の接続と固定とを同時に行うように構成してもよい。

【００５２】そうして、本発明においては、電流制限要素または定電流回路を第２のプリント配線基板に実装して中空基体の内部に収納したことにより、固体形光源装置の外観が簡素になるとともに、発光ダイオードの実装と電流制限要素または定電流回路の実装とを別に行うことができ、組み立てが容易になる。

【００５３】請求項４の発明の固体形光源装置は、請求項１ないし３のいずれか一記載の固体形光源装置において、中空基体は、バルブ部がほぼ真球状をなしていることを特徴としている。

【００５４】本発明は、中空基体のバルブ部の配光特性上好適な形状を規定している。すなわち、中空基体のバルブ部が真球状をなしていると、鉛直方向の配光特性がボール形の白熱電球のように良好な円状になるので、一般照明用の照明器具に用いたときに適合性が向上する。

【００５５】請求項５の発明の固体形光源装置は、ねじ口金と；バルブ部およびネック部を備え、ネック部がねじ口金に装着されている中空基体と；中空基体の外面に

分散して配設されていて、それぞれが白色発光タイプであるとともに、定格光束の総和が１５０１ｍ以上となる多数のチップ状の発光ダイオードと；発光ダイオードを所要に配線するとともに口金に接続する回路手段と；を具備していることを特徴としている。

【００５６】本発明は、一般照明用として用いることができる光束で発光する固体形光源装置を規定している。すなわち、一般照明用として市場で入手できる定格電圧１００Ｖの白熱電球は、最も小さいワットの区分が２０Ｗ形であり、その全光束が光拡散性のもので１７０１ｍ程度であるから、この光束値より概ね１０％程度低い１５０１ｍ以上あれば、一般照明用として遜色なく置換可能になる。そこで、本発明においては、実装されている全ての発光ダイオードの定格光束の総和を１５０１ｍ以上と規定している。なお、「定格光束」とは、実際に規定されているといないとにかかわらず、単一の発光ダイオードについての標準光度および標準半値幅に基づいて計算により求めた光束値をいう。また、「総和」とは、単一の発光ダイオードの定格光束と使用数との積により求めた値をいう。

【００５７】そうして、本発明によれば、所要の明るさで一般照明を行うことができる。たとえば、発光ダイオードの発光効率が１５１ｍ／Ｗ程度で、１個の発光ダイオードの定格消費電力が０．１Ｗであるとすると、１００個の発光ダイオードを用いれば、定格光束の総和が１５０１ｍとなる。

【００５８】請求項６の発明の固体形光源装置は、請求項１ないし５のいずれか一記載の固体形光源装置において、発光ダイオードの上から中空基体の外面に被着した透光性絶縁被覆を具備していることを特徴としている。

【００５９】本発明は、絶縁性能を向上した固体形光源装置の好適な構成を規定している。すなわち、中空基体の外面に発光ダイオードの上から透光性絶縁被覆を被着している。絶縁被覆は、たとえば透光性シリコーン樹脂、透光性フッ素樹脂などの合成樹脂を用いることができる。透光性絶縁被覆を形成するには、ディッピング、吹き付け、静電塗装などの既知の被着手段を用いることができる。

【００６０】そうして、本発明においては、発光ダイオードを中空基体の外面および内面のいずれで実装する構成であったとしても、リード部の外部露出部分やプリント配線部分が透光性絶縁被覆により覆われるので、絶縁の問題は生じないとともに、外観が優美になる。

【００６１】また、透光性絶縁被覆として透明性物質を用いることにより、光透過率を高い状態に維持することができる。

【００６２】さらに、光拡散性物質を用いることにより、中空基体の表面の輝度分布を均整化するとともに、外観が一層良好になる。

【００６３】【発明の実施の形態】以下、図面を参照して本発明の実施の形態を説明する。

【００６４】図１は、本発明の固体形光源装置の第１の実施形態を示す断面図である。

【００６５】図２は、同じく発光ダイオードの要部を示す一部切欠拡大平面図である。

【００６６】図３は、同じく発光ダイオードの要部を示す一部切欠拡大正面図である。

【００６７】図４は、同じく発光ダイオードの駆動回路を示す回路図である。

【００６８】各図において、１はねじ口金、２は中空基体、３は発光ダイオード、４は回路手段である。

【００６９】ねじ口金１は、Ｅ２６形ねじ口金である。

【００７０】中空基体２は、白色のＰＢＴを成形して形成され、バルブ部２ａおよびネック部２ｂからなる。バルブ部２ａは、バルブ主要部２ａ１およびバルブ基体部２ａ２からなる。バルブ主要部２ａ１は、図示を省略しているが、複数に分割して成形されているが、接着されて真球の主要部を構成している。また、図示を省略しているが、バルブ主要部２ａ１には多数の配線孔がほぼ一定のピッチで形成され、また内面に配線孔を所要に接続するプリント配線が形成されている。バルブ基体部２ａ２は、バルブ主要部２ａ１と別に成形されているが、バルブ主要部２ａ１と嵌合され、かつ、接着されることにより、ほぼ真球状をなすバルブ部２ａを構成する。ネック部２ｂは、バルブ基体部２ａ２と一体に成形されていて、ねじ口金１に挿入してねじ口金１の開口端近傍を部分的に加締めて両者を結合している。

【００７１】発光ダイオード３は、図２および図３に示すように、発光部３ａおよびリードフレームを延長して形成した一対のリード線３ｂからなる。発光部３ａは、セラミックス基板３ａ１、透光性樹脂シール部３ａ２および透光性樹脂シール部３ａ２内に埋設された図示を省略している埋設部品からなる。埋設部品は、リードフレーム、発光ダイオードチップおよびボンディングワイヤである。一対のリード線３ｂは、ともに基板面に対して直角に折曲されていて、中空基体２の図示しない配線孔に挿入され、中空基体２の内面側ではんだ付けされている。発光ダイオード３の一例としては、順電圧３．６Ｖ、順電流２０ｍＡ、定格光度１５６０ｍｃｄ、半値幅５０°であり、発光効率は約１５１ｍ／Ｗである。この発光ダイオード３を全部で１８０個用いることにより、消費電力約１３Ｗ、定格光束の総和が１９４１ｍとなり、一般照明用の２０Ｗ形白熱電球相当の固体形光源装置が得られることになる。

【００７２】回路手段４は、図４に示すように、主として第１のプリント配線基板４ａおよび第２のプリント配線基板４ｂを備えている。第１のプリント配線基板４ａは、中空基体の内面に形成され、多数の発光ダイオード３を実装して直並列接続回路を形成している。直並列接

続回としては、たとえば３０個の発光ダイオードを直列接続してなる直列回路を６つ並列接続して発光ダイオード群を構成する。第２のプリント配線基板４ｂは、第１のプリント配線基板４ａとは分離していて、電流制限要素４ｂ１および整流回路４ｂ２を実装している。電流制限要素４ｂ１は、抵抗器からなり、その一端が整流回路４ｂ２の直流出力端の正極に接続している。また、第２のプリント配線基板４ｂは、整流回路４ｂ２の直流出力の正極が電流制限要素４ｂ１および導線ｗ１を介して第１のプリント配線基板４ａの発光ダイオード群のアノード側へ接続し、負極が導線ｗ２を介して同じく発光ダイオード群のカソード側へ直接接続している。さらに、第２のプリント配線基板４ｂは、整流回路４ｂ２の交流入力端極が導線ｗ３、ｗ４を介してねじ口金１に接続しているとともに、支持されている。ねじ口金１は、１００Ｖ交流電源ＡＣに接続する。

【００７３】そうして、本実施形態によれば、ボール形の光拡散ガラスバルブを備えた一般照明用の白熱電球と基本的な輪郭が類似した固体形光源装置が得られる。

【００７４】なお、図示を省略しているが、中空基体２の外面に露出している発光ダイオード３のリード線３ｂの充電部は、部分的に被着された絶縁塗料により被覆されている。

【００７５】図５は、本発明の固体形光源装置の第２の実施形態を示す断面図である。

【００７６】図６は、同じく発光ダイオードを示す拡大平面図である。

【００７７】図７は、同じく発光ダイオードを示す拡大正面図である。

【００７８】図８は、同じく発光ダイオードを示す拡大底面図である。

【００７９】各図において、図１ないし図３と同一部分については同一符号を付して説明は省略する。本実施形態は、発光ダイオード３゛が表面実装されるとともに、透明絶縁被覆５を具備している点で異なる。

【００８０】すなわち、発光ダイオード３゛は、図６ないし図８に示すように、発光部３ａ゛および導電膜のリード部３ｂ゛からなる。発光部３ａ゛は、セラミックス基板の上面に被着した導電膜に発光ダイオードチップをボンディングワイヤ（いずれも図示しない。）を介して接続し、また上記導電膜はスルーホール（図示しない。）を介して後述するリード部３ｂ゛に接続している。リード部３ｂ゛は、その一対がセラミックス基板３ａ１の底面に離間して形成されている。

【００８１】回路手段４゛は、第１のプリント配線基板４ａ゛が中空基体２の外面に形成されている。

【００８２】透明絶縁被覆５は、透明シリコーン樹脂からなり、発光ダイオード３゛およびその他の所要の配線を形成した後に、中空基体２のバルブ部２ａの主要部をシリコーン樹脂液にディップし、固化させて形成されている。したがって、第１のプリント配線基板４ａ゛の充電部は、透明絶縁被覆５により被覆されるので、絶縁の問題はない。

【００８３】図９は、本発明の固体形光源装置の第３の実施形態における要部を示す正面図である。

【００８４】図において、図１と同一部分については同一符号を付して説明は省略する。本実施形態は、中空基体２がＰＳ形を呈している点で異なる。

【００８５】そうして、本実施形態によれば、ＰＳ形の光拡散ガラスバルブを備えた一般照明用の白熱電球と基本的な輪郭が類似した固体形光源装置が得られる。

【００８６】図１０は、本発明の固体形光源装置の第４の実施形態における要部を示す正面図である。

【００８７】図において、図９と同一部分については同一符号を付して説明は省略する。本実施形態は、中空基体２がＴ形を呈している点で異なる。

【００８８】そうして、本実施形態によれば、Ｔ形の光拡散ガラスバルブを備えた電球形蛍光ランプと基本的な輪郭が類似した固体形光源装置が得られる。

【００８９】

【発明の効果】請求項１ないし４の各発明によれば、バルブ部およびネック部を備え、ネック部がねじ口金に装着されている中空基体の少なくとも主要部の外面に分散し、かつ、底面が中空基体の外面にほぼ当接して多数のチップ状で白色発光タイプの発光ダイオードを配設するとともに、発光ダイオードを所要に配線し、かつ、口金に接続する回路手段を具備していることにより、一般照明用の白熱電球に近い配光特性が得られるとともに、発光ダイオードの中空基体からの突出高さが小さくて発光部の外形が中空基体の形状により支配的に決定されるため、外観が一般照明用の白熱電球の光拡散形ガラスバルブか電球形蛍光ランプのグローブに近い形状になって、外観に違和感がなく、しかも比較的質量が小さい固体形光源装置を提供することができる。

【００９０】請求項２の発明によれば、加えて回路手段が中空基体の少なくともバルブ部に形成した第１のプリント配線基板を備えていて、発光ダイオードが第１のプリント配線に実装されていることにより、発光ダイオードの中空基体への配設が容易な固体形光源装置を提供することができる。

【００９１】請求項３の発明によれば、加えて回路手段が中空基体の内部に収納された第２のプリント配線基板および第２のプリント配線基板に実装された電流制限要素または定電流回路を備えていることにより、外観が簡素になるとともに、発光ダイオードの実装と電流制限要素または定電流回路の実装とを別に行うことができて、組み立てが容易固体形光源装置を提供することができる。

【００９２】請求項４の発明によれば、加えて中空基体がバルブ部がほぼ真球状をなしていることにより、鉛直

方向の配光特性がボール形の白熱電球のように良好な円状になり、一般照明用の照明器具に用いたときに適合性が一層向上する固体形光源装置を提供することができる。

【００９３】請求項５の発明によれば、バルブ部およびネック部を備え、ネック部がねじ口金に装着されている中空基体の少なくとも主要部の外面に、それぞれが白色発光タイプであるとともに、定格光束の総和が１５０１ｍ以上となる多数のチップ状の発光ダイオードを分散して配設し、かつ、回路手段が発光ダイオードを所要に配線するとともに口金に接続していることにより、一般照明用として用いることができる固体形光源装置を提供することができる。

【００９４】請求項６の発明によれば、加えて発光ダイオードの上から中空基体の外面に被着した透光性絶縁被覆を具備していることにより、リード部の外部露出部分やプリント配線部分が透光性絶縁被覆により覆われ、絶縁の問題が生じないとともに、外観が優美になる固体形光源装置を提供することができる。

【図面の簡単な説明】

【図１】本発明の固体形光源装置の第１の実施形態を示す断面図

【図２】同じく発光ダイオードの要部を示す一部切欠拡大平面図

【図３】同じく発光ダイオードの要部を示す一部切欠拡大正面図

【図４】同じく発光ダイオードの駆動回路を示す回路図

【図５】本発明の固体形光源装置の第２の実施形態を示す断面図

【図６】同じく発光ダイオードを示す拡大平面図

【図７】同じく発光ダイオードを示す拡大正面図

【図８】同じく発光ダイオードを示す拡大底面図

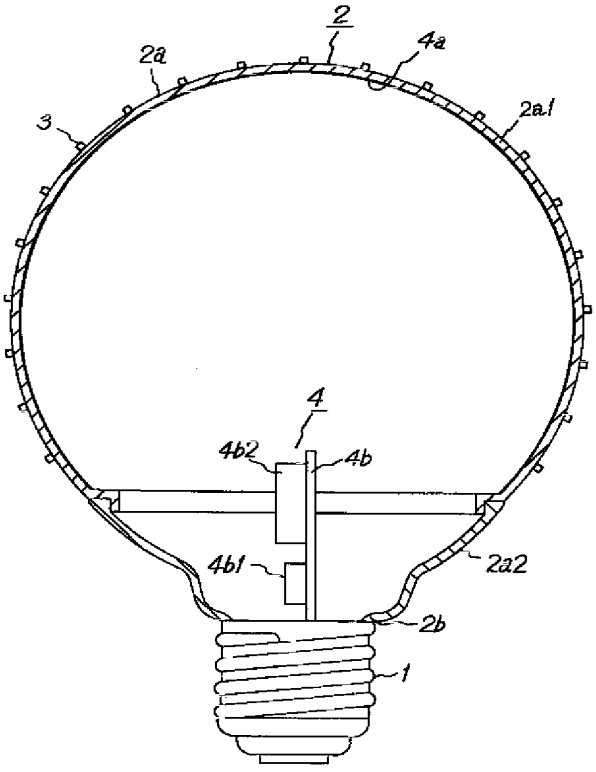
【図９】本発明の固体形光源装置の第３の実施形態における要部を示す正面図

【図１０】本発明の固体形光源装置の第４の実施形態における要部を示す正面図

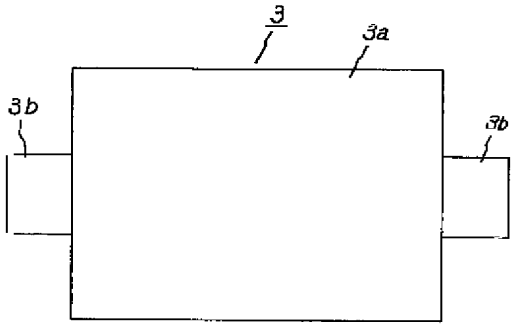
【符号の説明】

１…ねじ口金
２…中空基体
２ａ…バルブ部
２ａ１…バルブ主要部
２ａ２…バルブ基体部
２ｂ…ネック部
３゛…発光ダイオード
４゛…回路手段
４ａ゛…第１のプリント配線基板
４ｂ…第２のプリント配線基板
４ｂ１…電流制限要素
４ｂ２…整流回路
５…透明絶縁被覆

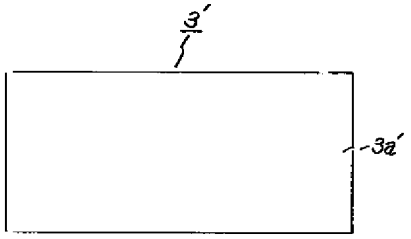
【図１】



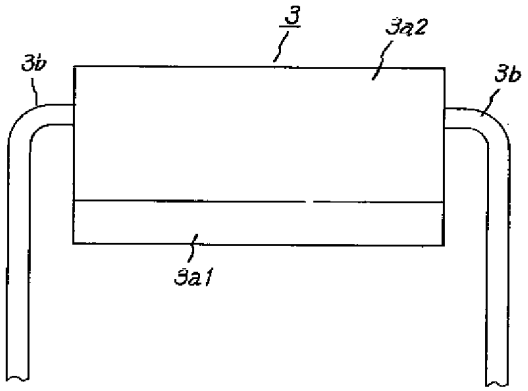
【図２】



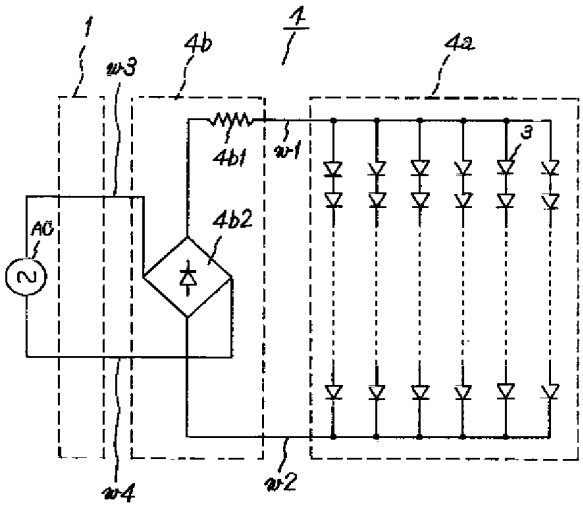
【図６】



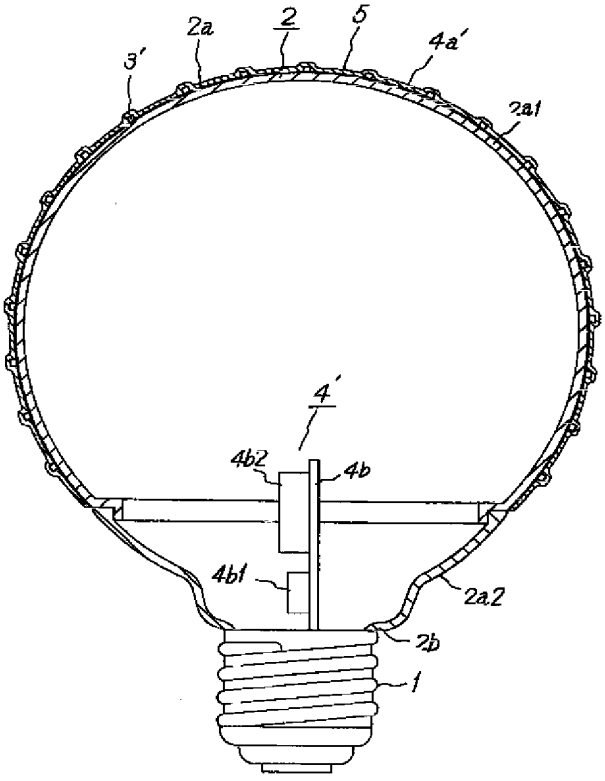
【図3】


3
3a2
3b
3b
3a1

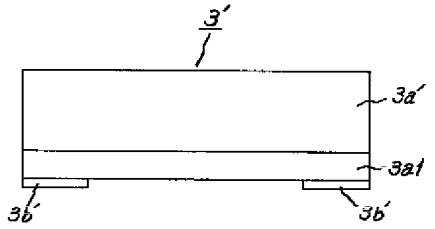
【図4】


1
4b
1
4a
w3
4b1
w1
3
AC
4b2
w4
w2

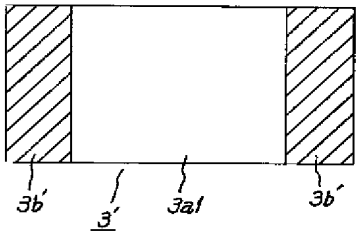
【図5】


2a
2
5
4a'
3'
2a1
4'
4b2
4b
4b1
2a2
2b
1

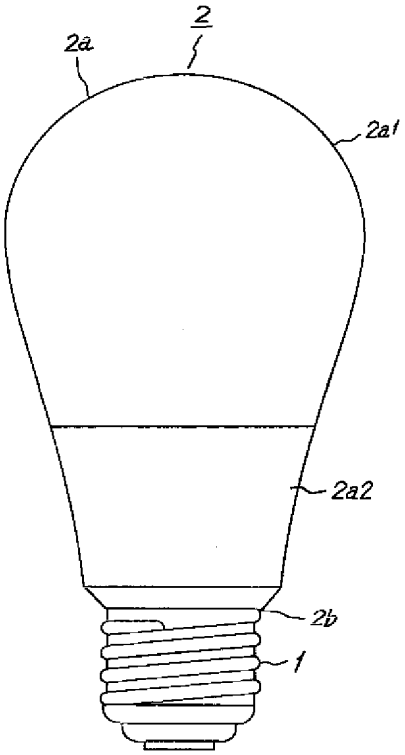
【図7】


3'
3a'
3a1
3b'
3b'

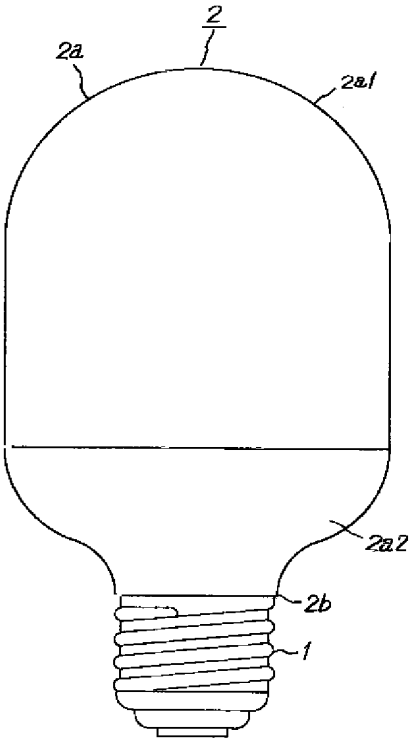
【図8】


3b'
3'
3a1
3b'

【図9】



【図10】



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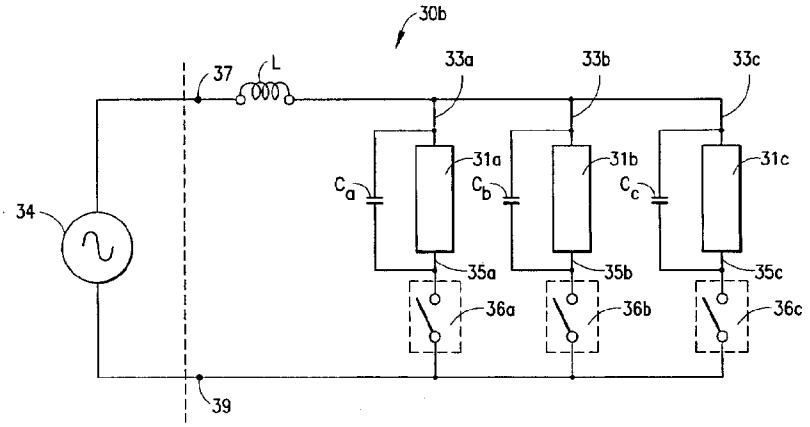
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(54) Title: AC POWERED LED CIRCUITS FOR TRAFFIC SIGNAL DISPLAYS



(57) Abstract: An LED array circuit (30b) includes a number of series connected LED pairs (32), each pair (32) including two parallel connected oppositely polarized LEDs. The array is coupled to a standard AC voltage source (34) in series with an inductor having Q>5 and a reactance which is equivalent to the resistance of a current limiting resistor. The use of an inductor in place of a resistor increases the efficiency of the array to approximately 80%. The efficiency of the array is increased even further by coupling a capacitor parallel to the array and by tuning the inductor and capacitor to the frequency of the AC voltage source (34). According to one embodiment of the invention, a single module is provided with a plurality of LED arrays (31a-31c), with each LED array (31a or 31b or 31c) having its own capacitor coupled in parallel thereto, and its own series coupled switch (36a or 36b or 36c). The module is coupled to and across the AC voltage source (34), with one node of the module coupled to the AC voltage source (34) by an inductor.

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AC POWERED LED CIRCUITS FOR TRAFFIC SIGNAL DISPLAYS

BACKGROUND OF THE INVENTION

1. Field of the Invention

The invention relates to light emitting diode arrays. More particularly, the invention relates to circuits incorporating light emitting diode arrays which are powered by an alternating current and which are advantageously used in traffic signal and other displays.

2. State of the Art

Modern traffic signal systems include two major components: the controller and the display (lights). The technology of modern traffic signal controllers is quite evolved and includes modern computer technology which incorporates traffic flow sensors, timers, and the like. Over the last seventy years, however, traffic signal displays have not changed significantly. The displays utilize high power broad spectrum incandescent bulbs with colored filters to produce the desired traffic signal color. It is well known that traffic signal displays are inefficient, as they consume large amounts of energy in order to produce a display which is bright enough to be seen in broad daylight. The inefficiency of the displays is due in part to the general inefficiency of incandescent bulbs, and is exacerbated by the fact that much of the light energy produced by the bulbs is wasted by filtering the light. Moreover, traffic signal displays require frequent maintenance. Incandescent bulbs have a relatively short life span, typically less than eight thousand hours, shorter still if switched on and off frequently and if constantly exposed to the elements; all of which are the case with traffic signals.

It is known in the art to use a light emitting diode (LED) array in lieu of incandescent bulbs in a traffic signal. Such arrays are disclosed, for example, in U.S. Patent Number 4,271,408 to Teshima et al., U.S. Patent Number 4,298,869 to Okuno, and U.S. Patent Number 4,954,822 to Borenstein, the complete disclosures of which are hereby incorporated herein by reference. An LED array can provide many advantages when used in lieu of an incandescent bulb. The primary advantages are that an LED array is much more efficient than an incandescent bulb and requires little or no maintenance. In most cases, an LED array will consume about one tenth the power that a filtered incandescent bulb will consume to produce the same light output. The life cycle costs of a traffic signal using an LED array in lieu of an incandescent bulb is also significantly reduced since incandescent bulbs used in traffic signals typically must be replaced once or twice a year. A well designed LED array could be expected to function for more than twenty years before requiring replacement. Another, less apparent advantage is that a single array can be used to display many different illuminated symbols such

as international symbols for turn only, do not enter, walk, don't walk, etc. The LED array is more resistant to the elements and is more mechanically durable than an incandescent bulb. It is also possible to achieve a higher flashing rate with an LED array than with an incandescent bulb. It is known in industrial psychology that certain high flashing rates are more apt to draw attention than other slower flashing rates. In addition, an LED array does not require a light reflector like the relatively large parabolical reflectors used with incandescent bulbs. The elimination of the reflector is an advantage because during certain seasons at certain times of day, sunlight can be reflected off the reflector in an incandescent bulb traffic signal and cause a confusing display. Yet another advantage of an LED array is that, if it is properly arranged, when faults develop in the array, the entire array need not fail.

Despite all of the advantages of using LED arrays in traffic signal displays, there are several concerns which have prevented their widespread adoption. The first and perhaps the most significant concern is that an LED array is not easily retro-fitted to an existing traffic signal. This is primarily because existing incandescent displays operate with a "standard" 120 volt 60 Hz AC power supply. LEDs require a DC current of approximately 5 to 20 milliamps and a forward operating voltage of between 1.5 to 2.5 volts depending on the wavelength of the emitted light and the semiconductor material used. Another reason why retro-fitting is difficult is because the "standard" traffic signal housings are designed to accept a "standard" incandescent bulb. These issues have been addressed in the art. As shown in prior art Figure 1, an arrangement which has been proposed by Borenstein, supra., uses a step down isolation transformer 10 with a center tapped full-wave rectifier 12 to drive an array of LEDs 14 which are connected in parallel. Although Borenstein does not specify exactly how many LEDs are to be used, a typical traffic signal display will require at least between twenty and eighty LEDs. Assuming that fifty LEDs are used with Borenstein's power supply, it is difficult to imagine that an efficiency of more than 50% could be achieved. Moreover, a most common LED failure mode is a short where the LED becomes a short circuit. If the LEDs are arranged in parallel as taught by Borenstein, a short fault in one LED will disable the entire array.

As shown in prior art Figure 2, a simpler arrangement which has been proposed by Teshima et al., supra., uses a rectifier bridge 16 to convert the AC power supply to pulsating DC and an array of sixty-two 1.6 volt LEDs 18 in series with a resistor 20. A smoothing capacitor 22 is connected in parallel with the array for absorbing ripple components of the power supply. Unfortunately, the rectifier circuit adds expense to the system and makes it less reliable. The resistor wastes energy and lowers the efficiency of the system. While Teshima et al. suggests that the rectifier can be eliminated by using pairs of oppositely polarized LEDs connected in series through a protective resistor, little information is given about this arrangement.

A simpler solution has been proposed by Okuno, supra., which is shown in prior art Figure 3. Okuno avoids the use of a rectifier bridge by providing an array of LEDs 24 which are connected in series and polarized in one direction and an array of LEDs 26 which are connected in series and polarized in the opposite direction. The two arrays 24 and 26 are connected in parallel so that a respective array is illuminated during each half cycle of the AC power supply. According to Okuno, however, a current limiting resistor 28 (a generator resistor) must be connected in series with the arrays. Assuming each array 24 and 26 includes twenty-five LEDs, the value of the resistor 28 should be approximately 3300 ohms to produce the desired average LED current. Since approximately 70% of the line voltage is dropped across the resistor 28, the resistor is the dominant factor in determining the LED current and energy is wasted by the resistor. In this example, the arrangement has an efficiency of only about 35% and the LED current has a range of ±25%. If a greater number of LEDs were used, the efficiency would increase, but the current range would widen.

Recently, committees have been formed to study the critical characteristics of LED arrays used in traffic displays and to make recommendations about these characteristics. See, e.g., Interim LED Purchase Specifications of the Institute of Transportation Engineers, Part 2, July 1998. One of the characteristics of LED arrays is the power factor (a value between zero and 1) and it has been recommended that the power factor be greater than 0.9. Another characteristic is total harmonic distortion (THD-F) which is recommended to be less than 20%. The ratio of peak to average current is indicative of the number of lumens obtained per watt of power. A low peak to average current is more efficient. Current regulation is also important in LED arrays as the line voltage (nominally 110-120 in the U.S.) normally fluctuates. One (US) standards committee recommends that current be regulated for voltage fluctuations between 80 and 134 volts. Some LEDs, especially red LEDs are sensitive to temperature and increase in brightness when ambient temperature drops. Therefore, many committees recommend that the circuits controlling traffic LEDs provide for temperature compensation. For LED traffic signals, it is also important that the LED array be tolerant to the failure of individual LEDs. Although the MTBF (mean time between failure) for an individual LED is greater than thirty years, it is quite likely that a single LED in an LED array having several hundred LEDs will fail in a shorter time. In particular, failure of an individual LED in an array should not cause more than 20% light loss. Whether an LED fails by shorting or by opening is another issue to be addressed.

Finally, some committees have expressed concern that LED arrays might interfere with other traffic control devices. In particular, some emergency vehicles are equipped with a light transmitter which modulates light in a manner similar to a TV remote control. Traffic signals are equipped with a light receiver so that the traffic signal can be controlled by an approaching

emergency vehicle. Since AC powered LED arrays of the type shown in prior art Figure 3 (self full wave rectifying) have a light output with a main frequency component of 120Hz (twice line frequency), there is some concern that this modulation will interfere with emergency vehicle remote traffic signal control.

SUMMARY OF THE INVENTION

It is therefore an object of the invention to provide a circuit incorporating an AC line powered LED array which is suitable for retro-fitting in an existing traffic signal display.

It is also an object of the invention to provide an AC line powered LED array circuit which does not require a rectifier bridge or a transformer.

It is another object of the invention to provide an AC line powered LED array circuit which has enhanced efficiency and does not use a current limiting resistance.

It is a further object of the invention to provide a highly efficient, low cost AC powered LED array circuit for use in traffic signal and other displays.

It is also an object of the invention to provide an AC line powered LED array having a large number of LEDs connected in series so that the cumulative voltage across the array may be comparable to or greater than an AC line voltage.

It is another object of the invention to provide an AC line powered LED array circuit which provides a relatively constant current through the LED array regardless of the type or number of LEDs in the array.

It is a further object of the invention to provide an AC line powered LED array and circuit which is highly fault tolerant.

It is still another object of the invention to provide AC line powered LED display which is compatible with existing traffic signal controllers.

It is also an object of the invention to provide an LED array and circuit which has a power factor greater than 0.9.

It is another object of the invention to provide an LED array and circuit which has a total harmonic distortion less than 20%.

It is a further object of the invention to provide an LED array and circuit which has a low peak to average current ratio.

It is still another object of the invention to provide an LED array and circuit which has current regulation for voltage variations from 80-134 volts.

It is also an object of the invention to provide an LED array and circuit which has a relatively constant light output regardless of ambient temperature.

It is another object of the invention to provide an LED array and circuit which is tolerant to the failure of individual LEDs.

It is a further object of the invention to provide an LED array and circuit which tolerates individual LED failures regardless of whether the failure is a short failure or an open failure.

It is still another object of the invention to provide an LED array and circuit which will not interfere with emergency vehicle remote control of traffic signals.

In accord with these objects which will be discussed in detail below, the LED array circuit of the present invention includes a number of series connected LED pairs, each pair including two parallel connected oppositely polarized LEDs, which are coupled to a standard AC voltage source by an inductor which is arranged in series between the AC voltage source and the LED array. The inductor is preferably provided with a Q>5 and a reactance which is equivalent to the resistance of a current generator or current limiting resistor. The use of an inductor in place of a resistor increases the efficiency of the array circuit to approximately 80% if the inductor is properly chosen. The efficiency of the array circuit is increased even further by coupling a capacitor in parallel to the array, thereby generating an impedance converter which converts an AC voltage source into a high impedance AC current source. By tuning the inductor and capacitor of the impedance converter to the frequency of the AC voltage source, the efficiency of the array is greater than 80%. Moreover, when the capacitor is included in the circuit, the power factor of the circuit is improved, non-linearity of the circuit is diluted, the impedance of the source is increased, and the LED array may include a large number of LEDs (e.g., forty pairs or more). In fact, so many LEDs may be included in the array such that the voltage drop across the array is greater than the AC line peak voltage itself.

According to a preferred embodiment of the invention, the LED array and circuit are mounted on a circuit board which is connected by spacers to a clear circular disk. The disk is

dimensioned to take the place of a standard traffic signal filter/lens. This embodiment is retro-fitted to an existing traffic signal by removing the bulb, reflector, and filter/lens from the traffic signal and mounting the clear circular disk in place of the filter. Alternatively, and in accord with another embodiment of the invention, a single retro-fittable unit is provided wherein an inductor, a capacitor, and an array of LEDs are contained in a housing having substantially the same size and shape as a standard incandescent bulb used in a traffic signal display. According to yet another embodiment of the invention, a plurality of individually switched arrays are contained in a single module where a first terminal of each array is coupled to a common point which is series connected through a single inductor to the AC voltage source, and a separate capacitor is coupled parallel to each array. The second terminal of each array is coupled through a respective individual switch to the AC voltage source. The second embodiment provides a module for several independently operable mutually exclusive displays.

Other embodiments of the invention include circuits which have improved power factors, LED arrays which tolerate the failure of individual arrays regardless of whether the failure is a short or open, circuits which compensate for the effects of temperature on LED luminance, circuits which regulate the current through the LED array as line voltage varies, circuits which balance the peak to average current ratio through the LED arrays, circuits which minimize harmonic distortion, and circuits which minimize the possibility of interference with emergency remote control of traffic signals. Further, according to the invention, circuits are provided for switching the current applied to LED arrays according to a plurality of parameters such as ambient temperature, ambient light, voltage, etc.

Additional objects and advantages of the invention will become apparent to those skilled in the art upon reference to the detailed description taken in conjunction with the provided figures.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a schematic diagram of a prior art LED array circuit using a transformed and rectified power supply with LEDs coupled in parallel;

Figure 2 is a schematic diagram of a prior art LED array circuit using a filtered and rectified power supply with LEDs coupled in series with a current limiting resistor;

Figure 3 is a schematic diagram of a prior art LED array circuit with oppositely polarized series connected LEDs coupled in series with a current limiting resistor;

Figure 4 is a schematic diagram of a first embodiment of an LED array circuit according to the invention;

Figure 5 is a schematic diagram of a second embodiment of an LED array circuit according to the invention;

Figure 6 is a partially transparent side elevation view of a housing for the LED array circuit of Figure 5 which is adapted for retro-fitting in an existing traffic signal display;

Figure 7 is a cross sectional schematic view of a prior art traffic signal display having an incandescent bulb, a reflector, and a colored filter/lens;

Figure 8 is a side elevation schematic view of an LED array according to the invention mounted on a circular disk for retro-fitting in an existing traffic signal display;

Figure 9 is a cross sectional view similar to Figure 7 showing the LED array of Figure 8 installed in an existing traffic signal display;

Figure 10 is a schematic diagram of a third embodiment of an LED array circuit according to the invention;

Figure 11 is a schematic diagram of an LED array circuit similar to Figure 4 but having a higher power factor than other embodiments;

Figure 12 is a schematic diagram of a portion of an LED array which is protected against the failure of individual LEDs;

Figure 13 is a schematic diagram of a series circuit for temperature compensation;

Figure 14 is a schematic diagram of a series circuit for current regulation;

Figure 15 is a schematic diagram of an enhanced series circuit for current regulation and balancing;

Figure 16 is a schematic diagram of a circuit for temperature compensation, current regulation, and balancing;

Figure 17 is a schematic diagram of an LED array circuit similar to Figure 5 but having a higher power factor;

Figure 18 is a schematic diagram similar to Figure 5 but with temperature compensation;

Figure 19 is a schematic diagram similar to Figure 5 but which provides higher current and lower voltage for parallel LED arrays;

Figure 20 is a schematic diagram of a series LED array with a full wave rectifier and filter capacitor for use with the L-C circuit power supply according to the invention;

Figure 21 is a schematic diagram similar to Figure 20 but showing groups of LEDs protected against the failure of individual LEDs;

Figure 22 is a schematic diagram similar to Figure 21 but with a circuit for temperature compensation and current regulation;

Figure 23 is a schematic diagram of a circuit including several series LED arrays coupled to each other in parallel, each having a current sharing impedance;

Figure 24 is a schematic diagram of a current sharing impedance for use in the circuit of Figure 23;

Figure 25 is a schematic diagram of a current sharing impedance for use in the circuit of Figure 23;

Figure 26 is a schematic diagram of dual series LED arrays having an electronic balancing circuit;

Figure 27 is a schematic diagram similar to Figure 26 but with a circuit for temperature compensation and current regulation;

Figure 28 is a schematic diagram similar to Figure 5 but with the locations of the inductor and capacitor interchanged;

Figure 29 is a schematic diagram similar to Figure 28 but with a tapped inductor;

Figure 30 is a schematic diagram of a circuit for switching a pair of LED arrays to provide a brighter or dimmer output;

Figure 31 is a schematic diagram of a circuit for automatically switching the circuit of Figure 30;

Figure 32 is a schematic diagram of a lossless resonant synchronous boost regulator circuit; and

Figure 33 is a schematic diagram of an LED array circuit and a separate switching circuit for controlling the light output of the array according to a plurality of parameters.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to Figure 4, a first embodiment of an LED array circuit 30 according to the invention includes an array of LEDs 31 arranged as a plurality of LED pairs 32, and an inductor L. The LED pairs 32 each include two parallel coupled LEDs 32a, 32b which are oppositely polarized. The LED pairs 32 are coupled to each other in series to form the LED array 31. A first terminal or node 33 of the array is coupled to an AC voltage source 34 through the series connected inductor L, with the second terminal or node 35 of the array 31 coupled to the AC voltage source through a switch 36. It will be appreciated that the switch 36 shown in Figure 4 is merely representative of some type of switching circuit and in practice will likely be part of a traffic signal controller. It will also be understood that the connection of the circuit 30 to the AC voltage source 34 is preferably a removable connection as represented in Figure 4 by removable couplings 37 and 39. According to the invention, the inductor L is chosen to have a reactance equivalent to the resistance of a current generator or current limiting resistor and to have Q>5. The use of inductor L with the array 30 produces an efficiency of about 80% and achieves all of the advantages of LED arrays without suffering the disadvantages of the current limiting resistor of the prior art.

It will be appreciated that during one half cycle of the AC voltage source, one of the LEDs in each pair will light and during the other half cycle, the other LED in each pair will light. One of the advantages of arranging the LEDs as shown (i.e. in parallel oppositely polarized pairs which are series connected) is that if an LED faults either closed (short) or open, only that LED or one LED pair will be disabled. That is, if an LED shorts, all of the remaining LEDs will continue to function except for the one which is paired with the shorted LED and which will be shorted thereby. If, on the other hand, a red LED faults open, the LED which is paired with it

will be forced to conduct reverse voltage during the half cycle in which the open faulted LED would have lit.

Those skilled in the art should appreciate that the circuit of Figure 4 exhibits non-linear characteristics and that the most important factor in powering the LEDs is the average current which flows through the array of LEDs. If the voltage drop across the LED array is small relative to the peak line voltage, the current through the array is substantially related to the RMS short circuit current I_{SC} through the inductor L which is expressed below according to the approximation:

$$I_{SC} \approx \frac{V}{Z_L} \tag{1}$$

where V is the RMS line voltage and Z_L is the impedance of the inductor L. Since it is the average current rather than the RMS current which is of importance to the LEDs, the average short circuit current $I_{SC(AVG)}$ through the inductor L over one complete AC cycle is expressed according to approximation:

$$I_{SC(AVG)} \approx \left(\frac{2\sqrt{2}}{\pi}\right) I_{SC} \tag{2}$$

It will also be appreciated that the impedance Z_L of the inductor L is a complex number related to its inductance L by:

$$Z_L = |j2\pi FL| \tag{3}$$

where F is the AC line frequency and j is the square root of (-1). By combining the above approximations (1) and (2) and equation (3), the average short circuit current through the inductor L can be expressed according to:

$$I_{SC(AVG)} \approx \left(\frac{2\sqrt{2}}{\pi}\right)\left(\frac{V}{|j2\pi FL|}\right) \approx \frac{V\sqrt{2}}{\pi^2 FL} \tag{4}$$

Since each LED is ON for a half cycle and OFF for a half cycle, the average current through current $I_{LED(AVG)}$ through the array during each half cycle will be substantially equal to one half the average short circuit current $I_{SC(AVG)}$ through the inductor L so long as the voltage drop across the LED array is relatively small compared to the peak AC line voltage. For example, utilizing the relationship (4) above with an AC source of 120 V RMS at 60 Hz, an appropriate average current of approximately 24 ma through an array of approximately twenty LEDs every half cycle can be controlled by an inductor L having an inductance of 6 Henries.

The inductor L will maintain an appropriate average current through the array so long as the voltage drop across the array is relatively small as compared to the peak AC line voltage.

The efficiency, power factor, and control of current in the circuit of Figure 4 can be further enhanced by the addition of a capacitor C as shown in Figure 5. The circuit 30a of Figure 5 is substantially the same as that in Figure 4, but with the addition of capacitor C which is coupled in parallel to the LED array 31 across the terminals 33 and 35. In this circuit, the inductance of the inductor L is preferably chosen according to the relationship (4) given above. The L-C circuit shown in Figure 5 is not a filter circuit but is an impedance converter which effectively converts the AC voltage source into a high impedance AC current source when the L-C circuit is tuned to the frequency of the AC source according to approximation:

$$F \approx \frac{1}{2\pi\sqrt{LC}} \tag{5}$$

Thus, the value of the capacitor C is preferably chosen according to the approximation:

$$C \approx \frac{1}{(2\pi F)^2 L} \tag{6}$$

with a frequency of 60 Hz, and an inductor of approximately 6 Henries, the desired capacitance would be approximately 1μF. This arrangement effectively increases the current generator impedance Z_g of the circuit by a factor of Q such that $|Z_g| \approx QX_L$, with X_L being the reactance of the inductor L. It also increases the open circuit voltage V_{DC} by a factor of Q so that $V_{DC} \approx QV$. The AC voltage source therefore appears to the LED array as a current source even when the voltage drop across the array is comparable to the peak AC line voltage. Because of the high current generator impedance, the same tuned circuit can tolerate a wide range in the number and types of LED pairs without materially affecting the LED current. Thus, a standard tuned circuit can be used with many different types of LED arrays. Moreover, in principle, the tuned circuit can generate a voltage across the LED array which may be greater than the AC line voltage. Therefore, a very large number of LEDs can be used in the array. Indeed, in a preferred embodiment of the invention, forty or more pairs of LEDs are utilized. It should be noted that the inductor L, when used in the AC powered circuits described above, provides high impedance without energy wasting resistance.

Referring now to Figure 6, those skilled in the art will appreciate that the LED array 31, the inductor L and the capacitor C can be mounted in a housing 40 having the same size and shape as a conventional incandescent bulb with a conventional base connector 42. In this manner, the array is easily retro-fitted to existing traffic signal displays which utilize this type of fixture.

The invention may be easily adapted to replace incandescent lighting in virtually any kind of traffic signal display unit. Figure 7 shows a popular existing traffic signal display 50 having a weather tight enclosure or casing 52 which contains an incandescent bulb 54 and a parabolic reflector 56. The inside of the enclosure 52 is accessible via a hinged door 58 which carries a colored lens/filter 60 (e.g. red, yellow, or green) fitted to an opening in the door with a grommet 62. The bulb 54 is held in a socket 64 which is electrically coupled to a voltage source (not shown) via a quick connect block 66. The bulb 54, reflector 56, socket 64 and attached wires are also hinged to the enclosure 52. Thus the interior elements of the display 50 are all easily accessible and replaceable.

According to a preferred embodiment of the invention, and as shown in Figures 8 and 9, an LED array 31 is mounted on one side of a circuit board 70 which is provided with circuit traces and elements 72 on its other side. The circuit elements and traces may include the inductor L, the capacitor C, and the connections of the array 31 as described with reference to Figures 4 and 5 above. The circuit board 70 is coupled to a clear plastic disk 74 by a number of spacers 76 so that the LEDs 32 in the array 31 face the disk 74 as seen best in Figure 9. Preferably, both the disk 74 and the circuit board 70 are circular. The disk 72 is fitted with a grommet 62 which is substantially the same as the grommet 62 used to hold the filter/lens 60 in the prior art display 50 described above. The prior art display 50 of Figure 7 is modified by removing the lens/filter 60 with its grommet 62 and by removing the bulb 54, reflector 56, and socket 64. The disk 74 with its grommet 62 is fitted into the opening in the hinged door 53 and the circuit 72 is electrically coupled to the quick connect block 66. It has been found that the portion of the circuit board 70 which faces the disk 74 should be painted black before mounting the LEDs 32. This prevents unwanted reflection off the circuit board during bright daylight hours. It will be appreciated that the circuit 72 need not be mounted on the circuit board 70. All or part of the circuit 72 could be mounted off the board 70 inside the enclosure 52. As a practical matter, it may be advantageous to mount all of the circuit except for the inductor L on the circuit board 70 and mount the inductor L inside the enclosure 52

Figure 10 shows a circuit 30b utilizing multiple LED arrays according to the invention. LED arrays 31a, 31b, 31c, each of which are substantially the same as the LED array 31 shown in Figure 5, are coupled by their first terminals 33a-33c to the AC voltage source 34 through a common inductor L and are coupled by their second terminals 35a-35c through individual respective switches 36a-36c to the AC voltage source. Capacitors C_a, C_b, C_c are respectively coupled in parallel to each array 31a, 31b, 31c across their respective terminals. The circuit shown in Figure 10 assumes that each array is operated in mutual exclusivity so that the L-C circuit as described above operates in the same manner in this circuit when each array is turned

on. This type of circuit is well suited for a multiple display traffic signal. For example, if the LEDs in array 31a are all red light emitting, the LEDs in array 31b are all yellow light emitting, and the LEDs in array 31c are all green light emitting, the circuit is well suited for use in a red, yellow, and green traffic light where only one LED array is turned on at any given time. Using the circuit of Figure 10, a single inductor L can be shared by all of the LED arrays, thereby reducing the cost of the traffic signal display unit.

Figure 11 illustrates an improvement to the circuit of Figure 4 through the addition of an R-C network which increases the power factor. The circuit 130 of Figure 11 is similar to the circuit 30 described above with similar reference numerals (increased by 100 referring to similar parts. The series R-C network across nodes 137, 139 provides two benefits. The value of C can be chosen so that the power factor is greater than 0.9. In particular, C can be chosen to have a reactance similar to the reactance of the remainder of the circuit. The value of R, chosen in conjunction with C, can be chosen so that the R-C network protects the contacts of the switch 136 against arcing.

Figure 12 illustrates an LED module 232 containing four LED pairs 232-1, 232-2, 232-3, 232-4 protected by a pair of Zener diodes Z_a, Z_b. The Zener voltage (V_Z) of each diodes Z_a, Z_b is nominally the same the other. The sum of the Zener voltage (V_Z) of either Zener and the forward threshold of either Zener (V_d) is chosen to be just greater than the peak voltage across the LED pairs. Four LED pairs are shown for example. In practice, m number of LED pairs may be used.

During normal operation, the peak voltage drop (mV_f) across the group of m pairs of LEDs is less than V_Z+V_d and the protective Zener pair Z_A, Z_B do not conduct and are not stressed. If an LED shorts, the protection Zeners are not called into play and the operation is as previously described, except for the loss of light from the pair which includes the shorted LED.

If an LED fails open (e.g. 232-1a) light is lost from all the "a" LEDs in the group of m LED pairs and all of the "b" LEDs in the group still light. The function of the protective Zeners is to limit the voltage drop across the group in the "a" direction to slightly more than the normal mV_f. This excess voltage is readily limited to about 2 volts. The limiting of the difference of voltage drops in opposite directions reduces the DC bias stress on the inductor so that continued operation in this failed mode is practical.

The module 232 is preferably utilized with additional identical modules coupled to each other in series and to an inductor or L-C power supply described above. According to another aspect of the invention, a series circuit is added in series between the LED modules and the

power supply to improve the balance of current flowing in the "a" and "b" directions whether under normal or fault conditions. Figures 13-15 illustrate examples of this type of series circuit.

Figure 13 illustrates a series circuit 241 consisting of a negative temperature coefficient resistor R_{ntc}. The proper choice of the value and temperature coefficient of this resistor can reduce the temperature effect on light output from more than 3 to 1 to less than 1.5 to 1. The value of the resistor may be chosen empirically or with the aid of a graphing function.

Figure 14 shows a series circuit 341 which consists of an incandescent lamp "B". The lamp preferably has a current rating which is at least four times the current which will flow through it. Incandescent lamps increase their effective resistance rapidly as the operating current increases from zero to normal operating conditions. Resistance typically increases by a factor of 2.8 to 1 from 25% to 100% operating current. The benefit of this circuit, at the loss of some efficiency, is improved current regulation with line voltage variations and improved current balance in the "a" and "b" directions under both normal and fault conditions.

Figure 15 shows a series circuit which consists of two incandescent lamps B_a, B_b and two steering diodes D_a, D_b. In this circuit bulb B_a only responds to the current in the "a" LED direction and the B_b lamp only responds to the current in the "b" LED direction. In addition to the benefits of the circuit of Figure 14, this configuration improves the balance of current in the "a" and "b" directions. In order that the life expectancy of the incandescent lamps not materially affect the overall reliability of the overall circuit, the lamps should be operated well below their normal operational conditions.

Figure 16 illustrates an active electronic means for providing the functions of current regulation, current balancing, and temperature compensation at the same time. The basic principle of operation is to sense the current through the LED array 232 and shunt excess current around the array. Shown are two separate shunt regulators, one that senses the current when the "a" LEDs are conducting and one that senses the current when the "b" LEDs are conducting.

The "a" shunt regulator includes resistor R_{SIa}, Zener diode Z_a, transistor Q_a, current drawing resistor R_a, and switching diodes D_{a1}, D_{a2}. The "b" shunt regulator includes resistor R_{SIb}, Zener diode Z_b, transistor Q_b, current drawing resistor R_b, and switching diodes D_{b1}, D_{b2}.

The values of the resistor R_{SIa} is chosen so that when the current in the "a" LEDs exceeds the appropriate value, the voltage across R_{SIa} exceeds the sum of the Zener voltage of Z_a and the base emitter threshold voltage of Q_a, which causes Q_a to turn on thereby by-passing some of the input current around the array through the current drawing resistor R_a. The value of the resistor R_{SIb} is chosen in the same way with respect to the "b" LEDs. The switching diodes D_{a1}, D_{a2} remove the "a" regulator from the circuit when the "b" regulator is functioning and the switching diodes D_{b1}, D_{b2} remove the "b" regulator from the circuit when the "a" regulator is functioning. By incorporating an appropriate temperature sensitive resistance (negative TC) as part of R_{SIa} or R_{SIb}, temperature compensation will be accomplished. Illustratively, if R_{SIa} increases in value as ambient temperature goes down, by-pass current will start at a lower LED current as temperature decreases.

Figure 17 illustrates an improvement to the circuit of Figure 5 through the addition of an R-C network R and C_1 which is parallel to the L-C circuit and which increases the power factor. The circuit 130a of Figure 17 is similar to the circuit 30a (Figure 5) described above with similar reference numerals (increased by 100) referring to similar parts. The series R-C network across nodes 137, 139 provides two benefits. The value of C_1 can be chosen so that the power factor is greater than 0.9. The value of R, chosen in conjunction with C_1, can be chosen so that the R-C network protects the contacts of the switch 136 against arcing.

Figure 18 illustrates a circuit similar to the circuit 30a (Figure 5) described above with similar reference numerals (increased by 200) referring to similar parts. This circuit 230a differs from the circuit 30a by the inclusion of a negative temperature coefficient resistor R_{NTC} in series between node 237 and the inductor L. The resistor R_{NTC} changes resistance in response to changes in temperature and thereby compensates for the sensitivity of LEDs to temperature.

Figure 19 illustrates a circuit similar to the circuit 30a (Figure 5) described above with similar reference numerals (increased by 300) referring to similar parts. This circuit 330a differs from the circuit 30a by the inclusion of a step-down autotransformer L_P across the nodes 333, 335. The inductance of transformer L_P is preferably greater than or equal to four times the inductance of inductor L and the tap coefficient (k) is preferably less than 1.0. This circuit provides, across nodes 333', 335', a lower voltage and a higher current than provided by the circuit 30a across nodes 33, 35. In particular, the circuit increases the short circuit current by a factor 1/k and decreases the open circuit voltage by the factor k. This circuit is useful for powering an LED array which requires more current and less voltage, e.g. a parallel array.

Figure 20 illustrates a circuit 331 which can replace the LED array 31, 131, 231 described above. The circuit 331 includes a series LED array 332, a full wave rectifier D_1-D_4 and a filtering capacitor C_F. The advantages of using this circuit in conjunction with the L or L-C power supply of the invention are several. The peak to average current ratio approaches 1.0 and light modulation (flicker) is significantly reduced. More complex series-parallel arrays can be used such as those described below with reference to Figures 23, 26, and 27. DC current issues do not exist for the inductor. Since current is only flowing in one direction it is not necessary to balance the current flow in opposite direction.

Figure 21 illustrates a circuit similar to the circuit illustrated in Figure 20 but with improved failure performance. The LED array 432 includes "n" groups of "m" series connected LEDs. Each group of "m" LEDs has a parallel connected Zener diode Z_a which conducts if one of the LEDs in the group should fail open.

Figure 22 illustrates a circuit similar to the circuit illustrated in Figure 21 but with a shunt regulator similar to those described above with reference to Figure 16. The shunt regulator includes resistors R_1, R_{SA}, transistor Q_1, and Zener diode Z_b. The shunt regulator provides current regulation and temperature compensation as described above.

Those skilled in the art will appreciate that in an array of series connected LEDs the current is the same in all the LEDs. In an array of parallel connected LEDs, the current in each LED differs. Generally, the series connected array is preferable but for the need to protect the array from an open failed LED. Figure 23 illustrates a complex array of "m" series arrays coupled in parallel. As shown in Figure 23, each series array 632-1 through 632-n is provided with a sharing impedance 641-1 through 641-n. The sharing impedance is preferably comparable to the total dynamic impedance of the array alone. Figures 24 and 25 illustrate that the sharing impedance 641 may be either a resistor 641' or an incandescent lamp 641". The non-linear characteristics of the lamp produces better balance and more efficiency than the resistor.

Figure 26 illustrates a circuit 731 similar to the circuit 631 described above, but with an electronic current balancing circuit for balancing two series LED arrays 732-1 and 732-2 which are coupled parallel to each other. The current balancing circuit includes seven resistors R_1-R_6, R_C and two transistors Q_1, Q_2 which form a differential current steering circuit. In normal operation, the current through resistors R_1, R_C, and R_2 is equal. If an LED in the array 732-1 fails open, the voltage across resistor R_1 will drop lower than the voltage across the resistor R_2. A higher dynamic impedance is created at the node of R_5 and the collector of Q_2 than the sum of R_1 and R_5. This causes the differential transistors Q_1, Q_2 to steer more of the current

through the resistor R_C to the array 732-1 and less to the array 732-2. The circuit 731 provides excellent balance and efficiency.

Figure 27 illustrates a circuit 731a which is substantially the same as circuit 731 with the addition of a shunt regulator such as described above with reference to Figures 16 and 22. The shunt regulator includes resistors R_{SA}, R_7, transistor Q_3 and Zener diode Z. In addition, the circuit 731a optionally includes a negative temperature compensation resistor R_{NTC}.

Figure 28 illustrates a circuit 830 which is similar to the circuit 30a of Figure 5 but with the location of the inductor L and capacitor C interchanged. Circuit 830 is not as preferred as embodiment as the circuit 30a has a better power factor and lower harmonic distortion. However, one advantage of circuit 830 is that the exciting voltage of the inductor is limited to the LED array voltage which may allow the inductor to be smaller and cheaper. Another advantage of interchanging the locations of the inductor and capacitor is illustrated in Figure 29.

Figure 29 illustrates a circuit 830a which is substantially the same as the circuit 830 but where the inductor L is provided with a tap to provide the function of a step down autotransformer as described above with reference to Figure 19 without the addition of an additional component.

Figure 30 illustrates a pair of LED arrays 932-1, 932-2, each having an associated series circuit 941-1, 941-2, and a double pole double throw switch 951 controlled by unit 953. The switch 951 changes the circuit arrangement so that the LED arrays may be arranged in series or in parallel (shown). The average current through individual LEDs when the arrays are in series is approximately twice current through individual LEDs when the arrays are in parallel. Thus, the total light output of the two arrays is either doubled or halved by toggling the switch 951. According to the invention, the switching unit 953 may be used to compensate for temperature or may be used to dim the LEDs at night. Figure 31 shows a controller unit 953' which includes a relay 955 and a photocell 957 designed to dim the LEDs at night. It will be appreciated that the photocell 957 is provided with a filter (not shown) which filters out the wavelength of the LEDs.

Figure 32 shows a circuit 1030 which is similar to the circuit shown in Figure 21 having an inductor L, a capacitor C, a series LED array 1032 with a full wave rectifier D_1-D_4, and a filter capacitor C_F. The circuit 1030 also includes an LED array current sensor and controller 1059, a zero crossing detector 1061, and an opto relay 1063. Those skilled in the art will appreciate that at the time the voltage across the capacitor C is crossing zero, the current

stored in the inductor L is near its peak and is about to be passed into the load. The circuit of Figure 32 causes the voltage across the capacitor to be momentarily held at zero after the zero crossing instant. This causes the inductor to be charged with a higher current than it would otherwise thereby delivering more current (power) to the load. The LED current sensor and controller 1059 measures the difference between the desired average current and the actual average current. A voltage proportional to the difference is stored on a capacitor (not shown). At the time that the zero crossing is indicated by the detector 1061, the controller 1059 generates a pulse having a length proportional to the aforementioned stored voltage. (Below some threshold, no pulse is generated.) The pulse is used to activate the opto relay 1063 which shorts the capacitor C for the duration of the pulse. Since the relay shorts the capacitor when the energy in it is zero, this circuit is in principle lossless.

Figure 33 illustrates a system according to the invention having a separate LED circuit 1130 and traffic light controller circuit 1170. The LED circuit 1130 may be any of the circuits previously described. The controller circuit 1170 includes a triac 1172 which is controlled by a controller 1174 in response to inputs 1176, 1178, 1180. The inputs 1176, 1178, 1180 may include a temperature sensor, a voltage sensor, a photocell, etc. The triac and controller, therefore, control the brightness of the LED array as well as whether it is on or off. Those skilled in the art will appreciate that a similar triac and controller could be located in the LED assembly 1130, rather than at the traffic controller location, to provide appropriate dimming of the LED array while the traffic controller only controls whether the array is on or off.

There have been described and illustrated herein several embodiments of an AC powered LED array and circuits associated with it. While particular embodiments of the invention have been described, it is not intended that the invention be limited thereto, as it is intended that the invention be as broad in scope as the art will allow and that the specification be read likewise. Thus, while particular configurations have been disclosed in reference to a housing for the LED array and associated circuits, it will be appreciated that other configurations could be used as well. Furthermore, while the circuit of the invention has been described with reference to traffic signal displays, it will be appreciated that the circuit is useful in any AC powered illumination apparatus, including, but not limited to illuminated safety displays such as fire alarm indicators, exit signs, airport and shipping displays, etc. It will therefore be appreciated by those skilled in the art that yet other modifications could be made to the provided invention without deviating from its spirit and scope as so claimed.

Claims:

1. An LED array circuit powered by a substantially sinusoidal AC voltage source of known frequency, comprising:

a) a first set of LEDs arranged as a first plurality of LED pairs, each LED pair comprising two oppositely polarized LEDs coupled to each other in parallel, and each LED pair being series connected to another LED pair, said first set of LEDs having first and second terminal nodes, coupled to and across the substantially sinusoidal AC voltage source;

b) an inductor arranged in series with and coupling one of said first and second terminal nodes to the substantially sinusoidal AC voltage source, said inductor having a Q value and reactance chosen for improved power efficiency; and

c) a first capacitor coupled in parallel to said first set of LEDs at said first and second terminal nodes, wherein said inductor and said first capacitor form an impedance converter circuit which is tuned to the known frequency of the substantially sinusoidal AC voltage source thereby effectively converting the AC voltage source into substantially an AC current source, said substantially AC current source with said first set of LEDs providing said circuit with improved power efficiency.

2. A circuit according to claim 1, wherein:

said inductor has a Q greater than five.

3. A circuit according to claim 1, wherein:

said first set of LEDs comprises at least forty LEDs.

4. A circuit according to claim 1, wherein:

the values of said inductor and said first capacitor are chosen according to the approximate relationship $F \approx \frac{1}{2\pi\sqrt{LC}}$,

where F is the frequency of the substantially sinusoidal AC voltage source, L is the value of said inductor, and C is the value of said first capacitor.

5. A circuit according to claim 1, further comprising:

d) a second plurality of LED pairs, each second plurality of LED pairs comprising two oppositely polarized LEDs, said second plurality of LED pairs being coupled to each other in series to form a second set of series connected LEDs having two terminal nodes coupled to and across the substantially sinusoidal AC voltage source, one of said two terminal nodes of the second plurality of series connected LEDs being coupled to the substantially sinusoidal AC voltage source by said inductor.

6. A circuit according to claim 5, further comprising:

e) a first switch means for coupling said first set of series connected LEDs to the substantially sinusoidal AC voltage source; and

f) a second switch means for coupling said second set of series connected LEDs to the substantially sinusoidal AC voltage source.

7. A circuit according to claim 1, further comprising:

d) a second plurality of LED pairs, each pair of said second plurality of LED pairs comprising two oppositely polarized LEDs, said second plurality of LED pairs being coupled to each other in series to form a second set of series connected LEDs having two terminal nodes coupled to and across said substantially sinusoidal AC voltage source, with one of said terminal nodes being coupled by said inductor to the substantially sinusoidal AC voltage source; and

e) a second capacitor coupled in parallel with said second set of series connected LEDs.

8. A circuit according to claim 7, further comprising:

f) a first switch means for coupling said first set of series connected LEDs to the substantially sinusoidal AC voltage source; and

g) a second switch means for coupling said second set of series connected LEDs to the substantially sinusoidal AC voltage source.

9. A circuit according to claim 1, wherein:

said first set of series connected LEDs are mounted on one side of a substantially circular circuit board, and

said substantially circular circuit board is attached to a substantially circular clear plastic disk with spacers such that said first plurality of series connected LEDs face said clear plastic disk.

10. An LED array circuit powered by a substantially sinusoidal AC voltage source of known frequency, comprising:

a) a plurality of series connected LEDs having first and second terminal nodes, coupled to and across the substantially sinusoidal AC voltage source, said plurality of series connected LEDs comprising a plurality of LED pairs, each LED pair comprising two oppositely polarized LEDs coupled to each other in parallel, and each LED pair being series connected to another LED pair;

b) an inductor arranged in series with and coupling one of said first and second terminal nodes to the substantially sinusoidal AC voltage source; and

c) a first capacitor coupled in parallel to said plurality of series connected LEDs at said first and second terminal nodes, wherein said inductor and said first capacitor form an impedance converter circuit which is tuned to the known frequency of the substantially sinusoidal AC voltage source thereby effectively converting the AC voltage source into substantially an AC current source, wherein

said plurality of series connected LEDs comprising a number of LEDs sufficient to cause a voltage drop across said first set of LEDs to be greater than a peak voltage of the AC voltage source.

11. A circuit according to claim 10, wherein:

said inductor has a Q greater than five.

12. A circuit according to claim 10, wherein:

the values of said inductor and said first capacitor are chosen according to the approximate relationship $F \approx \frac{1}{2\pi\sqrt{LC}}$,

where F is the frequency of the substantially sinusoidal AC voltage source, L is the value of said inductor, and C is the value of said first capacitor.

13. A circuit according to claim 1, wherein:

said Q value is at least five.

14. An LED array circuit powered by a substantially sinusoidal AC voltage source of known frequency, comprising:

a) a first set of LEDs arranged as a first plurality of LED pairs, each LED pair comprising two oppositely polarized LEDs coupled to each other in parallel, and each LED pair being series connected to another LED pair, said first set of LEDs having first and second terminal nodes, coupled to and across the substantially sinusoidal AC voltage source;

b) an inductor arranged in series with and coupling one of said first and second terminal nodes to the substantially sinusoidal AC voltage source; and

c) a first capacitor coupled in parallel to said first set of LEDs at said first and second terminal nodes, wherein said inductor and said first capacitor form an impedance converter circuit which is tuned to the known frequency of the substantially sinusoidal AC voltage source thereby effectively converting the AC voltage source into substantially an AC current source, said inductor having an inductance value chosen to provide a desired current for lighting said first set of LEDs, and said inductor chosen to have a high impedance while providing energy efficiency.

15. A circuit according to claim 14, further comprising:

d) a second plurality of LED pairs, each second plurality of LED pairs comprising two oppositely polarized LEDs, said second plurality of LED pairs being coupled to each other in series to form a second set of series connected LEDs having two terminal nodes coupled to and across the substantially sinusoidal AC voltage source, one of said two terminal nodes of the second plurality of series connected LEDs being coupled to the substantially sinusoidal AC voltage source by said inductor.

16. A circuit according to claim 15, further comprising:

e) a first switch means for coupling said first set of series connected LEDs to the substantially sinusoidal AC voltage source; and

f) a second switch means for coupling said second set of series connected LEDs to the substantially sinusoidal AC voltage source.

17. A circuit according to claim 14, further comprising:

d) a second plurality of LED pairs, each pair of said second plurality of LED pairs comprising two oppositely polarized LEDs, said second plurality of LED pairs being coupled to each other in series to form a second set of series connected LEDs having two terminal nodes coupled to and across said substantially sinusoidal AC voltage source, with one of said terminal nodes being coupled by said inductor to the substantially sinusoidal AC voltage source; and

e) a second capacitor coupled in parallel with said second set of series connected LEDs.

18. A circuit according to claim 17, further comprising:

f) a first switch means for coupling said first set of series connected LEDs to the substantially sinusoidal AC voltage source; and

g) a second switch means for coupling said second set of series connected LEDs to the substantially sinusoidal AC voltage source.

19. A circuit according to claim 14, wherein:

said first set of series connected LEDs are mounted on one side of a substantially circular circuit board, and

said substantially circular circuit board is attached to a substantially circular clear plastic disk with spacers such that said first plurality of series connected LEDs face said clear plastic disk.

20. An LED array circuit powered by a substantially sinusoidal AC voltage source, comprising:

a) a first plurality of series connected LEDs having first and second terminal nodes, coupled to and across the substantially sinusoidal AC voltage source; and

b) a current limiting inductor arranged in series with and coupling one of said first and second terminal nodes to the substantially sinusoidal AC voltage source, said inductor having an inductance value chosen to provide a desired current through said LEDs, and having a Q value and reactance for improved power efficiency.

21. A circuit according to claim 20, further comprising:

c) a second plurality of series connected LEDs having two terminal nodes, one of said terminal nodes of said second plurality of LEDs being coupled to said first terminal node of said first plurality of LEDs, and the other of said terminal nodes of said second plurality of LEDs being coupled to said second of said terminal nodes of said first plurality of LEDs, such that said first plurality of LEDs are polarized in a first direction and said second plurality of LEDs are polarized in second direction opposite to said first direction.

22. A circuit according to claim 20, wherein:

said first plurality of series connected LEDs comprises a first plurality of LED pairs, each LED pair comprising two oppositely polarized LEDs coupled to each other in parallel, and each LED pair being series connected to another LED pair.

23. A circuit according to claim 22, wherein:

said inductor has a Q greater than five.

24. A circuit according to claim 20, wherein:
said inductor has a Q greater than five.

25. A circuit according to claim 22, further comprising:
c) a second plurality of LED pairs, each LED pair comprising two oppositely polarized LEDs, said second plurality of LED pairs being coupled to each other in series to form a second plurality of series connected LEDs having two terminal nodes coupled to and across the substantially sinusoidal AC voltage source, one of said two terminal nodes of the second plurality of series connected LEDs being coupled to the substantially sinusoidal AC voltage source by said inductor.

26. A circuit according to claim 25, further comprising:
d) a first switch means for coupling said first plurality of series connected LEDs to the substantially sinusoidal AC voltage source; and
e) a second switch means for coupling said second plurality of series connected LEDs to the substantially sinusoidal AC voltage source.

27. A circuit according to claim 26, further comprising:
f) a first capacitor coupled in parallel to said first plurality of series connected LEDs at said first and second terminal nodes.

28. A circuit according to claim 20, further comprising:
c) a first capacitor coupled in parallel to said first plurality of series connected LEDs at said first and second terminal nodes.

29. A circuit according to claim 20, wherein:
said first plurality of series connected LEDs are mounted on one side of a substantially circular circuit board, and
said substantially circular circuit board is attached to a substantially circular clear plastic disk with spacers such that said first plurality of series connected LEDs face said clear plastic disk.

30. A circuit according to claim 20, further comprising:
c) an R-C circuit coupled across said substantially sinusoidal AC voltage source.

31. A circuit according to claim 20, further comprising:

c) at least one Zener diode coupled in parallel with at least some of said series connected LEDs.

32. A circuit according to claim 20, further comprising:

c) a negative temperature coefficient resistor coupled in series with said first plurality of series connected LEDs.

33. A circuit according to claim 20, further comprising:

c) an incandescent lamp coupled in series with said first plurality of series connected LEDs.

34. A circuit according to claim 20, further comprising:

c) a current regulation circuit coupled in series with said first plurality of series connected LEDs.

35. A circuit according to claim 34, wherein:

said current regulation circuit comprises a first incandescent lamp, a second incandescent lamp coupled in parallel with said first incandescent lamp, a first diode coupled in series with said first incandescent lamp, and a second diode coupled in series with said second incandescent lamp, said first and second diodes being oppositely oriented.

36. A circuit according to claim 20, further comprising:

c) a current regulation circuit coupled in parallel with said first plurality of series connected LEDs.

37. A circuit according to claim 36, wherein:

said current regulation circuit includes a Zener diode and a transistor.

38. A circuit according to claim 20, further comprising:

c) a first capacitor coupled in parallel to said first plurality of series connected LEDs.

39. A circuit according to claim 38, further comprising:

d) an R-C circuit coupled across said substantially sinusoidal AC voltage source.

40. A circuit according to claim 38, further comprising:

d) a negative temperature coefficient resistor coupled in series with said first plurality of series connected LEDs.

41. A circuit according to claim 38, further comprising:

d) a full wave rectifier and a filter capacitor coupled in parallel with said first plurality of series connected LEDs.

42. A circuit according to claim 41, further comprising:

e) at least one Zener diode coupled in parallel with at least some of said series connected LEDs.

43. A circuit according to claim 38, further comprising:

d) a current regulation circuit coupled in series with said first plurality of series connected LEDs.

44. A circuit according to claim 43, wherein:

said current regulation circuit includes an incandescent lamp.

45. A circuit according to claim 43, wherein:

said current regulation circuit includes a resistor.

46. A circuit according to claim 43, wherein:

said current regulation circuit includes a transistor.

47. A circuit according to claim 38, further comprising:

d) a current regulation circuit coupled in parallel with said first plurality of series connected LEDs.

48. A circuit according to claim 47, wherein:

said current regulation circuit includes a Zener diode and a transistor.

49. A circuit according to claim 20, further comprising:

c) a brightness control circuit coupled to said first plurality of series connected LEDs.

50. A circuit according to claim 49, wherein:

said brightness control circuit includes a second plurality of series connected LEDs and a switch means coupled to said first plurality of series connected LEDs and said second plurality of series connected LEDs,

said switch means selectively coupling said first plurality of series connected LEDs and said second plurality of series connected LEDs in series or in parallel with each other.

51. A circuit according to claim 49, further comprising:

d) sensor means for sensing a first ambient condition, said sensor means coupled to said brightness control circuit such that said brightness control circuit is responsive to said first ambient condition.

52. A circuit according to claim 51, wherein:

said first ambient condition is temperature.

53. A circuit according to claim 51, wherein:

said first ambient condition is daylight.

54. A circuit according to claim 51, wherein:

said first ambient condition is the voltage value of said substantially sinusoidal voltage source.

55. A circuit according to claim 49, wherein:

said brightness control circuit includes a triac coupled in series with said first plurality of series connected LEDs.

56. A circuit according to claim 55, further comprising:

d) sensor means for sensing a first ambient condition, said sensor means coupled to said triac such that said triac is responsive to said first ambient condition.

57. A circuit according to claim 56, wherein:

said first ambient condition is temperature.

58. A circuit according to claim 56, wherein:

said first ambient condition is daylight.

59. A circuit according to claim 56, wherein:

said first ambient condition is the voltage value of said substantially sinusoidal voltage source.

60. A circuit according to claim 38, further comprising:

d) a relay coupled in parallel with said first capacitor for selectively shorting out said capacitor;

e) a zero crossing detector for detecting when the voltage through said capacitor is crossing zero, said zero crossing detector coupled to said relay for shorting out said capacitor when the voltage through said capacitor is crossing zero.

61. A circuit according to claim 60, further comprising:

f) a current sensor and controller coupled to said first plurality of series connected LEDs, coupled to said zero crossing detector, and coupled to said relay, whereby said relay is activated for a period of time in proportion to the difference between the actual average current and a desired average current.

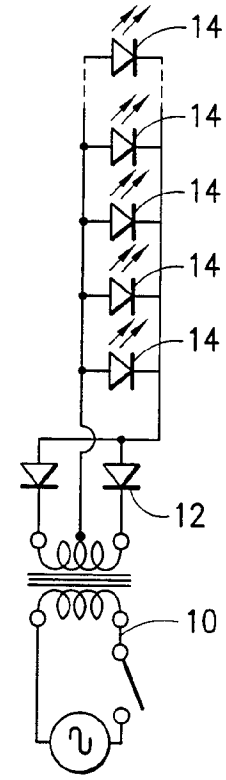


FIG.1
PRIOR ART

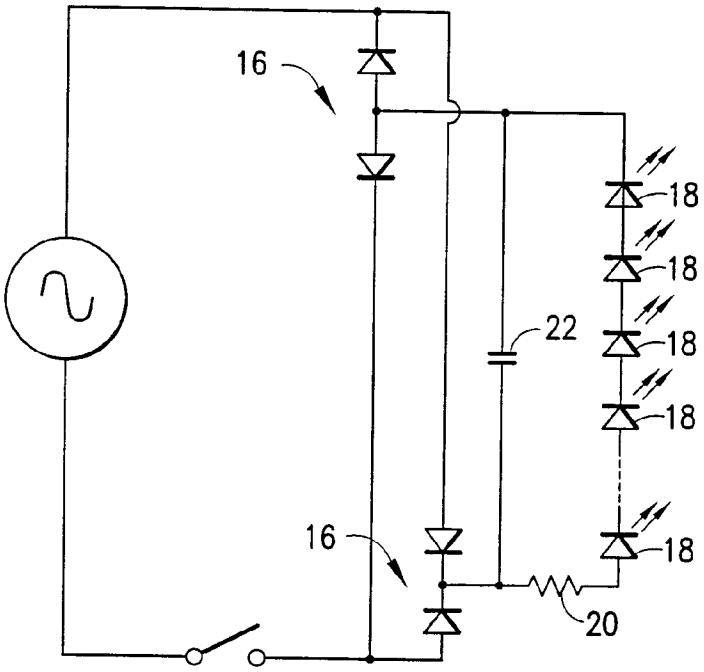


FIG.2
PRIOR ART

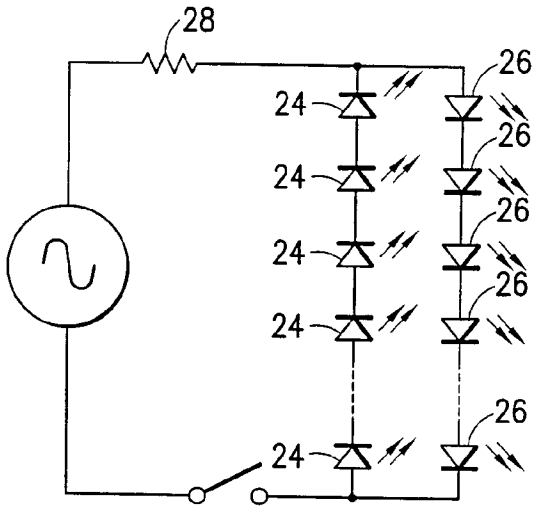


FIG.3
PRIOR ART

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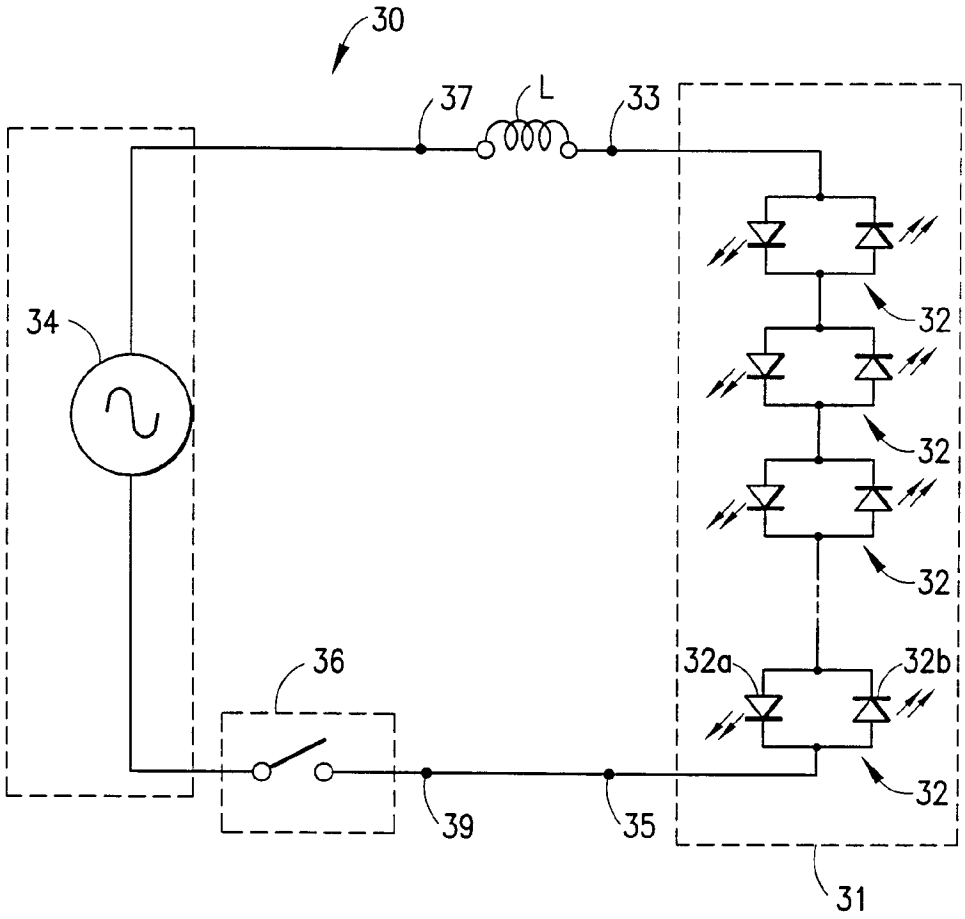


FIG.4

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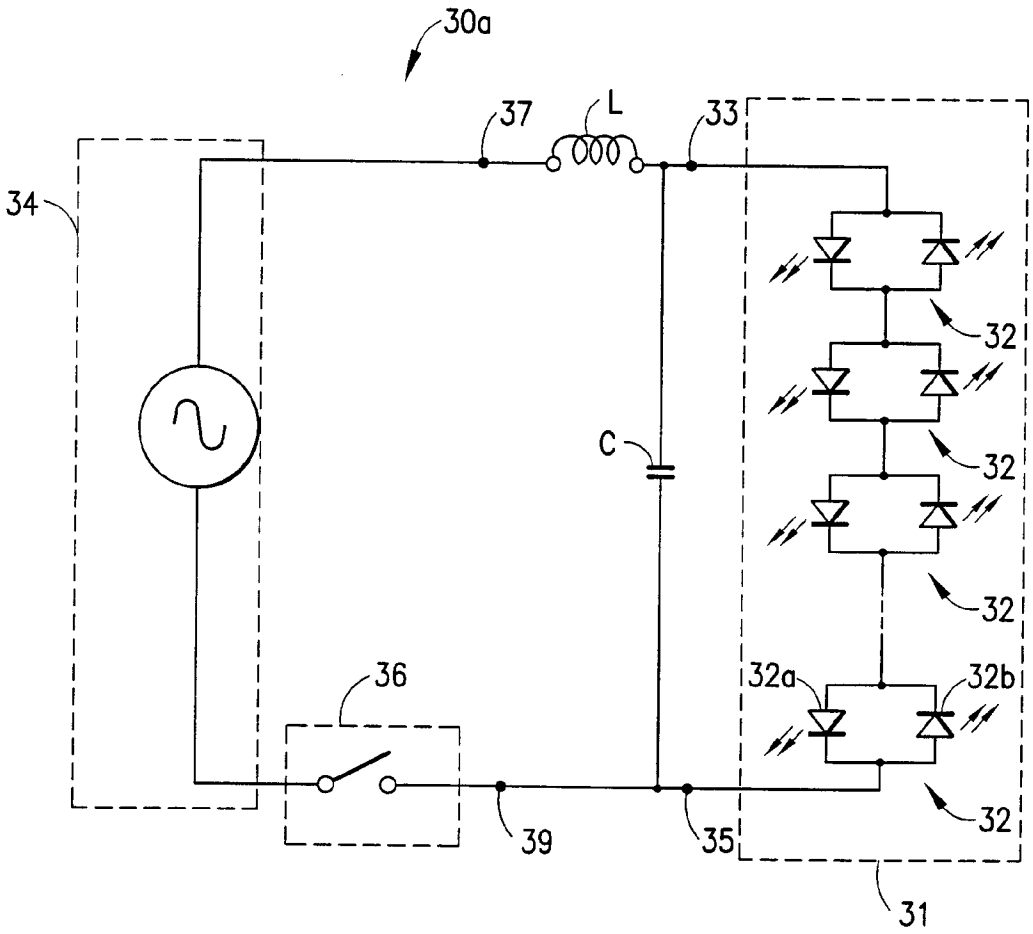


FIG.5

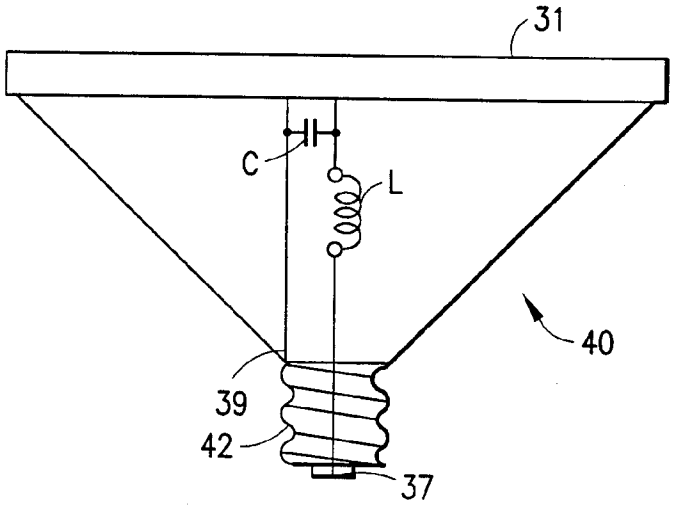


FIG.6

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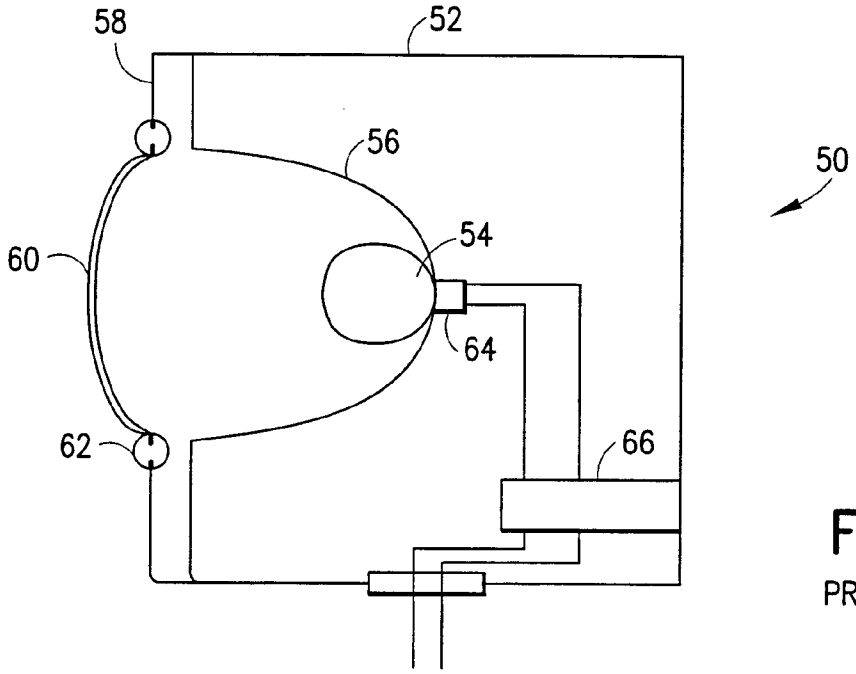


FIG.7
PRIOR ART

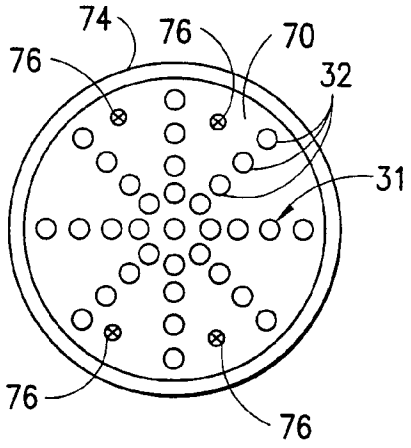


FIG.8

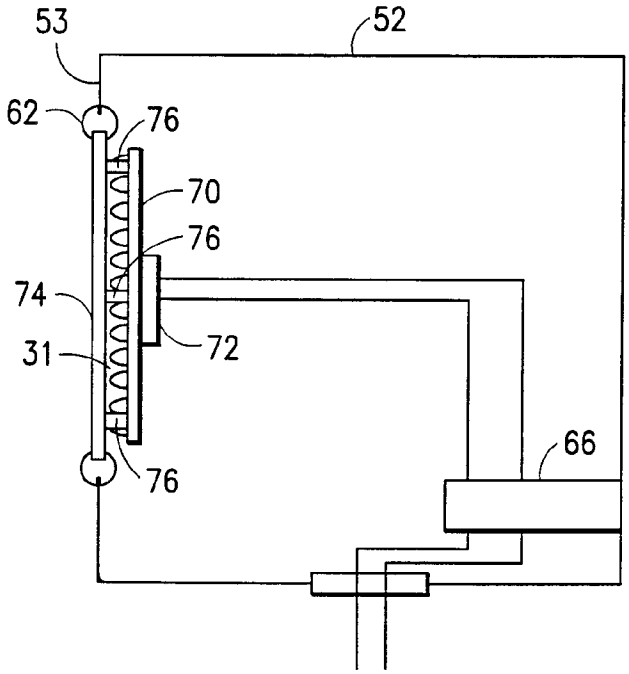


FIG.9

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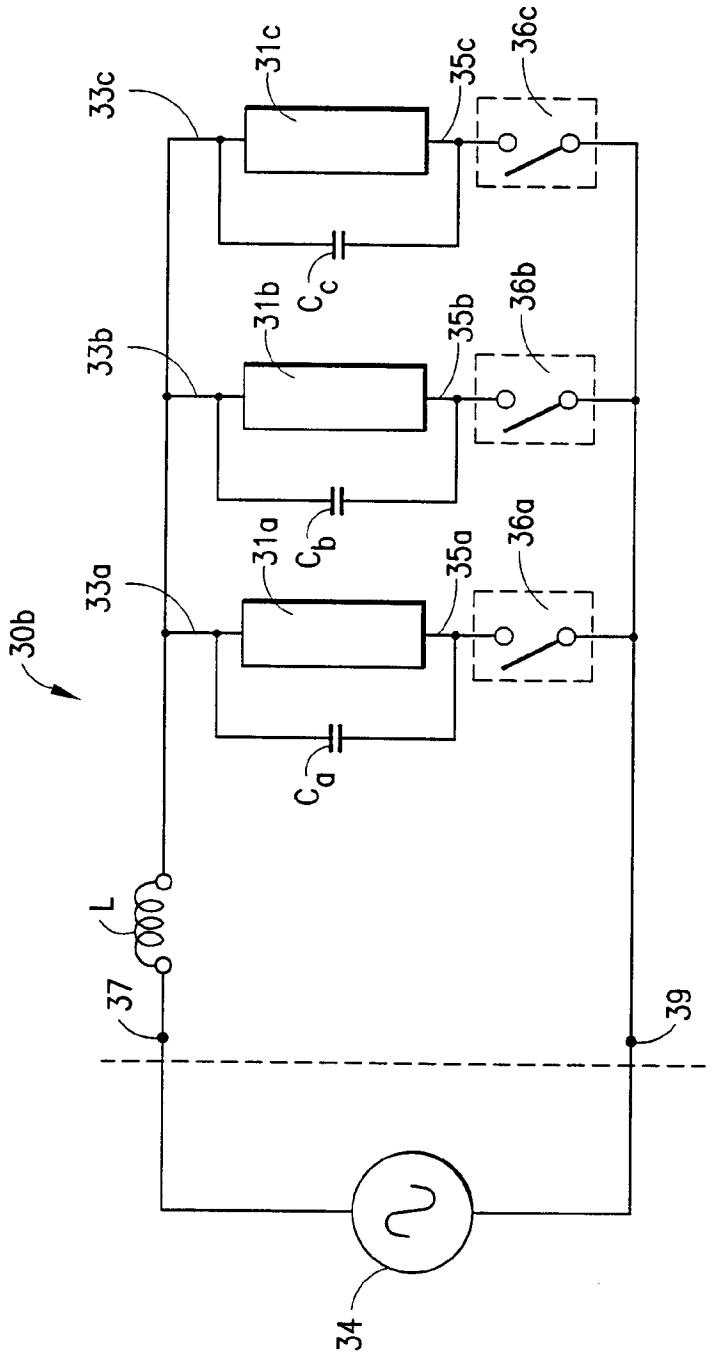


FIG.10

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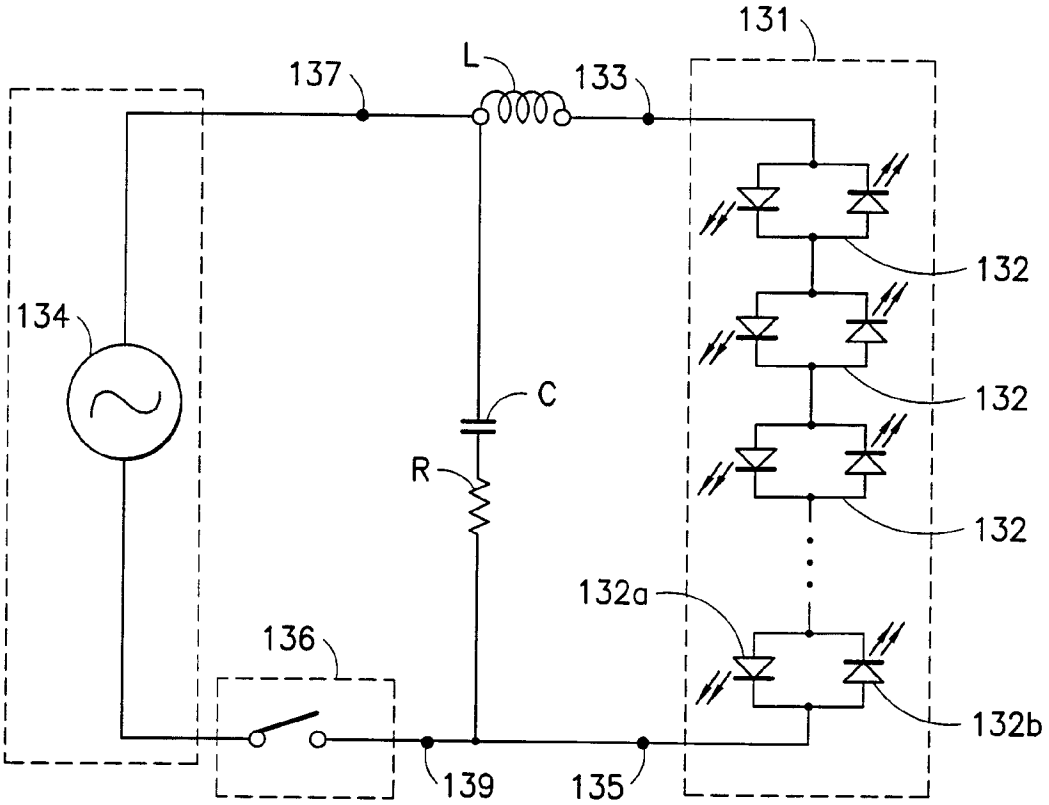


FIG.11

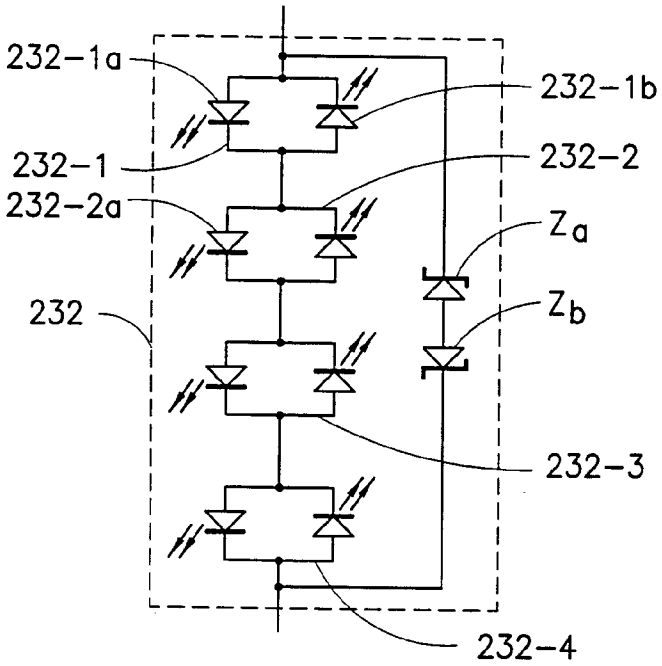


FIG.12

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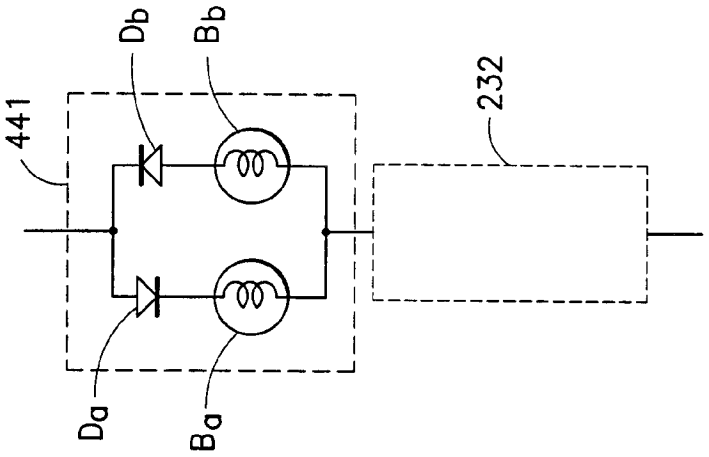


FIG.15

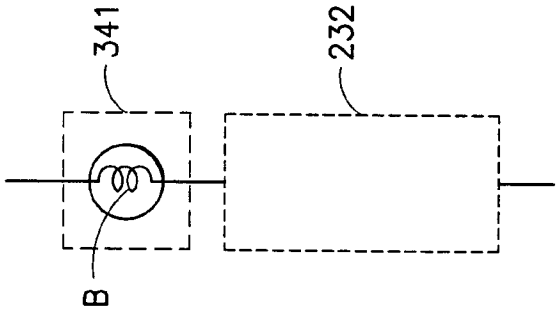


FIG.14

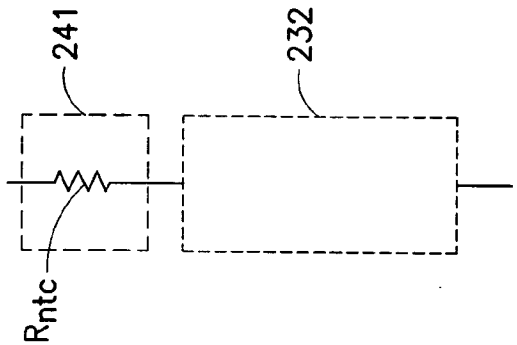


FIG.13

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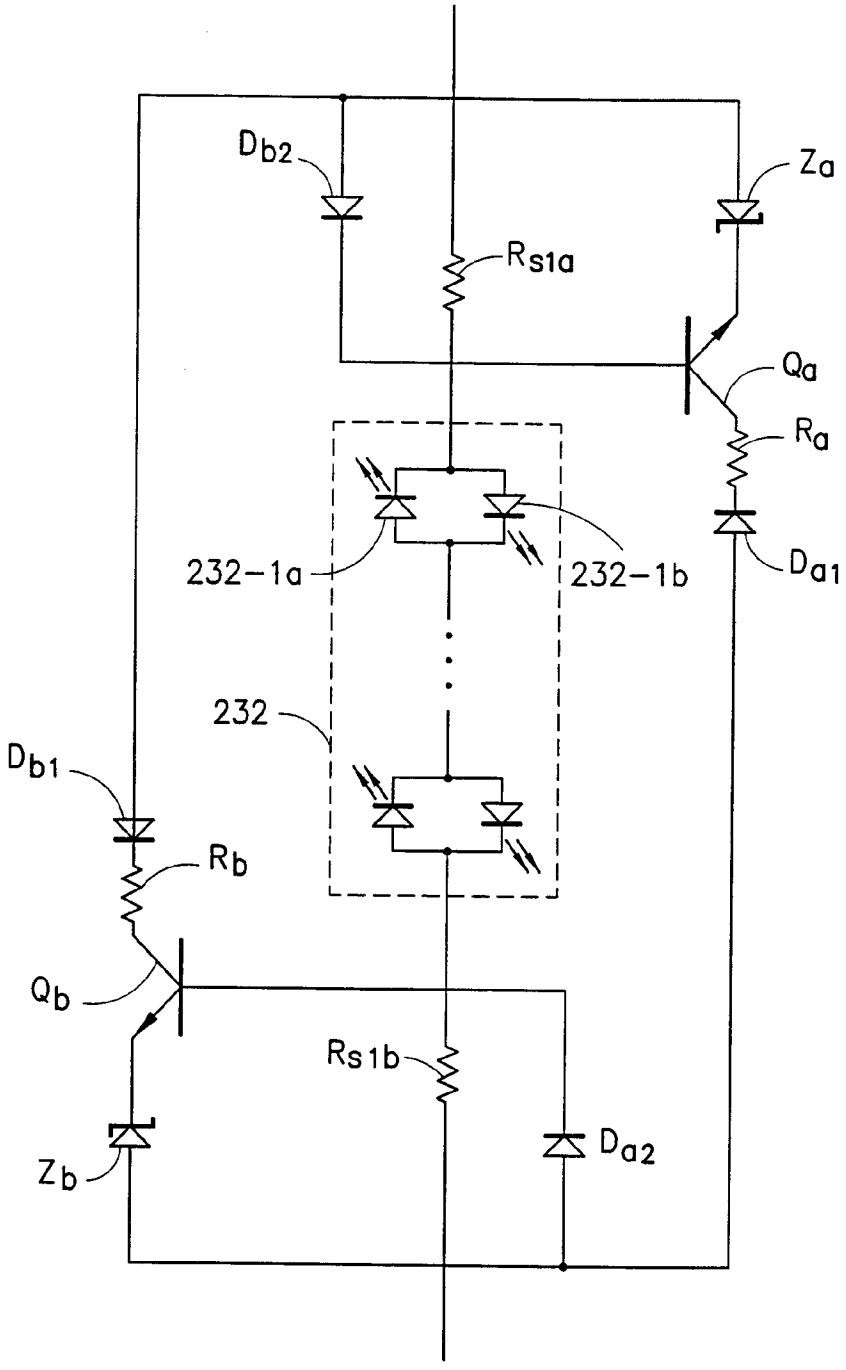


FIG.16

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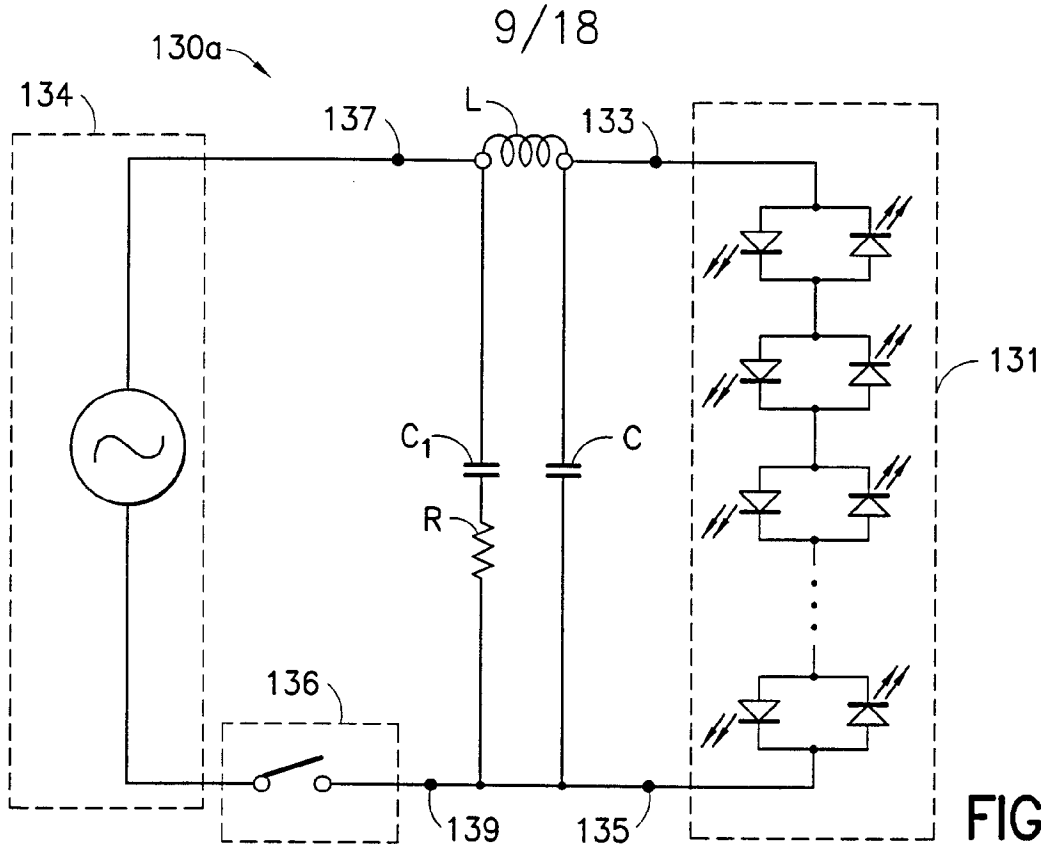


FIG.17

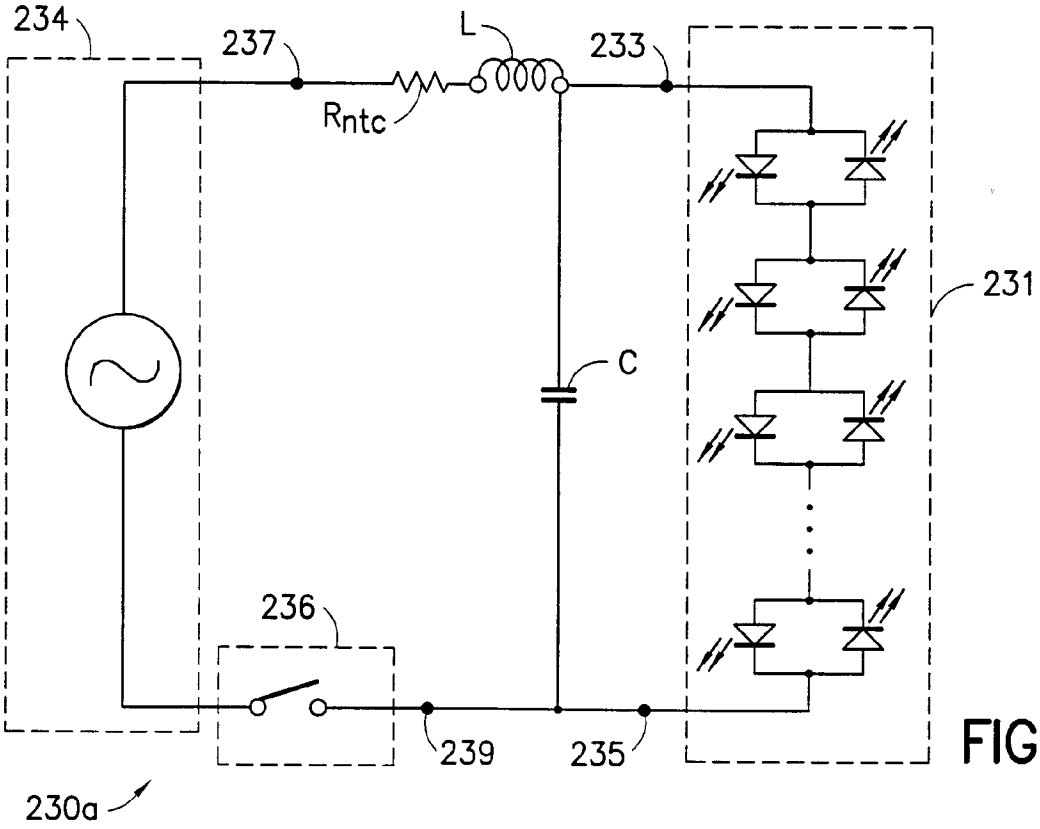


FIG.18

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Ex. 1003 - Page 1799

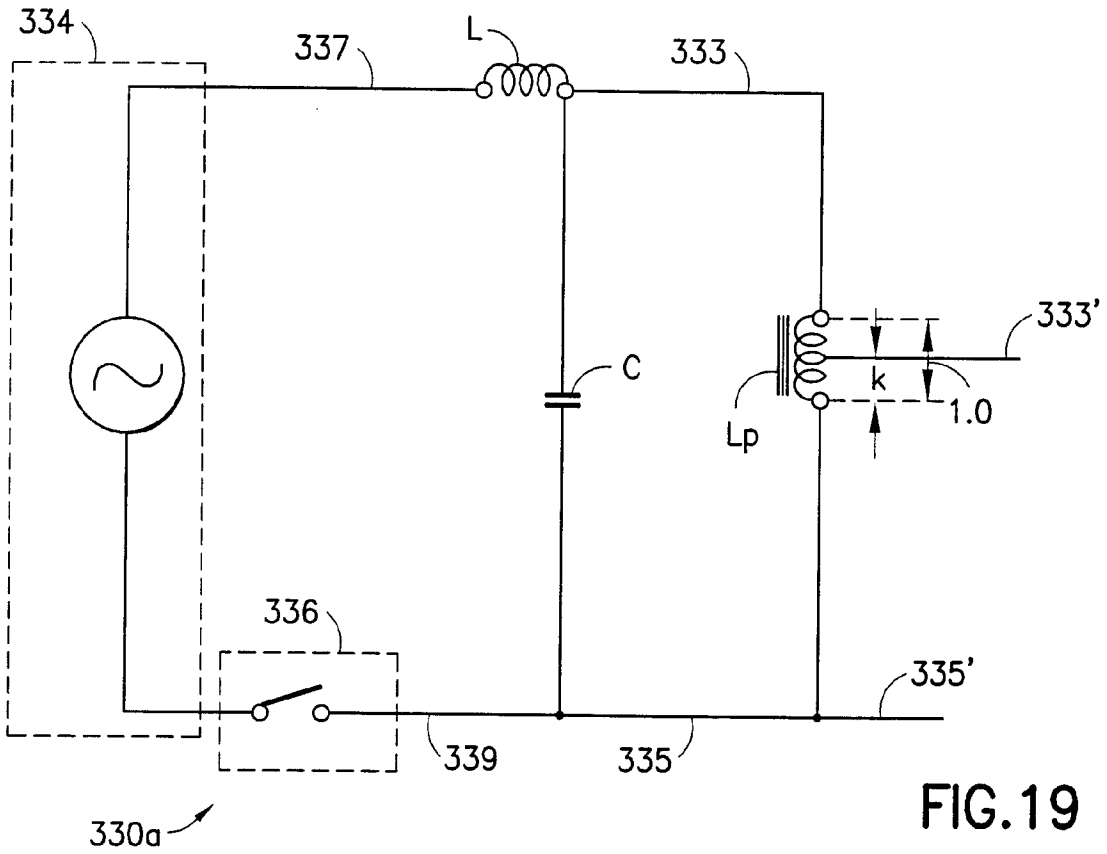


FIG.19

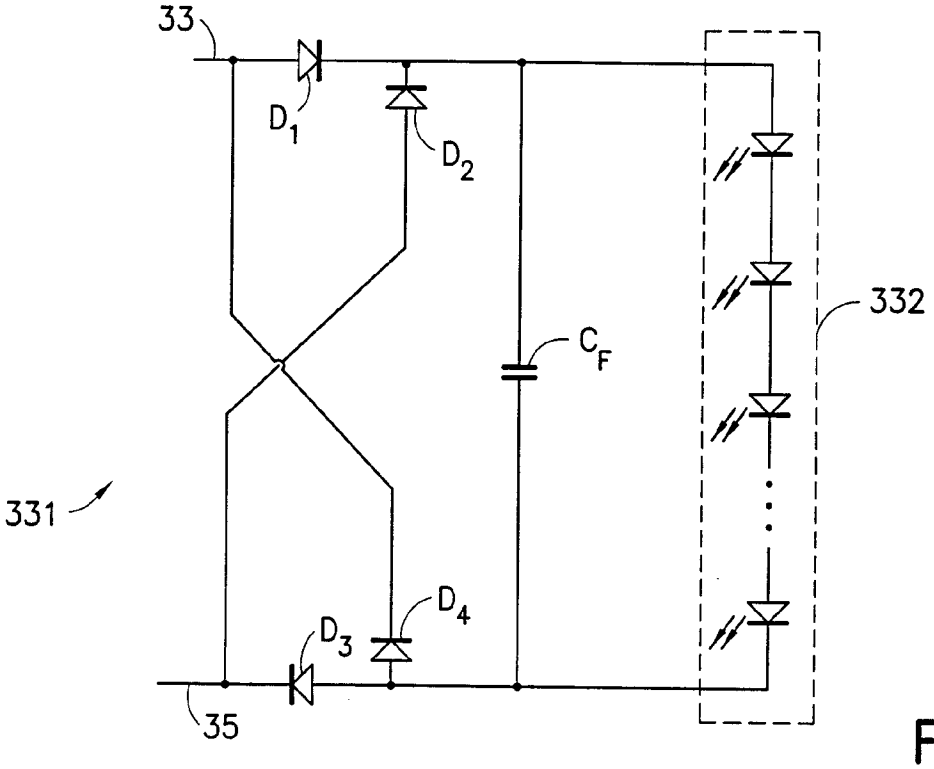


FIG.20

PGR2023-00016 - Home Depot
Ex. 1003 - Page 1800

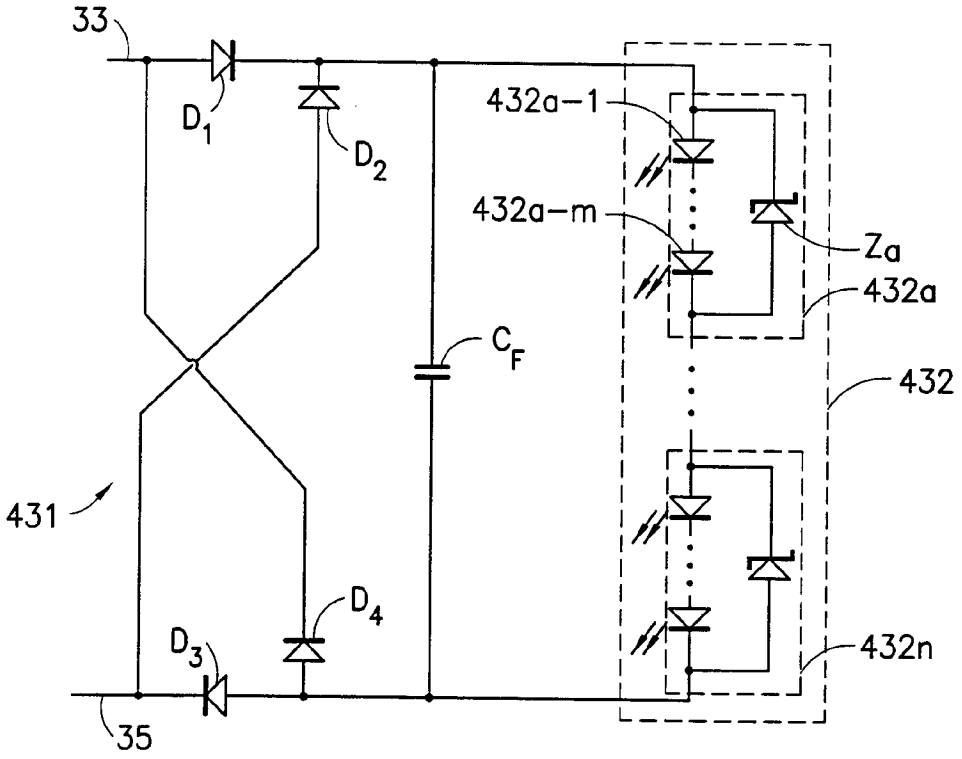


FIG.21

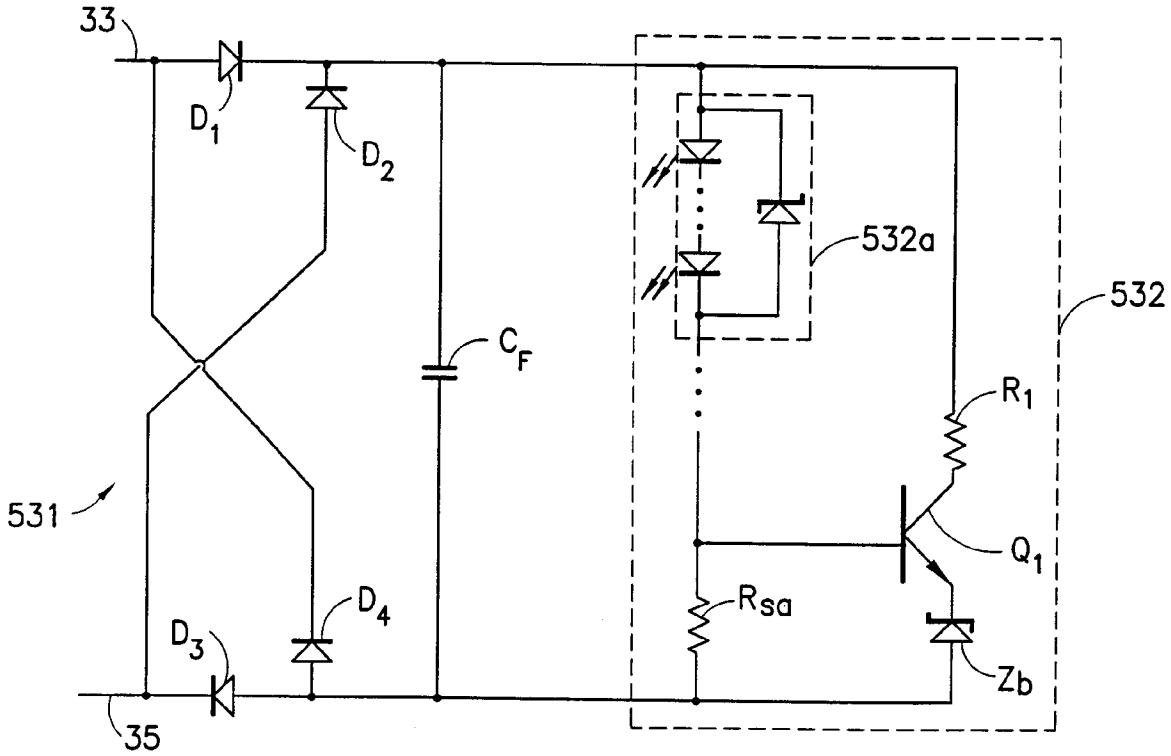


FIG.22

PGR2023-00016 - Home Depot
Ex. 1003 - Page 1801

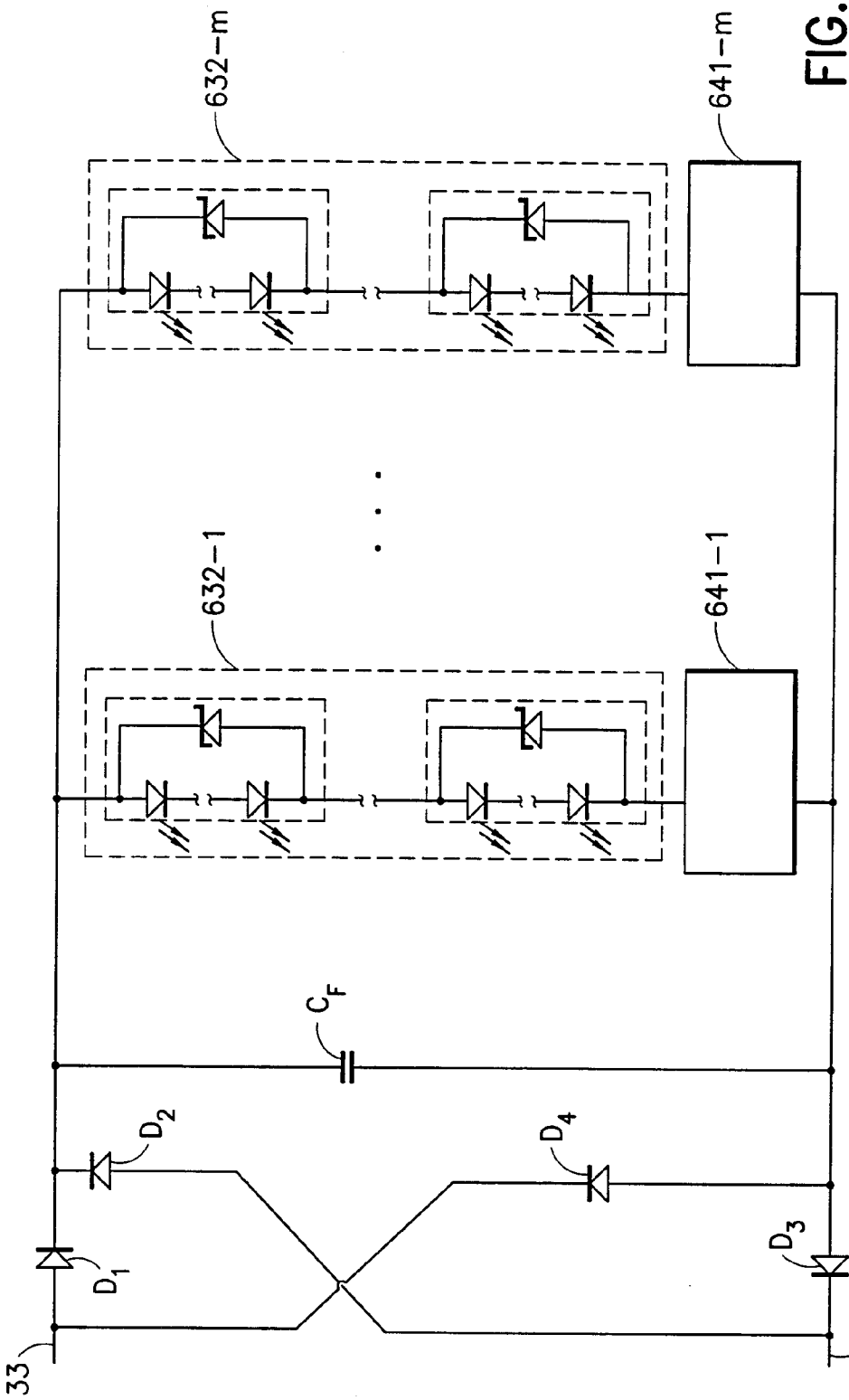


FIG.23

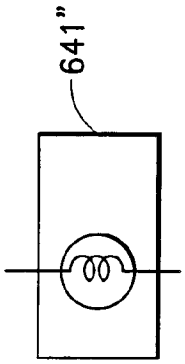


FIG.25

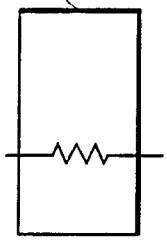
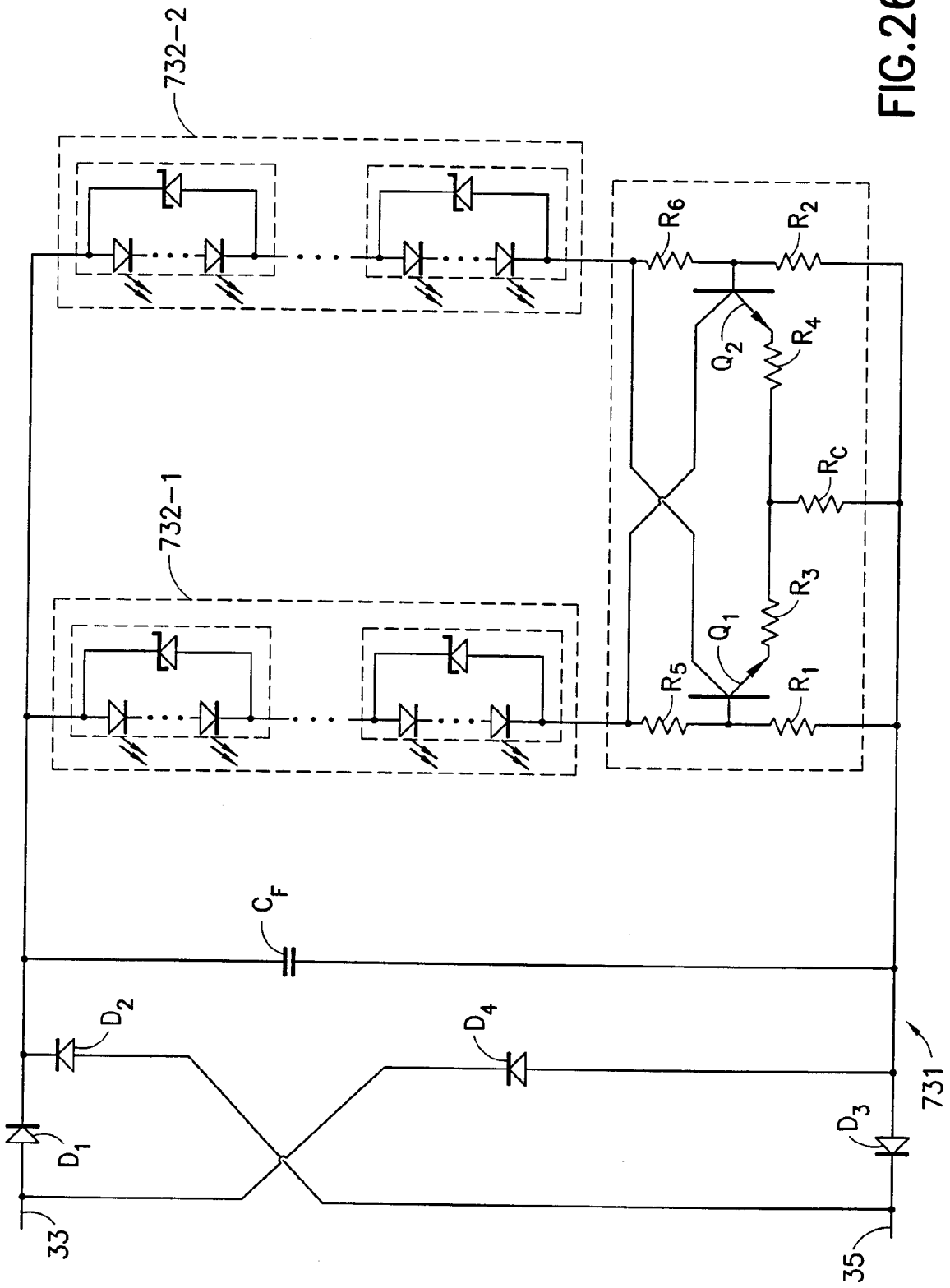


FIG.24

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Ex. 1003 - Page 1802

FIG.26



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Ex. 1003 - Page 1803

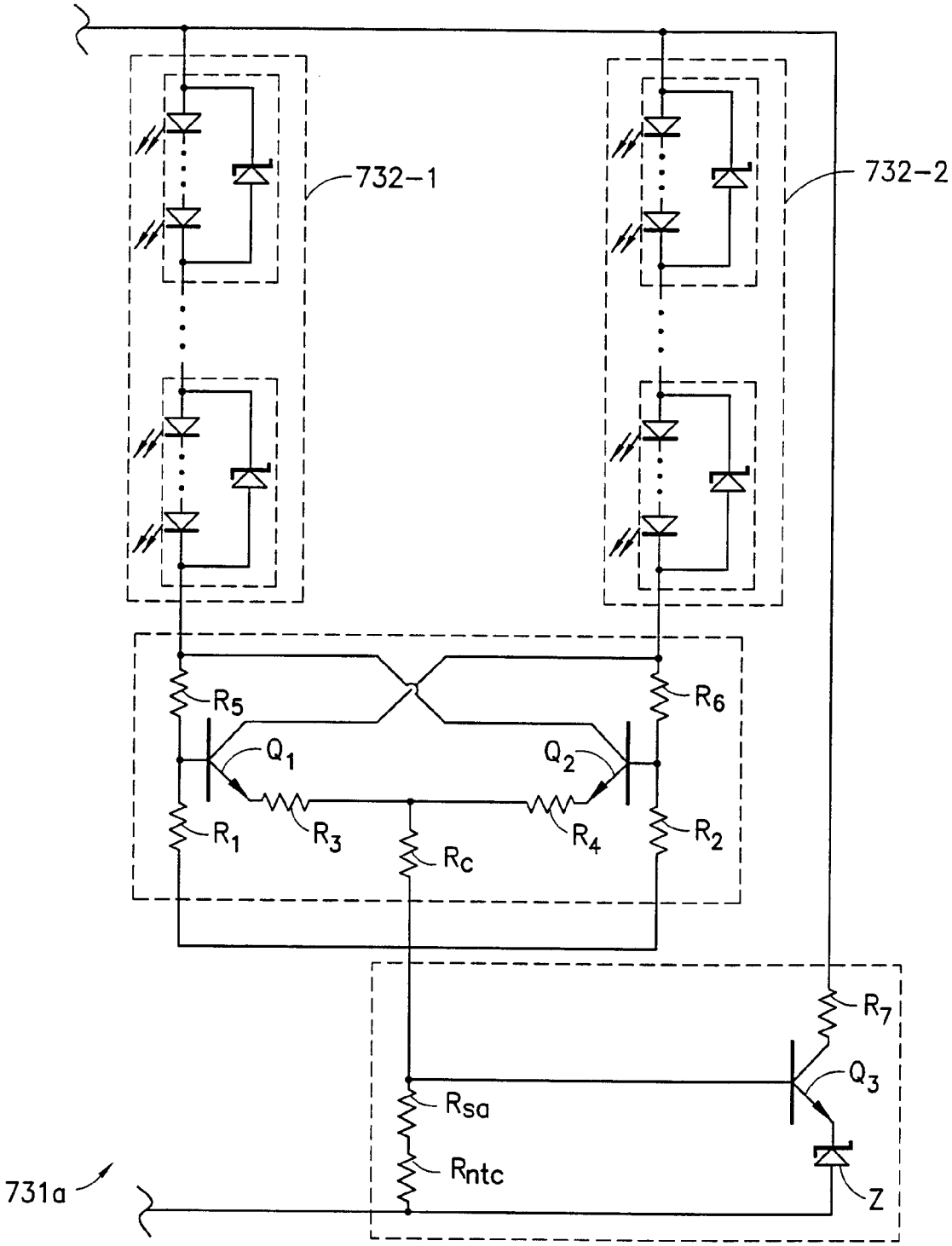


FIG.27

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Ex. 1003 - Page 1804

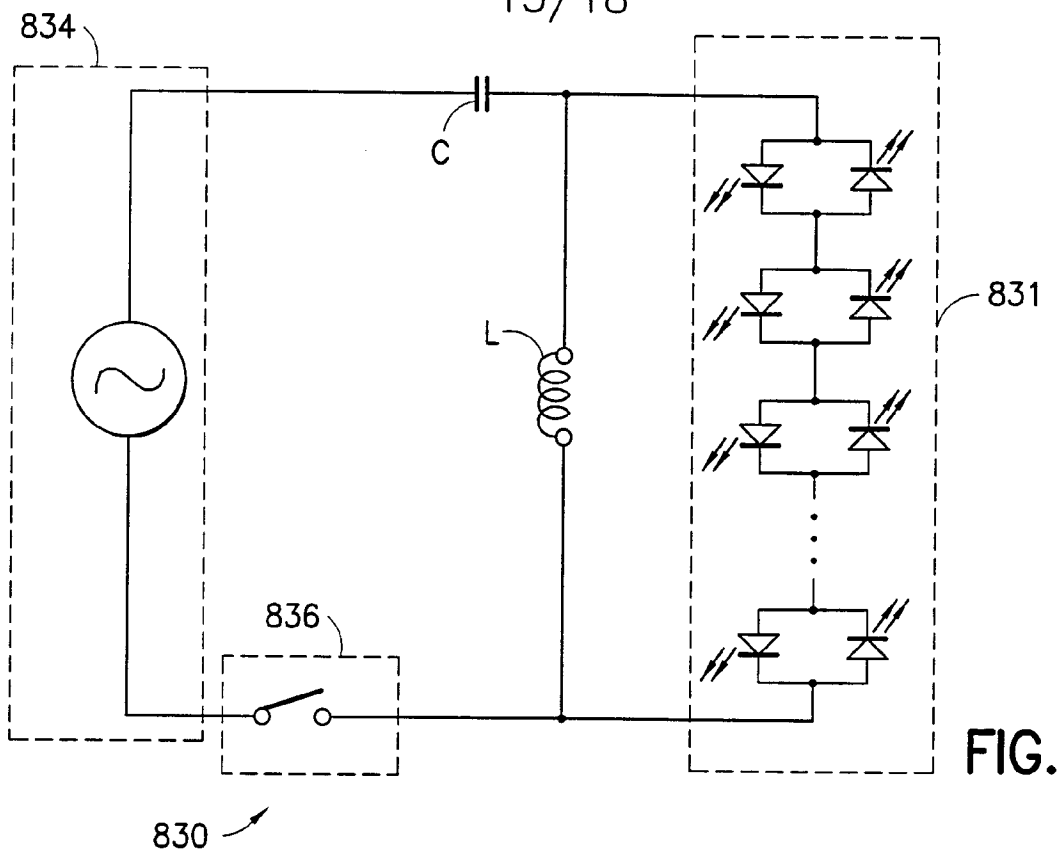


FIG.28

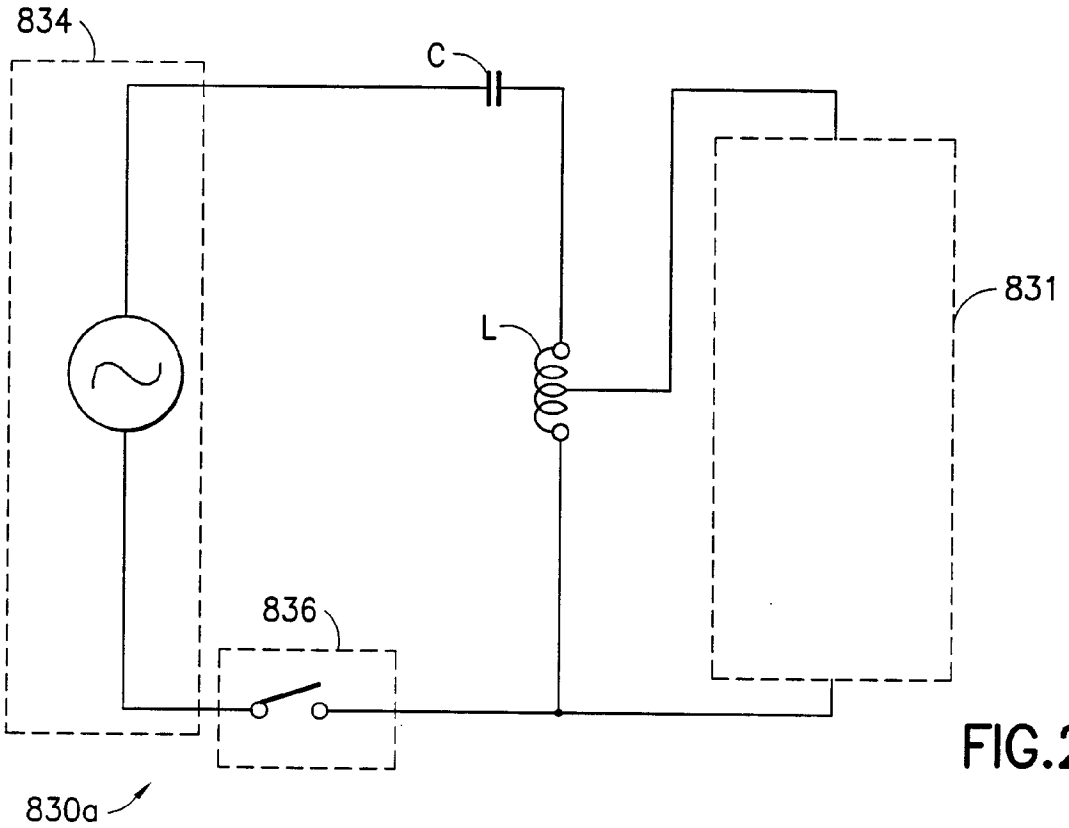


FIG.29

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Ex. 1003 - Page 1805

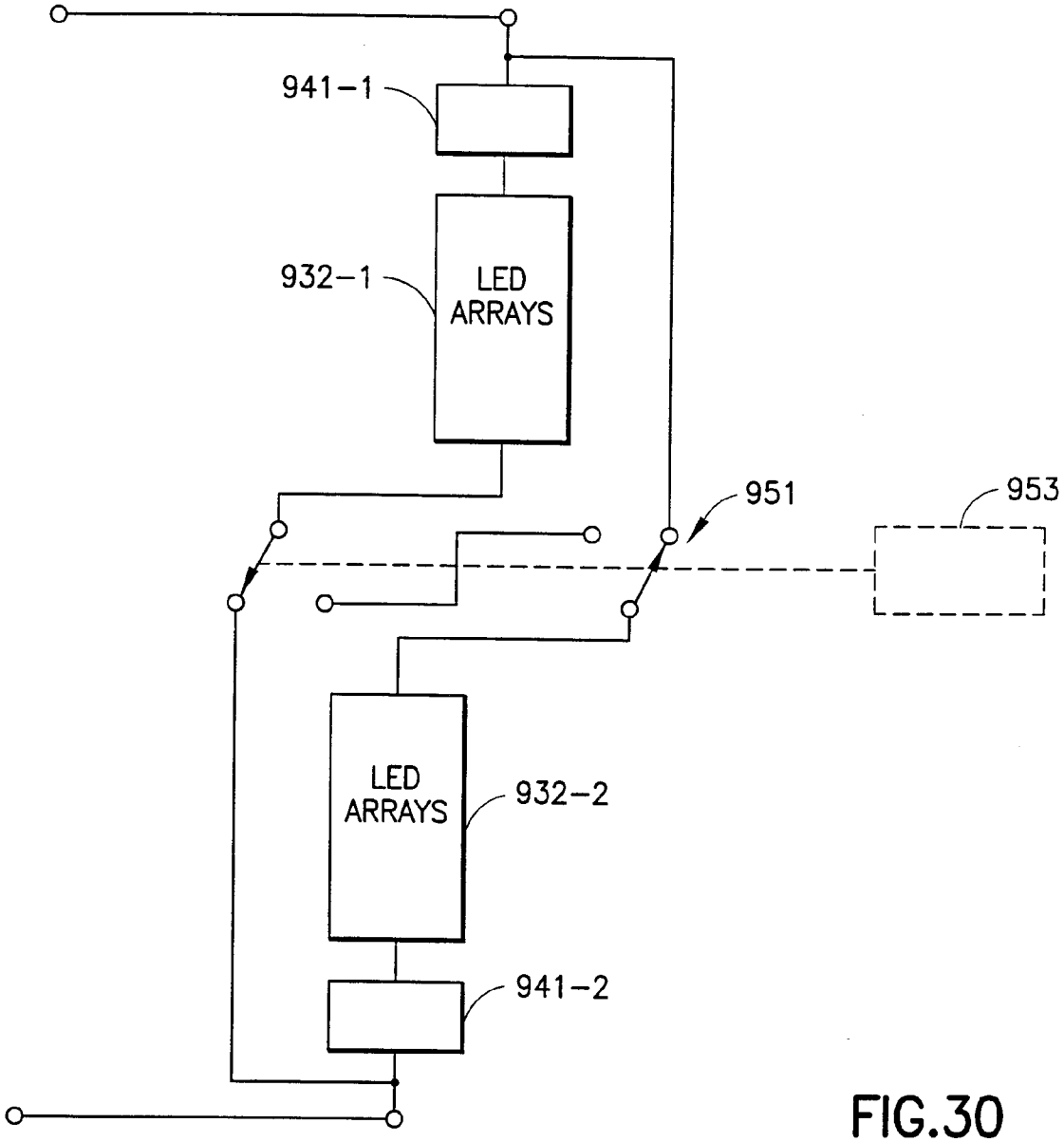


FIG.30

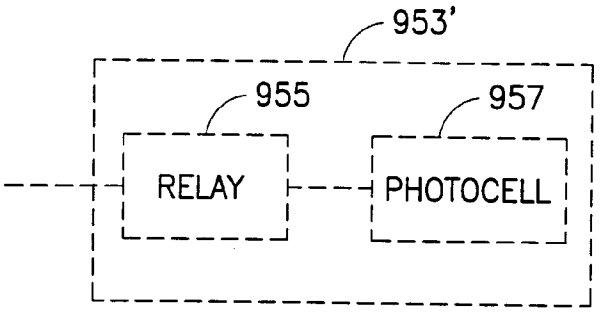
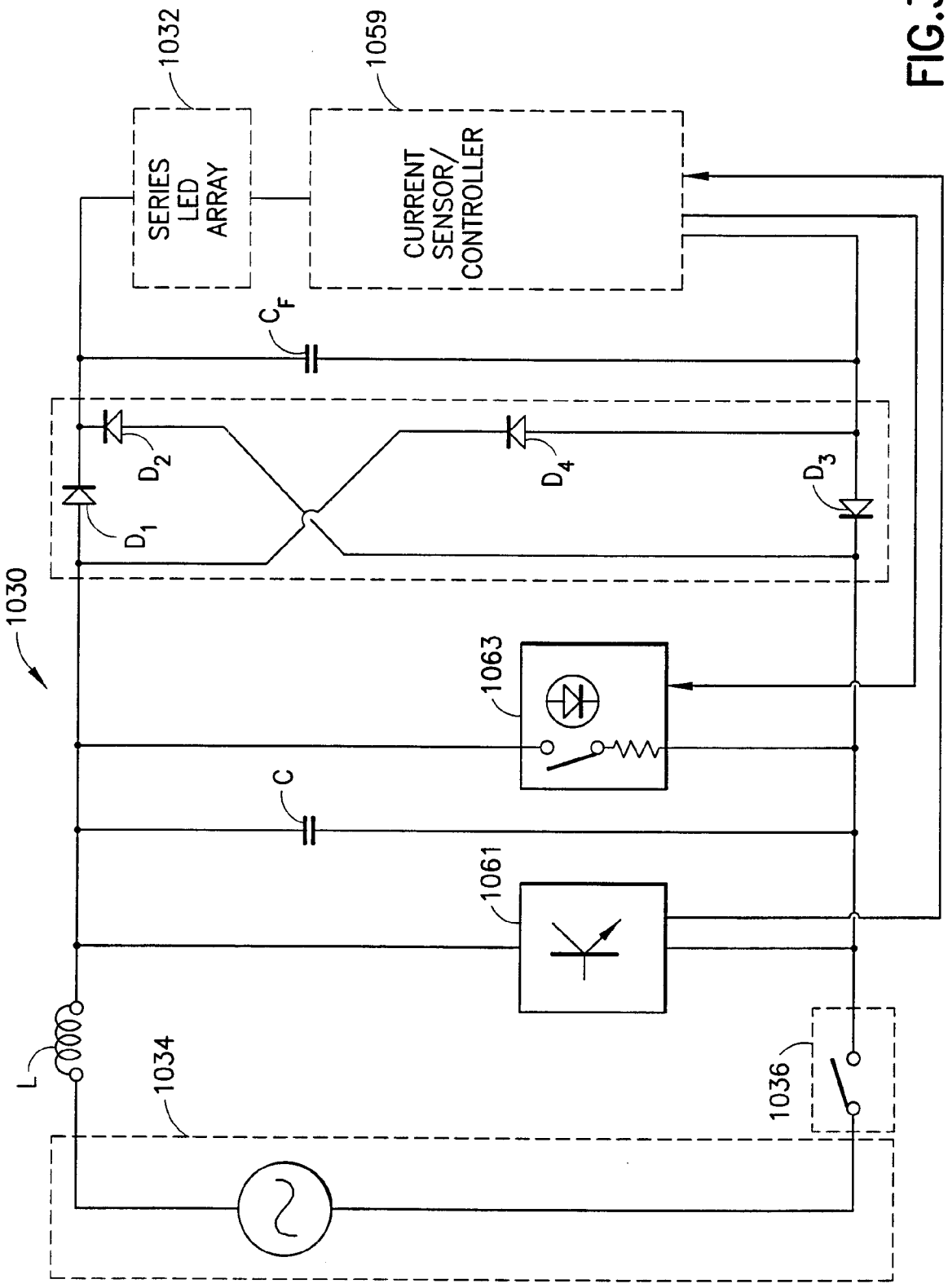


FIG.31

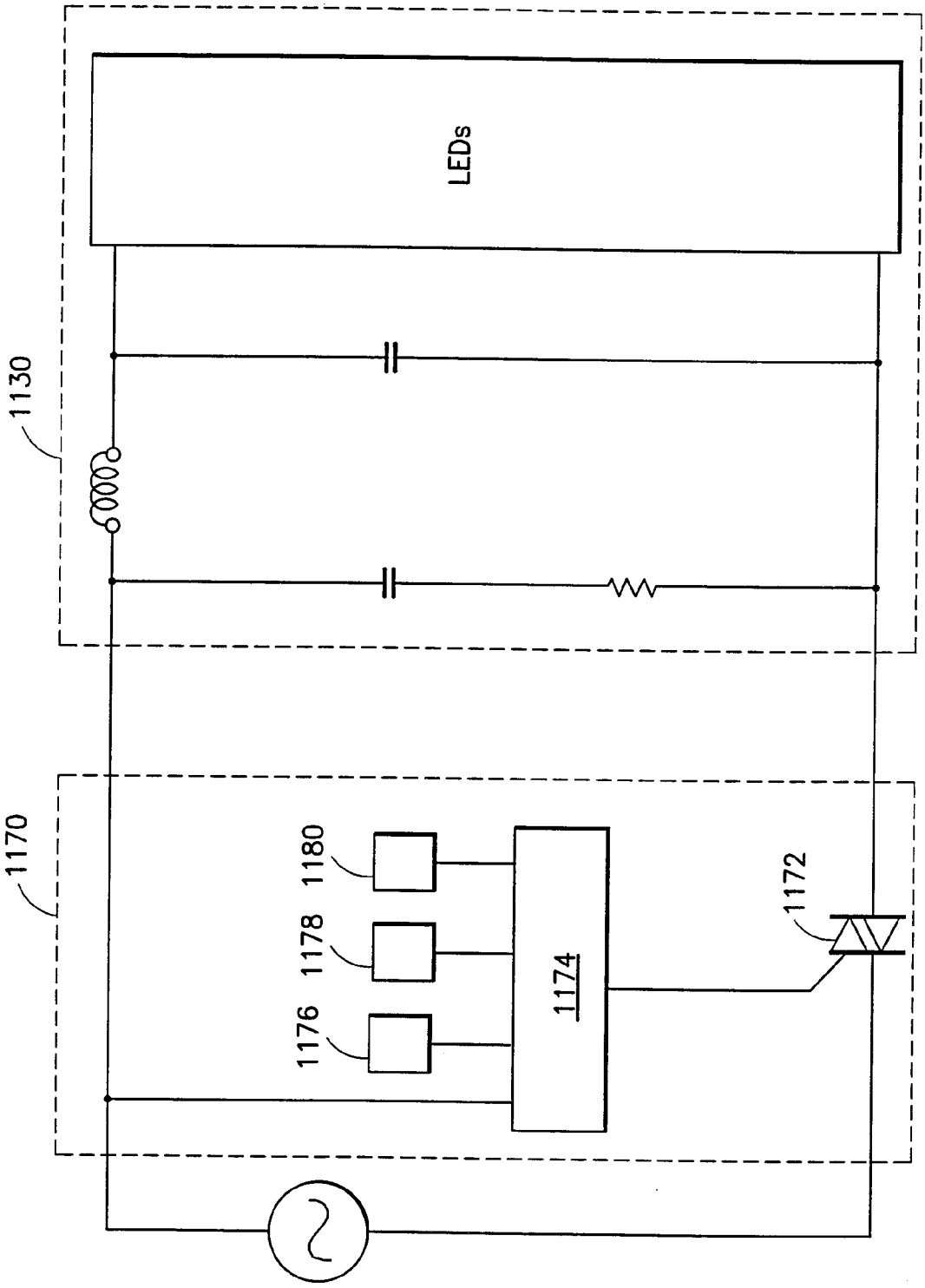
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Ex. 1003 - Page 1806

FIG.32



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FIG.33



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Ex. 1003 - Page 1808

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US99/14876

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) : G09G 3/36
US CL : 345/46, 82; 345/815.45
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 345/46, 82, 83; 345/815.45; 313/500; 362/800

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

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 4,517,500 A (GOTAL ET AL) 14 MAY 1985, FIGURES 1, 4 AND COLUMN 3, LINES 32-38.	20-61
A	US 5,459,478 A (BOLGER ET AL) 17 OCTOBER 1995, FIGURE 1 AND COLUMN 4, LINES 20-24.	31
A	US 3,676,735 A (ROCHE) 11 JULY 1972, FIGURE 1.	1-61
A	US 4,271,408 A (TESHIMA ET AL) 02 JUNE 1981, FIGURES 4, 8, COLUMN 6, LINES 28-55 AND COLUMN 7, LINES 22-33.	1-61
A	US 5,187,377 A (KATOH) 16 FEBRUARY 1993, SEE FIGURE 2.	1-61
A	US 3,869,641 A (GOLDBERG) 04 MARCH 1975, SEE FIUGRE 1.	1-61

[X] Further documents are listed in the continuation of Box C. [ ] See patent family annex.

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"E"	earlier document published on or after the international filing date	"Y"	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
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"O"	document referring to an oral disclosure, use, exhibition or other means		
"P"	document published prior to the international filing date but later than the priority date claimed		

Date of the actual completion of the international search	Date of mailing of the international search report
19 AUGUST 1999	29 SEP 1999

Name and mailing address of the ISA/US	Authorized officer
Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231	LUN-YI LAO
Facsimile No. (703) 305-3230	Telephone No. (703) 305-4873

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Ex. 1003 - Page 1809

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US99/14876

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 4,321,598 A (WARNER) 23 MARCH 1982, SEE FIGURE 3.	1-61

Form PCT/ISA/210 (continuation of second sheet)(July 1992) ★

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
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PCT

(10) International Publication Number
WO 02/062623 A3

(51) International Patent Classification[7]: B60R 1/12

(21) International Application Number: PCT/US02/01785

(22) International Filing Date: 22 January 2002 (22.01.2002)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:

60/263,680	23 January 2001 (23.01.2001)	US
60/271,466	26 February 2001 (26.02.2001)	US
09/793,002	26 February 2001 (26.02.2001)	US
60/315,384	28 August 2001 (28.08.2001)	US
60/346,733	7 January 2002 (07.01.2002)	US

(71) Applicant: DONNELLY CORPORATION [US/US]; 414 East Fortieth Street, Holland, MI 49423 (US).

(72) Inventors: LYNAM, Niall, R.; 248 Foxdown, Holland, MI 49424 (US). LINDAHL, John, O.; Forty South 7th Street, Fruitport, MI 49415 (US).

(74) Agents: COLLINS, Catherine, S. et al.; Van Dyke, Gardner, Linn & Burkhart, L.L.P., Suite 207, 2851 Charlevoix Drive S.E., P.O. Box 888695, Grand Rapids, MI 49588-8695 (US).

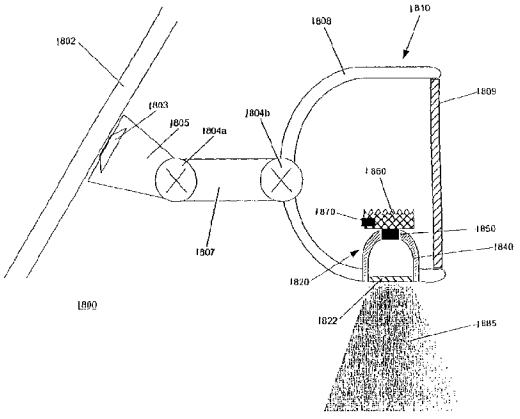
(81) Designated States *(national)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, OM, PH, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TN, TR, TT, TZ, UA, UG, UZ, VN, YU, ZA, ZM, ZW.

(84) Designated States *(regional)*: ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:
— *with international search report*

[Continued on next page]

(54) Title: IMPROVED VEHICULAR LIGHTING SYSTEM FOR A MIRROR ASSEMBLY



(57) Abstract: An improved vehicle lighting system for a vehicle is provided. The lighting system includes a light assembly, which is configured so as to illuminate, for example, a ground area adjacent an entrance to the vehicle or an interior portion of the vehicle. The light assembly includes a single non-incandescent light source, which comprises a single high-intensity power light emitting diode. The single high-intensity power light emitting diode preferably has a luminous efficiency of at least about 1 lumen per watt when the single high-intensity power light emitting diode is operated and wherein the single high-intensity power light emitting diode is preferably operated at a forward current of at least 100 milliamps. The single high-intensity power light emitting diode is preferably provided with a heat dissipation element, which functions as at least one of a heat sink and a heat dissipater for the power dissipated by the single high-intensity power light emitting diode. The single high-intensity power light emitting diode operates at an operational voltage that is less the battery/ignition voltage of the vehicle. Preferably the light assembly is provided with at least one of a series power resistor and a DC voltage to DC voltage converter.

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(88) Date of publication of the international search report:
20 February 2003

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 02/01785

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 B60R1/12

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 B60R

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

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 00 55685 A (GENTEX) 21 September 2000 (2000-09-21) page 17, line 26 -page 18, line 30	1,6-11, 16-18, 36-38, 41-46, 49-51, 60,61, 63, 73-76, 79-82, 98,99, 101-109, 112,118, 119
A	US 4 646 210 A (SKOGER) 24 February 1987 (1987-02-24)	

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

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Date of the actual completion of the international search	Date of mailing of the international search report
31 July 2002	06/08/2002

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Knops, J

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INTERNATIONAL SEARCH REPORT

rmation on patent family members

In onal Application No
PCT/US 02/01785

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 0055685 A	21-09-2000	AU 3527900 A	04-10-2000
		EP 1169668 A1	09-01-2002
		WO 0055685 A1	21-09-2000
US 4646210 A	24-02-1987	AU 4306185 A	02-01-1986
		CA 1263265 A1	28-11-1989
		EP 0165817 A2	27-12-1985
		JP 61012449 A	20-01-1986

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
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PCT

(10) International Publication Number
WO 02/23956 A3

(51) International Patent Classification[7]: H05B 33/08

(21) International Application Number: PCT/US01/28932

(22) International Filing Date:
13 September 2001 (13.09.2001)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
09/662,988 15 September 2000 (15.09.2000) US

(71) Applicant: **TELEDYNE LIGHTING AND DISPLAY PRODUCTS, INC.** [US/US]; 12525 Daphne Avenue, 2nd Floor, Hawthorne, CA 90250 (US).

(72) Inventors: **PANAGOTACOS, George, W.**; 810 Shepard Crest Drive, Corona, CA 92882 (US). **PELKA, David, G., Ph.D.**; 8315 Kenyon Avenue, Los Angeles, CA 90045 (US).

(74) Agent: **ALTMAN, Daniel, E.**; Knobbe, Martens, Olson and Bear, LLP, 620 Newport Center Drive, 16th Floor, Newport Beach, CA 92660 (US).

(81) Designated States *(national)*: AE, AG, AL, AM, AT, AT (utility model), AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, CZ (utility model), DE, DE (utility model), DK, DK (utility model), DM, DZ, EC, EE, EE (utility model), ES, FI, FI (utility model), GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, PH, PL, PT, RO, RU, SD, SE, SG, SI, SK, SK (utility model), SL, TJ, TM, TR, TT, TZ, UA, UG, UZ, VN, YU, ZA, ZW.

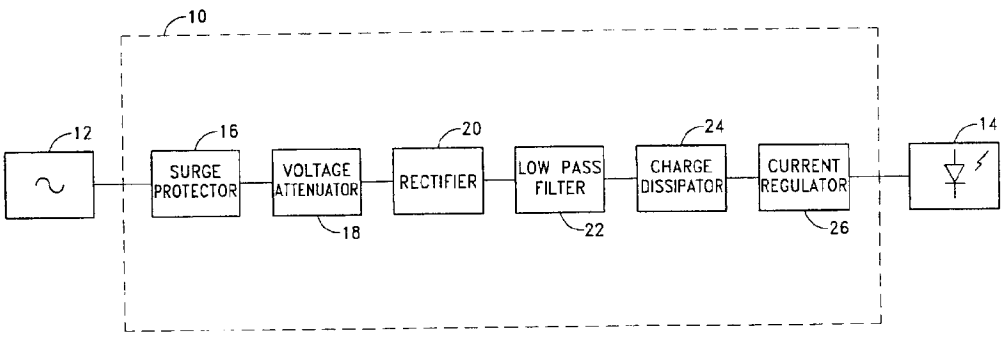
(84) Designated States *(regional)*: ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:
— *with international search report*

(88) Date of publication of the international search report:
30 May 2002

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: POWER SUPPLY FOR LIGHT EMITTING DIODES



(57) Abstract: A power supply for powering at least one light emitting diode (LED) with AC voltage comprises an AC input line, a step-down impedance, a rectifier, a low pass filter, and a current regulator. The AC voltage is carried through the AC input line to the step-down impedance, which attenuates the voltage. The rectifier subsequently rectifies the voltage while the lower pass filter removes ripple from the rectified voltage. The current regulator converts the rectified voltage into a substantially constant supply of DC current that is delivered to the LED.

WO 02/23956 A3

INTERNATIONAL SEARCH REPORT

Interr nal Application No
PCT/US 01/28932

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H05B33/08

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H05B

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

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 5 495 147 A (LANZISERA VINCENT A) 27 February 1996 (1996-02-27) column 4, line 16 -column 4, line 51; figures 1,3	1-31
Y	US 5 463 280 A (JOHNSON JAMES C) 31 October 1995 (1995-10-31) column 4, line 62 -column 5, line 9; figures 1,2,4	1-31
Y	EP 0 660 648 A (ILLINOIS TOOL WORKS) 28 June 1995 (1995-06-28) column 3, line 23 -column 3, line 32 column 4, line 8 -column 4, line 17; figure 1	1-31
A	WO 98 21917 A (FLECK LEONARD ;L F D LIMITED (GB)) 22 May 1998 (1998-05-22)	

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Date of the actual completion of the international search	Date of mailing of the international search report
5 March 2002	12/03/2002

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Speiser, P

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INTERNATIONAL SEARCH REPORT

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Inter nal Application No
PCT/US 01/28932

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EP 0660648 A	28-06-1995	US 5459478 A	17-10-1995
		EP 0660648 A1	28-06-1995
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		WO 9821917 A1	22-05-1998
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		TR 9900917 T2	21-07-1999
		US 6268702 B1	31-07-2001

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(51) International Patent Classification:
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PCT/IB2009/053385

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(25) Filing Language: English

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(30) Priority Data:
08161891.0 6 August 2008 (06.08.2008) EP

(71) Applicant *(for all designated States except US)*: **NXP B.V.** [NL/NL]; High Tech Campus 60, NL-5656 AG Eindhoven (NL).

(72) Inventors; and

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(54) **Title**: DIMMING LIGHTING DEVICES

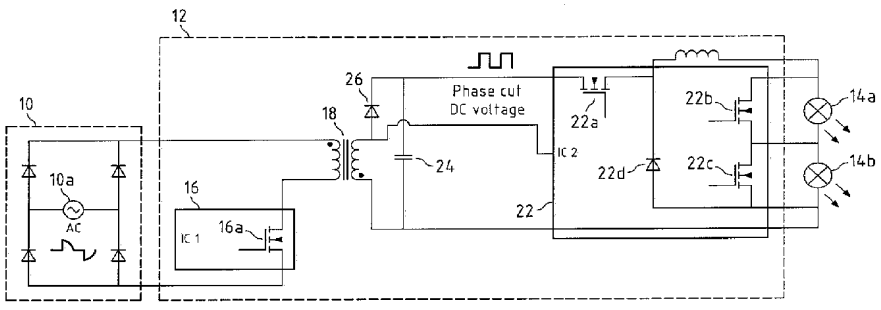


Fig.4

(57) **Abstract**: The application relates to dimming lighting devices. A component comprises an input for receiving input power and the primary side from a primary power supply, and transformer for transforming the input power on the primary side to the output power on the secondary side, a transformer electrically decoupling the primary side from the secondary side, a first circuit arranged at the primary side for receiving within the receive input power at least one light intensity information, and a second circuit at the secondary side for determining at least dimming color point information and for driving the lighting device at least according to dimming color point information.

WO 2010/016002 A1

Dimming Lighting Devices

FIELD OF THE INVENTION

The present patent application relates to dimming lighting devices, for example LED lighting devices.

BACKGROUND OF THE INVENTION

Existing dimmers use the common power line to provide dimming information to the light source by cutting the phase of the mains voltage. These so-called phase cut dimmers can be used to dim existing halogen or incandescent light bulbs. With the rise of LEDs in general lighting, there exists the need to also allow dimming the light emitted by the LEDs. When dimming light, the color point, e.g. the color temperature of an incandescent lighting device, changes in accordance with changing intensity. This change of color temperature needs to be created with an LED as well, to obtain realistic dimming impressions.

From WO 2005/048658 A1, there is known a resonant power LED control circuit for the independent, simultaneous brightness and color or color temperature control of two LEDs. In order to provide for controlling the brightness and the color of the LEDs simultaneously, there is provided a single resonant converter, which is formed of a half or full bridge DC/AC converter. On the primary side, a transformer is fed with driving current depending on the intensity information received from the driving power, i.e. the mains power, which is controlled from a dimmer. On the secondary side, two inductances are connected to the primary side, where the two inductances drive respective LEDs. Depending on the phase of the primary current, the two LEDs driven by the inductances are driven with different driving currents. This is provided by connecting the LEDs to the respective inductances, such that one LED is driven at a high phase and one LED is driven at a low phase. When the phase changes, the respective other LED is activated. Depending on the phase ratio of the primary driving current, the LEDs receive respectively different input currents and thus have different bright intensity. When the LEDs have

different primary colors, the combined color point of both LEDs can change with different light intensity of the respective LEDs.

However, the proposed solution lacks the possibility to adjust the color point, e.g. the light temperature of the output light from both LEDs according to different needs. Further, the proposed solution requires a transformer having three taps on the secondary side. Also, the driver for driving the primary side of the transformer is complex and not compatible with known dimming solutions for incandescent light bulbs.

Therefore, there is a need for a compatible solution for setting the color point of a lighting device in accordance with dimming the light intensity. There is further the need for providing the possibility to provide dimming of light intensity while also setting the color point information using the common driving voltage, i.e. the power line. Still another need is to provide a solution compatible with dimming incandescent light bulbs.

SUMMARY OF THE INVENTION

These and other objects are solved by a component comprising an input for receiving input power from a primary power supply, at least one circuit, wherein the circuit is arranged for receiving within the received input power at least light intensity information, wherein the circuit is arranged for driving at least two lighting devices at least according to the light intensity information, and wherein the circuit is arranged for determining the driving ratio between the at least two lighting devices according to the light intensity information.

Providing a circuit for both obtaining the light intensity information and the driving ratio between the at least two lighting devices increases flexibility for lighting devices. The present application improves component integration and reduces manufacturing cost. The integration of determining and applying light intensity information and driving ratio to lighting devices reduces the form factor of driving circuits.

According to embodiments, there is provided a component comprising an input for receiving input power at a primary side from a primary power supply, a first circuit arranged at the primary side for receiving within the received input power at least light intensity information, and a second circuit at the secondary side for

determining at least dimming color point information and for driving a lighting device at least according to the dimming color point information.

It has been found that providing two separate integrated circuits at the primary and the secondary side allows for providing dimming lighting devices, e.g. LEDs or OLEDs, with automatic color adjustment depending on the light intensity information. Further, the provision of two separate circuits, e. g. integrated or discrete circuits, allows for the usage of widely spread dimmers, for example R-type dimmers, R, L-type dimmers, or R, C-type dimmers. The R-type dimmers are leading edge phase cut dimmers. The R, L-type dimmers are also leading edge phase cut dimmers. The R, C-type dimmers are trailing edge phase cut dimmers. These dimmers provide for the mains voltage with a phase cut either at the leading edge or the trailing edge of the wave of the mains voltage.

Available integrated circuits on the market are already capable of receiving phase cut dimming information on the mains voltage and of driving an incandescent light bulb accordingly. However, the known solutions do not have output terminals for more than one lighting terminals, in particular, no output terminals for connecting at least two different LEDs and for driving these at least two different LEDs.

The problem when driving LEDs lies in that the color point does not change with changing light intensity. The spectral light information of the light emitted from an LED is always constant. However, incandescent light bulbs change with changing intensity also their color point. This provides for a realistic dimming impression.

In order to provide this realistic dimming impression also using LEDs, it is necessary, to adjust the color point emitted from a lighting device, e.g. consisting of more than one LED, in accordance with the change of light intensity information. In order to provide this change of color point, it is possible, to drive two different LEDs having different primary color with changing intensity. The intensity relation between the at least two LEDs allows for setting the color point.

According to embodiments, the circuit may be a first circuit arranged at a primary side. Further, according to embodiments, a second circuit may be arranged for driving the at least two lighting devices and for determining the driving ratio between the at least two lighting devices according to the light intensity information.

According to the embodiments, the circuit is capable of receiving the dimming information, in particular in form of phase cut mains voltage. This dimming information may, according to embodiments, be transferred to a secondary side together with color point information. On the secondary side, a particularly arranged circuit may be capable of receiving the light intensity information. From the received light intensity information, the second integrated circuit can determine the corresponding color point. The secondary circuit can be arranged for driving a set of LEDs, at least two LEDs, depending on both the light intensity information and the color point information.

According to embodiments, at least one bypass switch may be arranged across at least one of the lighting devices for applying the driving ratios of the at least two lighting devices. The bypass switch may be a transistor, i.e. a CMOS transistor, which can be turned on and off according to the driving ratio. The switches may be driven by the circuit obtaining the driving ratio information.

The first circuit may comprise a switching element, wherein different transfer functions between the switching element and the lighting devices are provided for determining the driving ratios.

At least one storing element may be coupled to each lighting device according to embodiments. The storing element may be at least one of a capacitance, or an inductance.

For example, according to embodiments, the second circuit may determine the driving ratio from a signal input to a dedicated input pin of the second circuit. In order to allow for setting the color point in accordance with the light intensity, the second integrated circuit may be arranged for calculating the required color point depending on this received information.

The primary and the secondary sides may be decoupled using a transformer for transforming the input power on the primary side to output power on the secondary side, the transformer electrically decoupling the primary side from the secondary side.

The second integrated circuit can determine the driving ratio depending on the signal input and a pre-programmed color point curve, according to embodiments. For example, the pre-programmed curve can be similar to a black-body curve to mimic the dimming behavior of an incandescent light bulb. The pre-programmed curve may be a look-up table for mapping the dimming color point

information onto LED driving currents for respective LEDs at output terminals of the second integrated circuit. The pre-programmed curve may be stored in an additional memory in the integrated circuit.

According to embodiments, the first integrated circuit may create a stable DC voltage on the secondary side depending on the light intensity information. For example, the dimming information entering the component on the primary side needs to be transferred to the second integrated circuit on the secondary side. When using an integrated circuit on the primary side, which is compatible with known dimming solutions, this integrated circuit may already be prepared to handle the special requirements of phase cut dimmers, for example, providing latch currents required to bring the device into conduction mode and providing hold currents required to keep it in conduction.

The latch current and the hold current provided at input terminals of the first integrated circuit on the primary side may be used as input for the integrated circuit on the secondary side. As the latch current and the hold current may represent the phase of the phase cut mains voltage input at the input terminals of the first integrated circuit, this information may represent the light intensity information. This light intensity information may be provided, according to embodiments, to the second integrated circuit on the secondary side via an opto-coupler, an analogue signal, or a pulse-width modulated (PWM) signal. Thus, the second integrated circuit on the secondary side already has information about the light intensity. Having this information, the second integrated circuit needs no further information for setting the light color point. Therefore, the integrated circuit on the primary side may drive the transformer such that it creates a stable DC supply voltage on the secondary side, input to the integrated circuit. This stable driver voltage may allow for driving the LEDs. From the light intensity information received on other pins, the integrated circuit on the secondary side may calculate both driving current and driving ratio for driving at least two LEDs.

As already mentioned, the first integrated circuit may transmit dimming information for example as phase information to the second integrated circuit, and the second integrated circuit may determine from the dimming information the driving ratio between the at least two lighting devices (e.g. dimming color point information), according to embodiments. This has the advantage that the dimming information, e.g. phase information may be provided by an integrated circuit

on the primary side being already capable of determining the latch and hold currents, which already carry the phase information. The embodiments, where the first integrated circuit creates a stable DC voltage on the secondary side, and utilizes latch and hold currents may have the advantage, that the dimming range may be broader and the color adjustment may be determined by the integrated circuit on the secondary side. The dimming range may be determined by the phase cut dimmer. The integrated circuit on the primary side needs to have intelligence to translate the phase information into a usable signal, for example a PWM signal, input to the second integrated circuit. Further, a decoupling capacitor might be required.

According to further embodiments, the integrated circuit on the primary side may create a pulsed DC voltage on the secondary side depending on the light intensity information. This may be done by driving the primary side of the transformer, such that the secondary side of the transformer creates a pulsed DC voltage. The pulsed DC voltage on the secondary side may have pulses of different width. This pulsed voltage may be regarded as phase cut DC voltage. The phase cut of the DC voltage may represent the light intensity information, already received within the mains power on the primary side. Therefore, according to embodiments, the first integrated circuit may create a phase cut DC voltage on the secondary side depending on the light intensity information.

The phase information of the secondary DC voltage may be input to a dedicated pin on the second integrated circuit. From this phase information, the second integrated circuit may determine dimming color point information. This may be done by tapping the secondary side of the transformer directly and analyzing the phase information of the pulsed DC voltage on the secondary side. Depending on this analysis, the second integrated circuit may determine a dimming color point for driving at least two LEDs. The stable DC voltage may also be used for driving the LEDs with respective driving power indicative of the light intensity in accordance with dimming information.

In order to convert the phase cut mains input power, i.e. an altering current, into a driving voltage for appropriately driving the primary side of the transformer, embodiments propose that the first integrated circuit comprises at least one transistor for converting the phase cut input voltage into a light intensity depending drive signal for transformer.

In order to set the color point using a light emitting diode, it is necessary that at least two different light emitting diodes with different basic colors, e.g. the wave length of the light output by the LED, are driven with according driving currents. By changing the driving currents, and thus the intensity of each of the LEDs, the color point may be adjusted. In order to adjust the color point, embodiments provide the second integrated circuit driving at least two lighting devices.

In order to create a realistic dimming impression, embodiments provide the second integrated driving at least two lighting devices depending on the dimming color point information such that the color point of the combined light of the at least two lighting devices represents a color temperature corresponding to the light intensity. As has been previously described, an incandescent light changes with changing intensity also its color temperature. To create a same impression using LEDs, the combined light of at least two LEDs is may be adjusted such that the light temperature is adjusted accordingly. For example, the driving ratio between the at least two lighting devices may be selected such that the color temperature of the combined light of the at least two lighting devices increases with decreasing light intensity.

Another aspect is an integrated circuit with a component as described above.

A further aspect is a system with such a component and at least two lighting devices driven by such a component.

Further, embodiments provide the system with semiconductor lighting devices or organic lighting devices, e.g. LEDs or OLEDs.

Another aspect is a method comprising receiving input power from a primary power supply, receiving within at least one circuit at least light intensity information from the input power, determining at least driving ratio between the at least two lighting devices and driving a lighting device at least according to the light intensity information with the circuit.

Yet, another aspect is a computer program comprising instructions operable to cause a processor to configure a component as previously described to receive input power from a primary power supply, receive within a at least one circuit at least light intensity information from the input power, and determine at least driving ratio between the at least two lighting devices and driving a lighting device at least according to light intensity information with the circuit.

These and other aspects of the application will be apparent from and elucidates with reference to the following Figures. In the Figures show:

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 an arrangement of a mains voltage with leading and trailing edge phase cutting;

Fig. 2 a first embodiment according to the application;

Fig. 3 a pre-programmed curve for transferring light intensity information into dimming color point information;

Fig. 4 a second embodiment according to the application;

Fig. 5 a third embodiment according to the application;

Fig. 6 a fourth embodiment according to the application;

DETAILED DESCRIPTION OF THE DRAWINGS

Fig. 1 illustrates a mains voltage 4 having a sinusoidal curve 2. This mains voltage 4 may be used for driving a device, i.e. an incandescent light bulb, using phase cutting. For phase cutting the mains voltage 4, devices, such as dimmers, are known, which provide for different types of phase cutting. For example there are R-type dimmers, which provide phase cutting at the leading edge of the curve 2, and are only intended for use with standard lightings and mains halogen lamps. Further, R, L-type dimmers are also leading edge phase cut dimmers, which are intended for use with standard lightings and halogen lamps. Eventually, R, C-type light dimmers are trailing edge phase cut dimmers, that are intended to be used also for halogen lamps using electronic ballast. As illustrated in Fig. 1, a usual curve 2 of a mains voltage 4 can be adjusted with a leading edge phase cut. The slope 6 of a leading edge phase cut is illustrated. As can be seen, each leading edge of a half wave of the curve 2 is put to zero, and the voltage is increased to the actual curve 2 at a certain time. The time, at which there is a rise in slope 6 may determine the light intensity. The longer the slope 6 is at a zero state, the lesser is the light intensity of the lighting device driven. Further shown is a slope 8 of a trailing edge phase cut dimmer. As can be seen, the first part of each half period of curve 2 is provided and the slope 8 is forced to zero at a certain time. The longer slope 8 is at zero, the lesser the light intensity.

Commonly known dimmers, such as wall mounted dimmers, provide such phase cut mains voltages to lighting devices. In order to utilize this kind of phase

cut mains voltage for other of lighting devices, such as LEDs, there is proposed a solution according to Fig. 2. Fig. 2 illustrates a driving component 10 with a mains power supply 10a and a dimming component 12. Further illustrated are two LEDs 14a, b, where LED 14a transmits light at a different wave length than LED 14b.

Within driving component 10, an AC mains power is adjusted using phase cutting, i.e. using a dimmer. The phase cut mains voltage is illustrated within component 10. Component 10 provides at its output terminals the phase cut mains voltage to the dimming component 12.

Within a dimming component 12, there is provided a first integrated circuit 16, a transformer 18, an opto-coupler 20 (optional) a second integrated circuit 22, a capacitor 24, and a diode 26.

Within first integrated circuit 16, there is provided a transistor 16a.

Within second integrated circuit 22, there is provided transistors 22a, 22b, 22c, and diode 22d. The integrated circuit 22 may comprise a circuit for determining the duty cycle Transformer 18 may be comprised of two inductances electrically decoupled, dividing dimming component 12 into a primary side at which the first integrated circuit 16 is arranged, and a secondary side at which the second integrated circuit 22 is arranged.

Capacitor 24 may be used for filtering HF components on the secondary side.

The integrated circuit according to Fig. 2 operates as follows.

The phase cut AC voltage is provided from component 10 to component 12. The phase cut mains voltage carries information about lighting intensity, i.e. provided from a phase cut dimmer. The more the phase of the curve 2 is cut, the less light shall be emitted, e.g. the less the intensity/brightness of the light shall be.

At the integrated circuit 16, a latch current and a hold current are determined for transistor 16a. Depending on the phase cut information within phase cut mains voltage, transformer 18 is driven with more or less driving power. The dimming information, e.g. the drive ratio, may be provided to opto-coupler 20, transmitting this information to the secondary side, in particular to a dedicated pin 22c on the second integrated circuit 22. It may also be possible that the dimming information, e.g. the drive ratio, is obtained from circuit 23 illustrated in dashed lines. In that case, circuit 23 illustrated in dashed lines comprises functionality which may

also be incorporated within the second integrated circuit 22. The drive ratio is obtained either on the primary side using opto-coupler, or on the secondary side using circuit 23 as separate component or integrated within integrated circuit 22.

When using the opto-coupler 20, it may be possible to provide for on the secondary side a stable DC supply voltage, and the duty cycle is determined within the integrated circuit 22. When the circuit 23 is used, the secondary side may have phase cut DC voltage and current.

By means of transistor 16a, transformer 18 is driven, such that the secondary side is driven with a stable DC supply voltage. Diode 26 and conductance 24 provide for stabilizing the current and voltage within the secondary side. At dedicated input terminals, second integrated circuit 22 receives the stable DC supply voltage. Depending on the DC supply voltage, transistor 22a drives the output current for LEDs 14a, 14b.

Receiving on dedicated input pin 22c from opto-coupler 20 dimming information, transistor 22b, 22c may be driven, such that the currents through LEDs 14a, 14b are turned on and off. By turning on and off the currents within the LEDs 14a, 14b using transistor 22b, 22c, the ratio and light output at which the LEDs 14a, 14b emit light, can be adjusted. This ratio can be used for setting a dimming color point of the light output by both LEDs 14a, 14b.

In order to drive the transistors 22b, 22c accordingly, integrated circuit 22 provides a pre-programmed curve for mapping the input phase information from opto-coupler 20 into drive information for transistor 22b, 22b, such that the light emitted by both LEDs 14a, 14b is a representation of the dimming color point, which a usual incandescent light bulb would emit. This curve may be a representation of a black-body to mimic incandescent dimming behavior.

By driving the transistors 22b, 22c with the color point information, the active/inactive periods of LEDs 14a, 14b can be adjusted such that the overall color point is in accordance with a dimming color point according to the set light intensity.

Fig. 3 illustrates a pre-programmed curve 30, representing the ratio between the LEDs 14a, 14b depending on the dimming information received via opto-coupler 20.

The dimming information received the opto-coupler 20 may be face information, for example a face cut angle. Using this face cut angle the light output of

LEDs 14a, 14b maybe controlled, such that the overall light output and the color point are adjusted. As can be seen, with increasing face cut angle, the light output of LED 14b decreases faster than the light output of LED 14a. This results in that with a small face cut angle, the ratio between light output by LED 14b and LED 14a is higher to LED 14b. For an increased face cut angle, LED 14a puts out more light than 14b creating a different color point.

Fig. 4 illustrates a further embodiment. Again, the dimming component 12 comprises a first integrated circuit 16, and a second integrated circuit 22.

Different to the embodiment illustrated in Fig. 2, the embodiment illustrated in Fig. 4 provides via integrated circuit 16 transformer 18 with a driving power, such that on the secondary side, a phase cut DC voltage is applied. This phase cut DC voltage is a representation of the phase cut AC mains voltage. The duration of the phases represents the light intensity, which the LEDs 14a, 14b shall emit light. The phase cut DC voltage is a representation of the light intensity information received from driving component 10.

Via a dedicated pin 22e, integrated circuit 22 receives information about the phase cut DC voltage within the secondary side circuit. This information is, as previously described, a light intensity information. Receiving this light intensity information on dedicated pin 22e, allows integrated circuit 22 to determine the on/off times of transistor 22b, 22c, in order to drive LEDs 14a, 14b such that they mimic the light color point in accordance with the light intensity state. The phase cut information is thus used within the second integrated circuit to determine the color point at which LEDs 14a, 14b output a combined light.

Another embodiment is to have signal paths from the primary side to the LED`s 14a and 14b, without the need for integrated circuit at the secondary side. Such signal paths may have different transfer functions such that the light output of the LED`s behave in a different way with respect to transferred power, therefore varying the light output ratio.

Fig. 5 illustrates a further embodiment according to the application. What differs from the embodiment of Fig. 4 is, that on the secondary side, two integrated circuits 22, 22', are provided. The transformer 18 is driven, such that light intensity information provides for on both secondary inductances the same output power. However, the phases of the secondary inductances are shifted by 180°. That is, when the diode 26a is conductive, diode 26b is not conductive and vise versa. The

phase information is provided to each of the circuits 22, 22`. Depending on this phase information, the LEDs 14a, 14b are turned on and off for a longer or a shorter period. This allows for adjusting the brightness of the LEDs independent of each other. The overall brightness of the LEDs 14a, 14b is, however, adjusted by the phase cut DC voltage on the secondary side.

Fig. 6 illustrates another embodiment. According to Fig. 6 the circuit 23 is arranged at the output of component 10. Circuit 23 may obtain both light intensity information as well as the dimming information for driving the lighting devices 14a, b. This information may be provided to circuit 22, within which the drive ratio is obtained and the lighting devices 14 are driven accordingly.

The proposed component allows for translating the phase information into useful color adjustments for LEDs. This allows simple architecture for providing complains with already known phase cut dimmers. Lighting applications using phase cut dimmers, like residential lighting and commercial lighting may thus be propagated to use LED lighting devices.

CLAIMS:

1. A component comprising:
- an input for receiving input power from a primary power supply (10),
- at least one circuit (16, 22),
- wherein the circuit (16, 22) is arranged for receiving within the received input power at least light intensity information,
- wherein the circuit (16, 22) is arranged for driving at least two lighting devices (14) at least according to the light intensity information, and
- wherein the circuit (16, 22) is arranged for determining the driving ratio between the at least two lighting devices (14) according to the light intensity information.

2. The component of claim 1, wherein the circuit is a first circuit (16) arranged at a primary side.

3. The component of claim 1, wherein a second circuit (22) is arranged for driving at least two lighting devices (14) and for determining the driving ratio between the at least two lighting devices according to the light intensity information.

4. The component of claim 3, further comprising at least one bypass switch arranged across at least one of the lighting devices (14) for applying the driving ratios of the at least two lighting devices (14).

5. The component of claim 2, wherein the first circuit (16) comprises a switching element (16a), wherein different transfer functions between the switching element (16a) and the lighting devices (14) are provided for determining the driving ratios.

6. The component of claim 5, further comprising at least one storing element coupled to each lighting device (14).

7. The component of claim 6, wherein the storing element is at least one of:
A) capacitor,
B) inductor.

8. The component of claim 1, further comprising a transformer (18) for transforming the input power on a primary side to output power on a secondary side, the transformer (18) electrically decoupling the primary side from the secondary side.

9. The component of claim 3, wherein the first and/or the second circuit (16, 22) comprises either an integrated circuit or a discrete circuit.

10. The component of claim 3, wherein the second circuit (22) determines the driving ratio from a signal input to a dedicated input pin (22e) of the second circuit.

11. The component of claim 10, wherein the second circuit (22) determines a driving ratio depending on a pre-programmed color point curve.

12. The component of claim 2, wherein the first circuit (16) creates a stable DC voltage on the secondary side depending on the light intensity information.

13. The component of claim 12, wherein the first circuit transmits dimming information to the second circuit (22) and wherein the second circuit (22) determines from the dimming information the driving ratio between the at least two lighting devices (14).

14. The component of claim 12, wherein an opto-coupler (20) transmits the dimming information from the first circuit (16) to the second integrated circuit (22).

15. The component of claim 12, wherein the first circuit (16) transmits an analogue signal or a pulse-width modulated signal carrying the dimming information to the second circuit (22).

16. The component of claim 2, wherein the first circuit (16) creates a pulsed DC voltage on the secondary side depending on the light intensity information.

17. The component of claim 16, wherein the first circuit (16) creates a phase cut DC voltage on the secondary side depending on the light intensity information.

18. The component of claim 16, wherein the second circuit (22) determines the driving ratio between the at least two lighting devices (14) from the pulsed DC voltage.

19. The component of claim 17, wherein the first circuit (16) is arranged for determining at least light intensity information from a phase cut input voltage.

20. The component of claim 19, wherein the first circuit (16) comprises the at least one switching element (16a) for converting the phase cut input voltage into a light intensity depending drive signal for the transformer (18).

21. The component of claim 1, wherein the driving ratio between the at least two lighting devices (14) is such that the color temperature of the combined light of the at least two lighting devices (14) decreases with decreasing light intensity .

22. The component of claim 1, wherein the lighting device (14) is an LED.

23. Integrated circuit with a component of claim 1.

24. System with a component of claim 1, and at least two lighting devices (14) driven by the component of claim 1.

25. The system of claim 24, wherein the lighting devices (14) are semiconductor lighting devices or organic lighting devices.

26. The system of claim 24, further comprising a phase cut dimmer arranged for providing the input power from the primary power supply (10).

27. Method comprising:

- receiving input power from a primary power supply,
- receiving within at least one circuit (16, 22) at least light intensity information from the input power,
- determining at least driving ratio between the at least two lighting devices (14) and driving a lighting device (14) at least according to the light intensity information with the circuit (16, 22).

28. Computer program comprising instructions operable to cause a processor to configure a component of claim 1 to

- receive input power from a primary power supply,
- receive within a at least one circuit (16, 22) at least light intensity information from the input power,
- determine at least driving ratio between the at least two lighting devices (14) and driving a lighting device at least according to light intensity information with the circuit (16, 22).

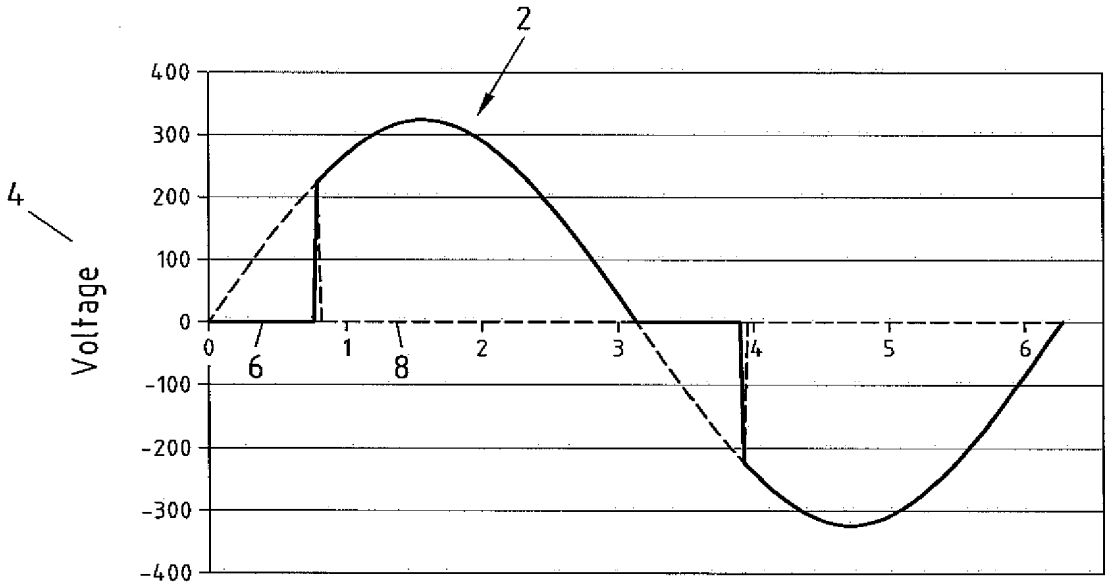


Fig.1

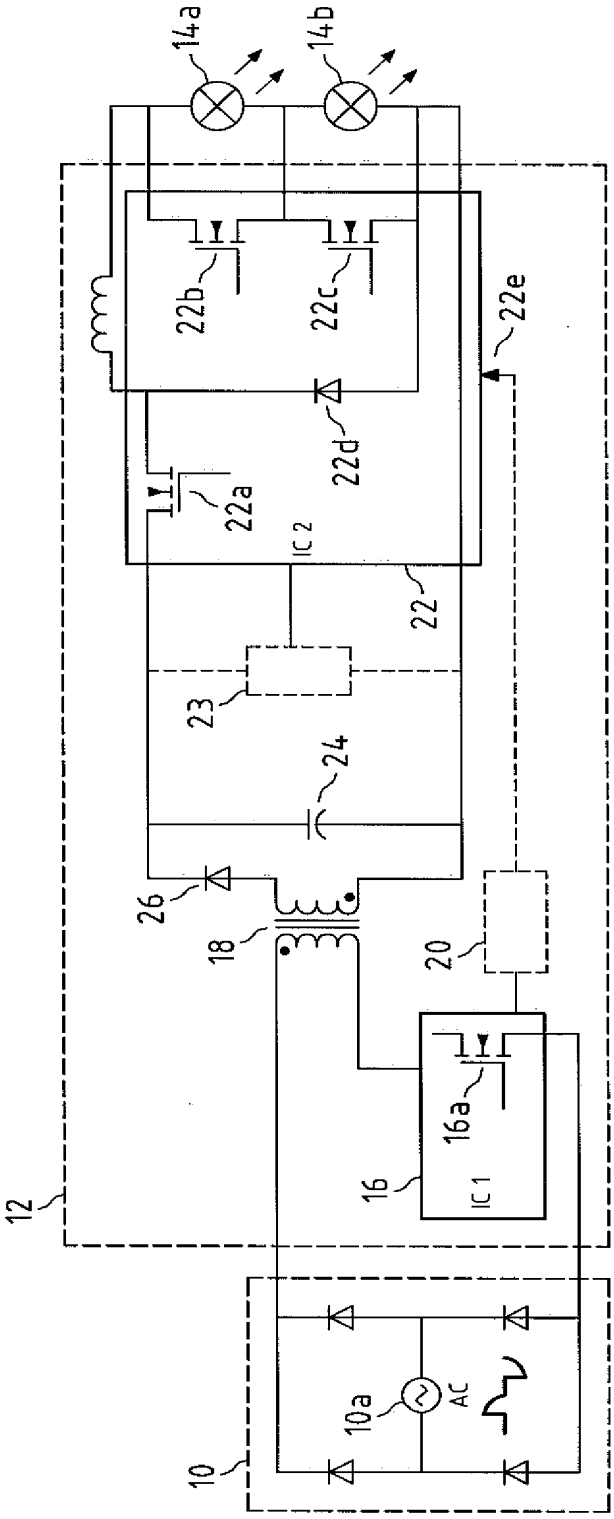

14a
14b
22b
22c
22e
22d
22a
IC 2
22
23
24
26
18
20
16a
16
IC 1
12
10a
AC
10

Fig.2

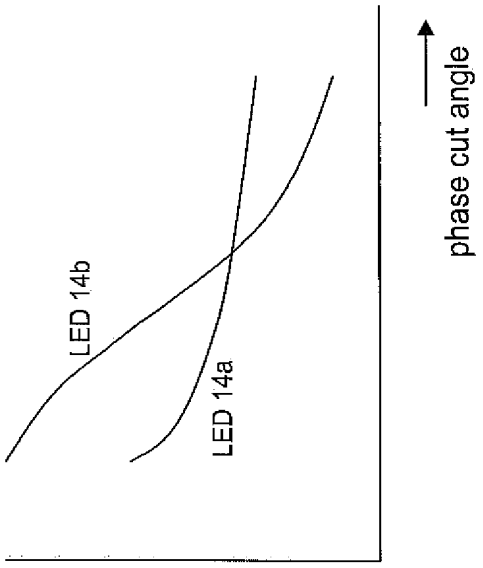


Fig. 3

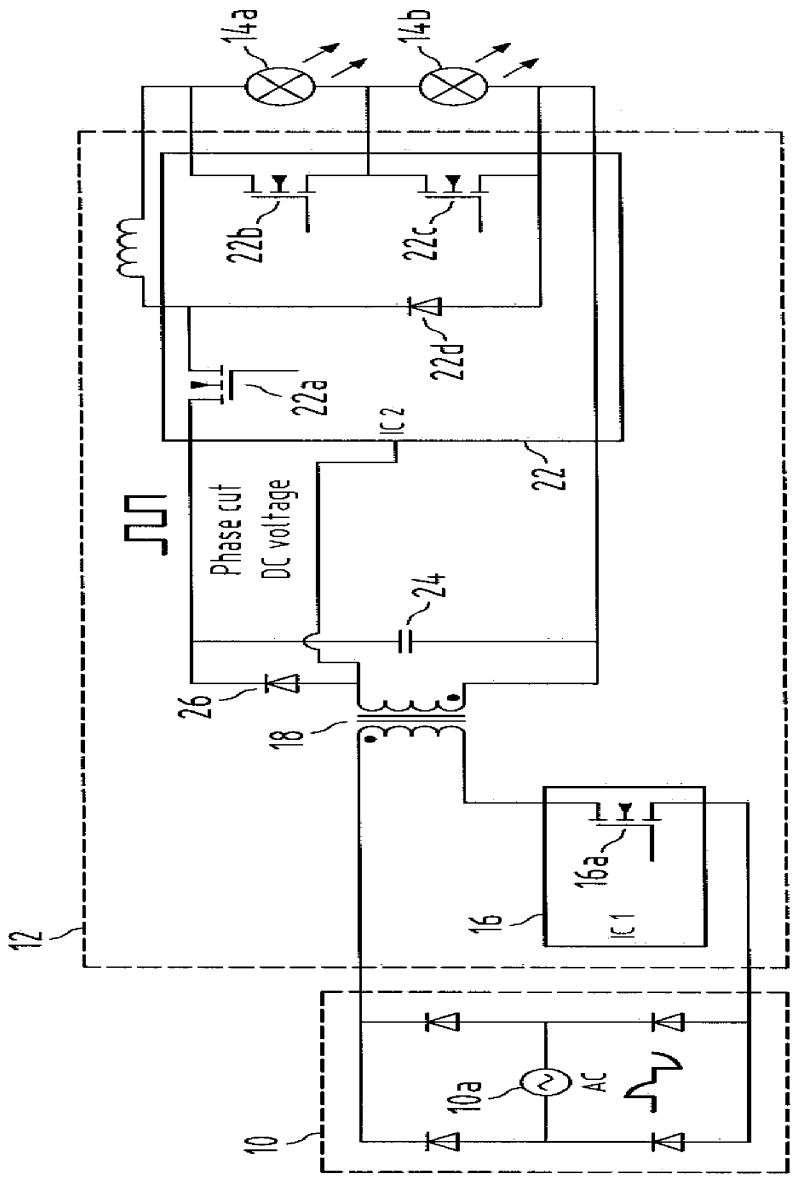


Fig.4

PGR2023-00016 - Home Depot
Ex. 1003 - Page 1838

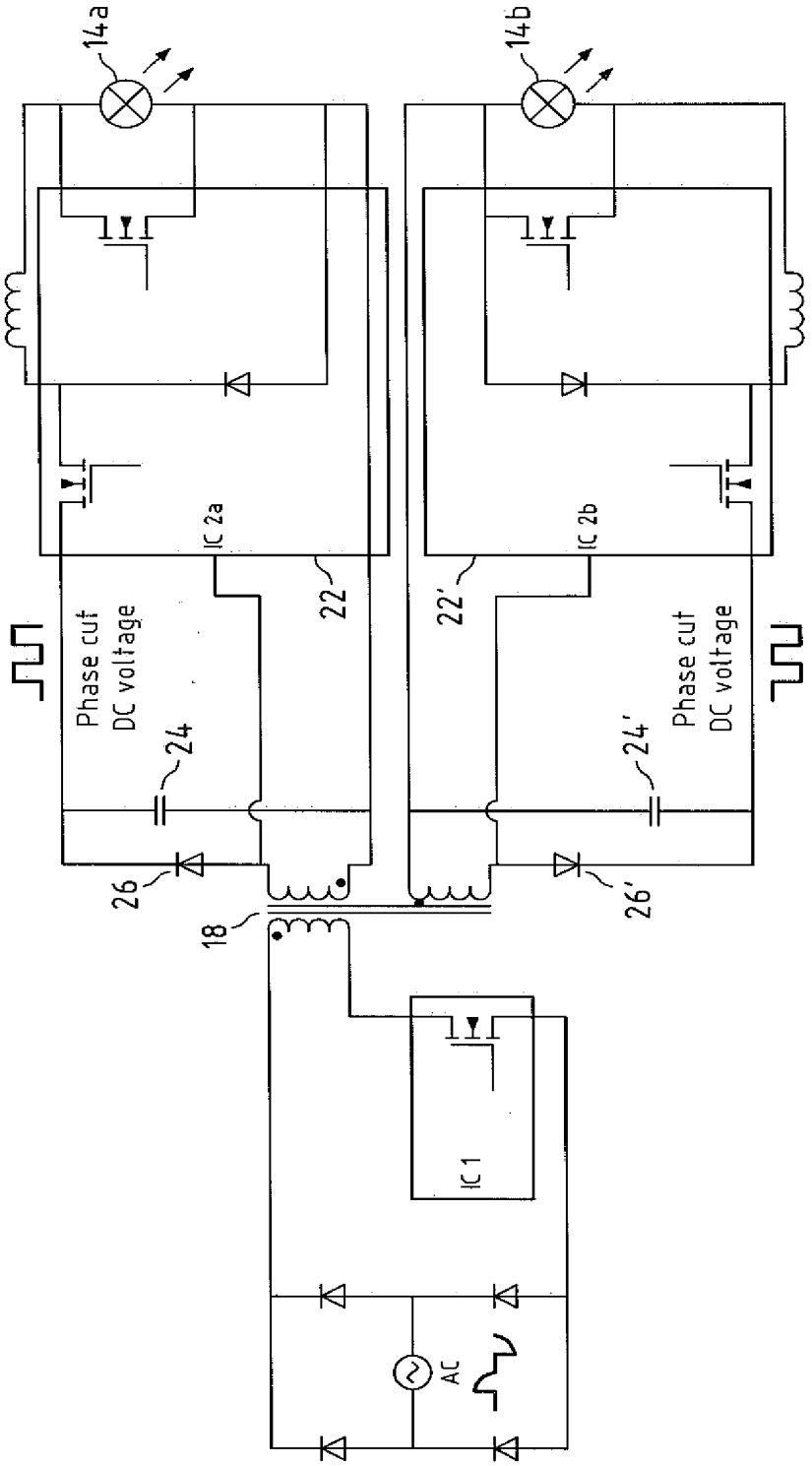

14a
14b
IC 2a
IC 2b
22
22'
Phase cut
DC voltage
24
24'
26
26'
18
IC 1
AC

Fig.5

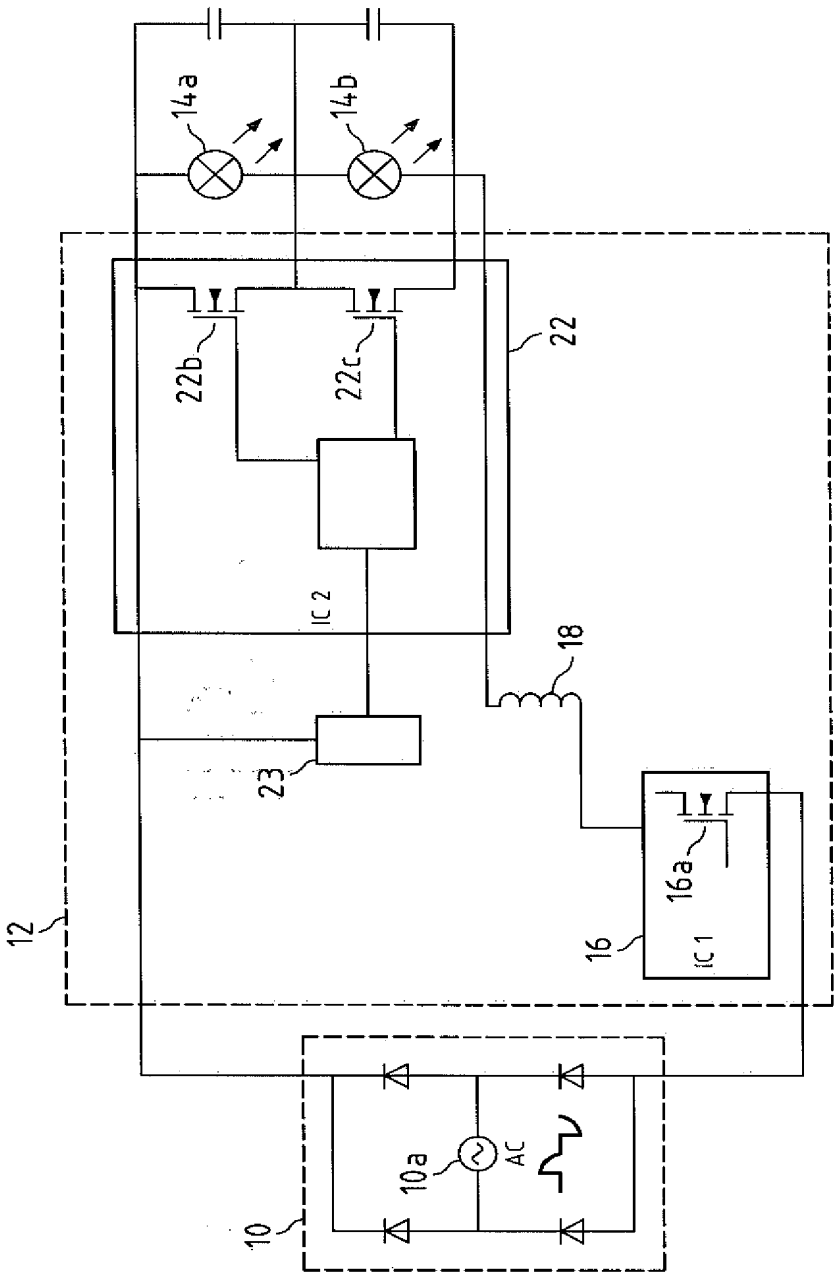


Fig.6

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2009/053385

A. CLASSIFICATION OF SUBJECT MATTER
INV. H05B33/08

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H05B

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

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2008/094423 A1 (SUMMERLAND DAVID T [GB]) 24 April 2008 (2008-04-24) paragraph [0025] - paragraph [0056]; figure 1	1-28
X	US 2008/094003 A1 (OOSTERBAAN THIJS [NL] ET AL) 24 April 2008 (2008-04-24) pages 2-3; figure 4	1-28
X	WO 2006/067521 A1 (HAYES STEPHEN BRYCE [GB]) 29 June 2006 (2006-06-29) pages 7-10; figure 1	1-28
X	US 7 288 902 B1 (MELANSON JOHN L [US]) 30 October 2007 (2007-10-30) columns 4-8; figures 4,5	1-28

-/--

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
17 December 2009	23/12/2009

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31–70) 340–2040, Fax: (+31–70) 340–3016	Morrish, Ian

Form PCT/ISA/210 (second sheet) (April 2005)

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2009/053385

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 2007/093938 A1 (KONINKL PHILIPS ELECTRONICS NV [NL]; BLOM ANTON C [NL]) 23 August 2007 (2007-08-23) page 2 - page 9; figure 1	1-28

Form PCT/ISA/210 (continuation of second sheet) (April 2005)

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/IB2009/053385

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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		JP 2008507817 T	13-03-2008
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		WO 2008112822 A2	18-09-2008
WO 2007093938 A1	23-08-2007	NONE	

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(74) Agents: **BEKKERS, Joost, Johannes, Joseph** et al.; High Tech Campus 44, NL-5656 AE Eindhoven (NL).

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(54) **Title**: DRIVER FOR PROVIDING VARIABLE POWER TO A LED ARRAY

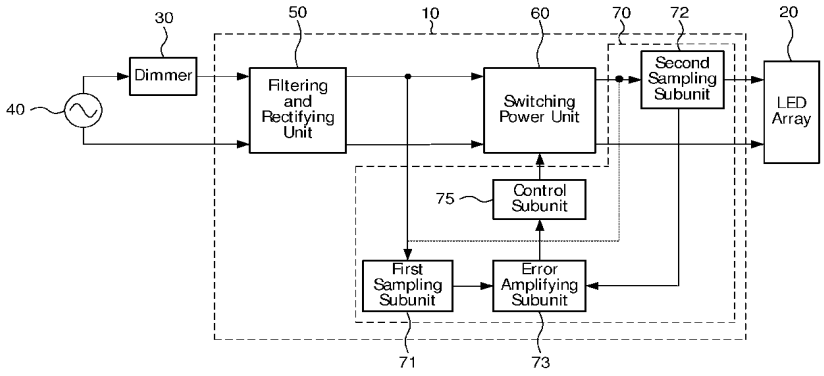


FIG. 1

(57) **Abstract**: A driver for providing variable power to a LED array, which can be coupled through a dimmer to an AC power supply, comprises a filtering and rectifying unit, a switching power unit, and a control unit. The filtering and rectifying unit is adapted to attenuate EMI and convert an AC power from the AC power supply into a DC power output. The switching power unit is adapted to receive the DC power output and provide an output current to the LED array. The control unit is adapted to determine the output current in response to a comparison between a dim reference signal representing phase-modulating information of the AC power and a feedback signal representing an average value of the output current. The LED array can thus be controlled by a dimmer at the primary side so as to adjust its light output, and can further be utilized in currently existing lighting infrastructures.

WO 2010/035155 A2

DRIVER FOR PROVIDING VARIABLE POWER TO A LED ARRAY

FIELD OF THE INVENTION

The present invention relates in general to a driver for providing power to a light-emitting diode (LED) array, more specifically, to a driver for providing variable power to a LED array. The present invention also relates to a method of providing variable power to a LED array.

BACKGROUND OF THE INVENTION

Light-emitting diodes (LEDs) are used as a kind of solid-state light source. Compared with traditional light sources, such as incandescent or fluorescent lamps, its advantages are compactness, high efficacy, good color, various and variable colors, etc. Thus, LEDs are widely applied in indoor lighting, decoration lighting, and outdoor lighting. Some of these applications require the output light from the LEDs to be adjustable from 1% to 100% of the maximum light output, that is, users often require a dimming capability.

In order to dim the light output of the LEDs, it is required to control the output current of the LED driver to follow a certain dim input. Currently, most LED drivers achieve the dimming function by chopping the output current through an extra Mosfet, and the current to the LEDs can be controlled by changing the duty cycle of the Mosfet via a dim input. Alternatively, the dimming function is achieved by modulating the output current by a dim input, which is usually an analog voltage level or PWM (pulse width modulation) signal. These dimming methods have a common feature in that the dim input is at the secondary side of the driver, which is referred to as secondary dimming.

In traditional lighting, a phase-modulating dimmer is commonly used for dimming the light output and is usually connected at the power input terminal of the driver. The phase-modulating dimmer cuts the phase of the input voltage from the power supply, and finally the output current to a burner is controlled. By turning a knob of the dimmer, users can thus easily control the light output. Since the dim input is at the primary side of the driver, such a dimming method is referred to as primary dimming.

Due to the dim input of the LED driver described above at the secondary side rather than at the primary side, these LED drivers are incompatible with phase-modulating dimmers, which are originally utilized to alter the brightness or intensity of the light output in traditional lighting. Consequently, many of these drivers are incompatible with the existing lighting system infrastructure, such as the lighting systems typically utilized for incandescent or fluorescent lighting.

It is therefore desirable to develop a LED driver which is compatible with the existing phase-modulating dimmers.

SUMMARY OF THE INVENTION

In accordance with one aspect, the present invention provides a driver for providing variable power to at least one LED array. The driver is intended to be coupled through a phase-modulating dimmer to the AC power supply and comprises a filtering and rectifying unit, a switching power unit, and a control unit. The filtering and rectifying unit is adapted to attenuate electromagnetic interference (EMI) from/to the AC power supply and convert an AC power from the AC power supply into a DC power output. The switching power unit is adapted to receive the DC power output from the filtering and rectifying unit and provide an output current to the LED array. The control unit is adapted to determine the output current to the LED array in response to a comparison between a dim reference signal representing phase-modulating information of the AC power when the phase angle of the AC power is cut by the dimmer and a feedback signal representing an average value of the output current to the LED array.

In accordance with another aspect, the present invention provides a lighting device which comprises at least one LED array and the above-mentioned driver.

In accordance with yet another aspect, one embodiment of the invention provides a method of providing variable power to at least one LED array. The method comprises the steps of supplying current to the LED array by means of a power supply, and adjusting the current in accordance with a dimming demand signal at an input side of the power supply, by performing a comparison between a dim reference signal representing phase-modulating information at the input side of the power supply and a feedback signal representing an average value of the current to the LED array.

With the help of the driver/method according to embodiments of the invention, the LED array can be controlled by any of a variety of switches at the primary side (i.e. the input side), such as a phase-modulating dimmer, to adjust the light output, and can be further utilized with the currently existing lighting infrastructure.

BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing forms as well as other forms, features and advantages of the present invention will become apparent from the following detailed description of preferred embodiments with reference to the accompanying drawings. The detailed description and drawings are merely illustrative and do not limit the present invention.

Fig. 1 is a schematic diagram of a driver according to a first embodiment of the invention;

Fig. 2 is a circuit diagram of a driver according to a second embodiment of the invention;

Fig. 3 is a circuit diagram of a driver according to a third embodiment of the invention.

DESCRIPTION OF EMBODIMENTS

Fig. 1 illustrates a driver 10 according to a first embodiment of the present invention. The driver 10 is configured to provide variable power to a LED array 20. The driver 10 is coupled through a dimmer 30 to an AC power supply 40 for transforming an AC power from the AC power supply 40 into a DC power which is suitable for the LED array 20 and satisfies different dimming requirements.

The driver 10 comprises a filtering and rectifying unit 50, a switching power unit 60, and a control unit 70. The filtering and rectifying unit 50 is adapted to attenuate electromagnetic interference (EMI) from and/or to the AC power supply 40 and further convert an AC power from the AC power supply 40 into a DC power output. The switching power unit 60 is adapted to receive the DC power output from the filtering and rectifying unit 50, and further provide an output current to the LED array 20 under the control of the control unit 70. The control unit 70 is adapted to determine the output current to the LED array 20 in response to a comparison between a dim reference signal representing phase-modulating information of the AC power when the phase angle of the AC power is modulated by the dimmer 30 and a feedback signal representing an average value of the output current to the

LED array 20.

Advantageously, the control unit 70 may comprise a first sampling sub-unit 71, a second sampling sub-unit 72, an error amplifying sub-unit 73 and a control sub-unit 75.

The first sampling sub-unit 71 is configured to sample the dim reference signal and further cause the dim reference signal to be in a low frequency range. In some embodiments, the dim reference signal may be approximately a flat voltage signal. Here and in similar situations hereinafter, "approximately" is understood to mean that the voltage signal may fluctuate in a limited and acceptable range and is possibly not an absolutely flat signal. For example, the voltage value of the voltage signal may fluctuate around a certain value with an error of ±5%. Alternatively, the first sampling sub-unit 71 can be coupled to a primary side or a secondary side of the switching power unit 60.

The second sampling sub-unit 72 is configured to sample the feedback signal and further cause the feedback signal to be in a low frequency range. In some embodiments, the feedback signal is filtered out of high-frequency switching components and kept in a voltage waveform in accordance with a current waveform of the output current to the LED array 20.

The error amplifying sub-unit 73 is configured to implement the comparison between the dim reference signal from the first sampling sub-unit 71 and the feedback signal from the second sampling sub-unit 72. In some embodiments, the error amplifying sub-unit 73 is configured to have a crossover frequency of 5-30HZ.

The control sub-unit 75 is configured to implement the control operation on the switching power unit 60 based on the comparison result from the error amplifying sub-unit 73.

When the dimmer 30 is set at different operation levels by a user, the voltage of the AC power supply 40 will be cut at different phase angles, which will be embodied in the dim reference signal and further embodied in the comparison result. Therefore, the switching power unit 60 can operate under the control of the control unit 70 for providing an output current to the LED array 20 in accordance with the dimming demand signal by the user. The dimming function is realized by controlling the average value of the output current to the LED array 20 following the phase cut of the voltage of the AC power from the AC power supply 40.

Fig. 2 is an example of a circuit diagram of a driver 100 according to a second embodiment of the invention. The driver 100 is coupled between a LED array 120 and an AC power supply 140 via a dimmer 130 for providing a DC power to the LED array 120. The driver 100 comprises a filtering and rectifying unit 150 including an EMI filter 151 and an AC/DC converter 152, a switching power unit 160, and a control unit 170 including a first sampling sub-unit 171, a second sampling sub-unit 172, an error amplifying sub-unit 173, a third sampling sub-unit 174 and a control sub-unit 175.

The EMI filter 151 is adapted to attenuate electromagnetic interference (EMI) from/to the AC power supply 140. The AC/DC converter 152 is adapted to convert an AC power from the AC power supply 140 into a DC power output and may be a bridge rectifier. Alternatively, the EMI filter 151 and the AC/DC converter 152 may be any type in the art and a detailed description thereof will be omitted.

The switching power unit 160 is coupled between the AC/DC converter 152 and the LED array 120 and configured to receive the DC power output from the AC/DC converter 152 and further provide an output current to the LED array 120. The switching power unit 160 comprises a flyback transformer T1, an output rectifier diode D3, an output filter capacitor C6, an active switching transistor Q1, and a resistor R15.

The flyback transformer T1 includes a primary winding W1, a secondary winding W2 and an additional winding W3. The primary winding W1 combined with the active switching transistor Q1 and resistor R15 in series is coupled between an output terminal of the AC/DC converter 152 and ground at the primary side. The secondary winding W2 is connected to the LED array 120 via the rectifier diode D3 for providing current to the LED array 120. The capacitor C6 is connected in parallel with the LED array 120 and located after the rectifier diode D3 in the current flow direction. The output current to the LED array 120 equals the capacitor C6 current subtracted from the rectifier diode D3 current. The capacitor C6 current has a high AC frequency, so the output current to the LED array 120 is maintained at a low frequency by filtering the rectifier diode D3 current with capacitor C6. The additional winding W3 is operable to provide a zero-crossing detection signal to the control unit 170, as is well-known to those skilled in the art. The flyback transformer T1 is controlled by the control unit 170 via the active switching transistor Q1, which will be illustrated below.

The first sampling sub-unit 171 is configured to detect a dim reference signal from the primary side of the flyback transformer T1. The first sampling sub-unit 171 comprises resistors R1, R2, R3, a capacitor C1, a Zener diode D1, and an operational amplifier O1. Resistors R1 and R2 are first connected in series and then coupled between an output terminal of the AC/DC converter 152 and ground at the primary side. Resistors R1 and R2 form a voltage divider so as to sample the dim reference signal from the output of the AC/DC converter 152, and consequently the dim reference signal can represent phase-modulating information of the AC power. The phase modulation is caused by the dimmer 130 when set at a different operation level by a user. Resistor R3 and capacitor C1 are connected in series and then coupled between ground and a node of resistors R1 and R2. Resistor R3 and capacitor C1 form a low-pass filter, and their values are selected in such a way that they can cause the dim reference signal to be in a low frequency range. Alternatively, the values of resistor R3 and capacitor C1 are selected in such a way that the dim reference signal may even be approximately a flat voltage signal. Zener diode D1 is connected in parallel with capacitor C1 and is configured to clamp the maximum of the dim reference signal, so that the maximum of the output current to the LED array 120 can be limited in the case of a high input voltage from the AC power supply 140, e.g. 264V. Then the dim reference signal is buffered by the operational amplifier O1 before being sent to the error amplifying sub-unit 173. Consequently, after the above-mentioned treatments, the dim reference signal is extracted to represent phase-modulating information of the AC power and be in a low frequency range as well as at a level that the error amplifying sub-unit 173 can allow.

The second sampling sub-unit 172 is configured to sense a feedback signal representing an average value of the output current to the LED array 120 and cause the feedback signal to be in a low frequency range. Alternatively, the second sampling sub-unit 172 is configured to cause the feedback signal to be in a voltage waveform in accordance with a current waveform of the output current to the LED array 120. The second sampling sub-unit 172 comprises a current transformer T2, resistors R11, R12, R13, R14, a capacitor C5, a diode D2, and an operational amplifier O3.

The current transformer T2 includes a primary winding W4 and a secondary winding W5. The primary winding W4 can be coupled before or after diode D3, but before capacitor C6, in the current flow direction. The secondary winding W5, diode D2 and resistor R13 are

sequentially connected in series to form a loop. The feedback signal is extracted from a node of diode D2 and resistor R13. The voltage of the feedback signal V_f is proportional to the rectifier diode D3 current I_{D3}, and $V_f=N_{T2} X R_{13} X I_{D3}$, wherein N_{T2} is the ratio of turns of T2. The feedback signal is thus kept in a voltage waveform in accordance with a current waveform of the output current to the LED array 120.

Resistor R14 and capacitor C5 are connected in series and then coupled between ground at the primary side and a node of diode D2 and resistor R13, and form a low-pass filter to remove high-frequency components from the feedback signal. The values of resistor R14 and capacitor C5 are selected in such a way that the feedback signal is in a low frequency range. After the low-pass filter, the feedback signal represents the average current value of the output current to the LED array 120 over a mains period, in a low bandwidth.

The operational amplifier O3 is employed to enlarge the scale of the voltage of the feedback signal V_f and functions as an impedance matcher to subsequent circuitry. Resistors R11 and R12 are connected in series between ground at the primary side and the output terminal of the operational amplifier O3, and a node of resistors R11 and R12 is connected to an inverting input terminal of the operational amplifier O3. The voltage of the feedback signal V_f will thus be increased by 1+R11/R12 and will be at a level that the error amplifying sub-unit 173 can allow.

The error amplifying sub-unit 173 is configured to implement the comparison between the dim reference signal and the current feedback signal and produce a dim control voltage signal based on the comparison to the control sub-unit 175. In some embodiments, the dim control voltage signal varies as the dimmer 130 is varied from its highest to its lowest setting. As described above, the setting of dimmer 130 is sensed via the first sampling sub-unit 171, and embodied in the dim reference signal. As will be more fully explained below, the dim control voltage signal is used to control the light output of the LED array 120 via control of the output current to the LED array 120. In some embodiments, the light output of the LED array 120 is at its lowest level when the dim control voltage signal is at its highest level, and the light output of the LED array 120 is at its highest level when the dim control voltage signal is at its lowest level.

The error amplifying sub-unit 173 comprises an operational amplifier O2 and components such as resistors R7, R8, R9, R10 and capacitor C4. The operational amplifier O2 receives

the dim reference signal as an inverting input from the first sampling sub-unit 171 via resistor R9, and the feedback signal as a non-inverting input from the second sampling sub-unit 172 via resistor R10, and outputs a DC voltage as the dim control voltage signal for an input of the control sub-unit 175. The average value of the output current to the LED array 120 will thus follow the dim reference signal, i.e. the input voltage which has a phase angle cut by the dimmer 130. The series-wound combination of resistor R7 and capacitor C4 is in parallel with resistor R8 and coupled between the output terminal and the inverting input of the operational amplifier O2. The DC gain of the operational amplifier O2 is R8/R9. Resistor R7 and capacitor C4 will introduce a zero-crossing into the control loop of the control unit 170. Increasing the value of capacitor C4 will move this zero-crossing towards the low-frequency side and accordingly gives the control loop a larger phase margin, resulting in a stabler control.

The third sampling sub-unit 174 is configured to detect a voltage signal reflecting the voltage waveform of the AC power from the AC power supply 140, and the voltage signal is used to implement a power factor correction (PFC). In one embodiment, the third sampling sub-unit 174 comprises resistors R4, R5, and capacitor C2. Resistors R4, R5 are sequentially coupled in series between an output terminal of the AC/DC converter 152 and ground at the primary side, and capacitor C2 is in parallel with resistors R5. The resistors R4 and R5 form a voltage divider, and the voltage signal is extracted from a node of resistors R4 and R5 and formed on resistor R4. The voltage signal is thus reduced and directly proportional to the output voltage of the AC/DC converter 152, and will reflect the voltage waveform of the output from the AC/DC converter 152, and will accordingly reflect the voltage waveform of the AC power from the AC power supply 140 after the phase angle is cut by dimmer 130. The voltage signal is further provided to the control sub-unit 175 so as to be multiplied by the dim control voltage signal and used to force the output current to the LED array 120 so as to follow the waveform of the output voltage of the AC power. A high power factor can therefore be achieved.

If a relatively lower power factor is acceptable, for example, for a LED array with an input power lower than 25W, the third sampling sub-unit 174 cannot be included in some embodiments.

The control sub-unit 175 is selected to include an integrated circuit and is configured to

provide a transformer control signal to control the operation of the flyback transformer T1 based on the dim control voltage signal from the error amplifying sub-unit 173 and/or the voltage signal for PFC control from the third sampling sub-unit 174. In some embodiments, the control sub-unit 175 comprises a control IC such as L6561 or L6562 manufactured by ST Microeletronics Inc, or MC33262 from Onsemi, which has power factor correction configuration, and some components such as resistors R6 and R16, and capacitor C3. In order to have a good PFC performance, it is better in some embodiments to keep the cross-over frequency of the control unit 170 lower than 50HZ, which is mainly determined by the value of resistor R6 and capacitor C3. Alternatively, the cross-over frequency of the control unit 170 can be designed to be lower than 15HZ, or even lower than 10HZ.

If there is no special requirement imposed on the power factor, the control IC can be alternatively selected in a configuration without a power factor correction, such as UC384X manufactured by Texas Instruments. The control sub-unit 175 is thus configured to provide a transformer control signal to control the operation of the flyback transformer T1 merely on the basis of the dim control voltage signal from the error amplifying sub-unit 173. Alternatively, the control sub-unit 175 may have a different configuration, e.g. it may comprise a programmed processor or unit, as long as such a configuration fulfils the above-mentioned function.

Via the transformer control signal, the control unit 170 can adjust the current flow through the winding W1 of the flyback transformer T1 so as to match the LED array 120 current demands. The transformer control signal is input to the flyback transformer T1 when the control sub-unit 175 of the control unit 170 pulses the gate of active switching transistor Q1 through resistor R16. The pulsed signals from the active switching transistor Q1 allow energy transfer through the transformer windings W1/W2 so as to provide the output current to the LED array 120.

Fig.3 is another example of a circuit diagram of a driver 200 according to a third embodiment of the invention. In general, the driver 200 has a configuration similar to that of the driver 100 shown in Fig.2. The driver 200 is also coupled, by way of example, between a LED array 220 and an AC power supply 240 via a dimmer 230 for providing a variable DC power to the LED array 220.

The driver 200 comprises a filtering and rectifying unit 250 including an EMI filter 251

and an AC/DC converter 252, a switching power unit 260, and a control unit 270 including a first sampling sub-unit 271, a second sampling sub-unit 272, an error amplifying sub-unit 273, a third sampling sub-unit 274, and a control sub-unit 275. Except for the first sampling sub-unit 271, the second sampling sub-unit 272 and the error amplifying sub-unit 273, other parts of the driver 200 are designed to have the same functions as those of the corresponding parts of the driver 100. These corresponding parts may therefore have a similar configuration. Consequently, the following description of the driver 200 will mainly focus on the first sampling sub-unit 271, the second sampling sub-unit 272 and the error amplifying sub-unit 273.

The first sampling sub-unit 271 is configured to detect a dim reference signal from a secondary side of the flyback transformer T3. The first sampling sub-unit 271 is designed with components and a layout similar to those of the first sampling sub-unit 171 of the driver 100, except for its connection to the flyback transformer T3. The first sampling sub-unit 271 comprises resistors R21, R22, R23, a capacitor C21, a Zener diode D21, and an operational amplifier O4. Resistors R21 and R22 are first connected in series and then coupled between an output terminal at the secondary side of flyback transformer T3 and ground at the secondary side. Consequently, resistors R21 and R22 form a voltage divider so as to sample the dim reference signal from the output of flyback transformer T3. A description on the function and connection of other components of the first sampling sub-unit 271 is not repeated anymore because it is similar to the first sampling sub-unit 171 described hereinbefore. The output of the flyback transformer T3 is proportional to its input, which follows the AC power from the AC power supply, so that the dim reference signal can represent phase-modulating information of the AC power. Alternatively, resistor R23 and capacitor C21 can cause the dim reference signal to be in a low frequency range, even approximately a flat voltage signal.

The second sampling sub-unit 272 comprises resistors R20, R31, R32 and R33, a capacitor C23, and an operational amplifier O6. Resistor R20 is connected to ground at the secondary side via its output terminal and to a node of capacitor 20 of the switching unit 260 and an output terminal of the LED array 220 via its input terminal. A feedback signal is extracted from the input terminal of the resistor R20, and the voltage of the feedback signal V_f is proportional to the rectifier diode D20 current I_{D20}, and $V_f = R_{20} * I_{D20}$. Resistor R33 and capacitor C23, similar to resistor R14 and capacitor C5 of driver 100, are

connected in series and then coupled between ground at the secondary side and the input terminal of the resistor R20, and form a low-pass filter to remove high-frequency components from the feedback signal. The function and layout of the operational amplifier O6, resistors R31 and R32 is the same as that of the operational amplifier O3, resistors R11 and R12 (see the second embodiment described above). Consequently, the feedback signal sampled by the second sampling sub-unit 272 can represent the average value of the output current to the LED array 220 over a mains period, in a low bandwidth, and is at a level that the error amplifying sub-unit 273 can allow.

The error amplifying sub-unit 273 comprises an operational amplifier O5 and components such as resistors R27, R28, R29, R30 and a capacitor C22. The operational amplifier O5 is adapted to receive the dim reference signal from the first sampling sub-unit 271 via resistor R29 and the feedback signal from the second sampling sub-unit 272 via resistor R30, and is adapted to produce a comparison result between the dim reference signal and the feedback signal. The function and layout of resistors R27 and R28, and capacitor C22 is the same as that of resistors R7 and R8, and capacitor C4, as described above with reference to the second embodiment.

Since the dim reference signal and the feedback signal are produced at the secondary side of the switching unit 260, and the comparison result is used to control the switching unit 260 at the primary side, an isolation device, such as an electro-optical isolation device, is needed to isolate the primary and the secondary side for reasons of security. In this embodiment, the error amplifying sub-unit 273 therefore further comprises an optical coupler P1 as the isolation device. The comparison result from the operational amplifier O5 is sent to the optical coupler P1 via resistor R26, and a dim control voltage signal is obtained from the emitter of the optical coupler P1 via resistor R24. Resistor R25 is connected between the emitter of the optical coupler P1 and primary ground.

The control sub-unit 275 then controls the switching power unit 260 on the basis of the dim control voltage signal from the error amplifying sub-unit 273 and /or the voltage signal for PFC control from the third sampling sub-unit 174. Consequently, the light output of the LED array 220 is adjusted in accordance with the dimming requirement imposed by the user by employing a common dimmer at the AC power input side.

In the embodiments described above and shown in Figs.2 and 3, the active switching

transistor Q1 of the switching power unit can be selected to be an n-channel Mosfet. In an alternative embodiment, other types of transistors, such as an insulated gate bipolar transistor (IGBT) or a bipolar transistor, can be used instead of an n-channel Mosfet so as to adjust the current.

In some embodiments, as described above, the switching power unit is in a single stage configuration. Such a configuration has advantages such as low cost and relatively easy design because of the smaller number of required components. In other embodiments, the switching power unit can be configured in a two-stage configuration and may comprise, for example, a boost converter followed by a flyback converter, or a flyback converter followed by a buck converter.

In embodiments of the present invention, the dimmer employed may be any one of a variety of switches in the art, preferably a phase-modulating dimmer; the LED array may be one array or multiple arrays of LEDs of any type or color, and each array may include at least one LED; the AC power supply may be 220V/50HZ or 110V/60HZ without any special requirement.

In some embodiments as described above, the response frequency of the whole control loop is quite low, which is achieved by a low cross-over frequency of the error amplifying sub-unit and the control sub-unit. By low-pass filtering the signals of the reference signal from the first sampling sub-unit and the feedback signal from the second sampling sub-unit, the control loop only handles the average value of the output current to the LED array in a low frequency range. Consequently, in some embodiments of the present invention, the proposed control scheme can relatively easily achieve the output current control together with power factor correction at the input side (i.e. the primary side).

For easy understanding, an example of a method of providing variable power to one or more LED arrays will now be given in combination with the driver 100 described above. First, a current is supplied to one or more LED arrays, such as LED array 120, by a power supply which may comprise the driver 100. Then, when a dimming demand signal is inputted at an input side of the power supply, the control unit 170 of the driver 100 will control the switching power unit 160 to adjust the current to the LED array 120 so as to satisfy the dimming demand. As described above, the control is implemented on the basis of a comparison between a dim reference signal sampled by the first sampling sub-unit 171

and a feedback signal sampled by the second sampling sub-unit 172. The dim reference signal represents phase-modulating information at the input side of the power supply. The feedback signal represents an average value of the current to the LED array 120. For more details, reference is made to the description of drivers 100 and 200.

As the dimming input is at the primary side (i.e. the input side), a common dimmer can be used in embodiments of the present invention so as to control the light output of the LED array, which makes it possible to utilize the LED array in currently existing lighting infrastructures.

The embodiments described above are merely preferred embodiments of the present invention. Other variations of the disclosed embodiments can be understood and effected by those skilled in the art in practicing the claimed invention, from a study of the drawings, the disclosure, and the appended claims. These variations shall also be considered to be within the scope of the present invention. In the claims and description, use of the verb "comprise" and its conjugations does not exclude other elements or steps, and the indefinite article "a" or "an" does not exclude a plurality.

CLAIMS

1. A driver for providing variable power to at least one LED array, which driver can be coupled through a phase-modulating dimmer to an AC power supply, the driver comprising:

- a filtering and rectifying unit adapted to attenuate electromagnetic interference from/to the AC power supply and convert an AC power from the AC power supply into a DC power output;

- a switching power unit receiving the DC power output from the filtering and rectifying unit and adapted to provide an output current to the LED array; and

- a control unit adapted to determine the output current to the LED array in response to a comparison between a dim reference signal representing phase-modulating information of the AC power when the phase angle of the AC power is cut by the dimmer and a feedback signal representing an average value of the output current to the LED array.

2. The driver according to claim 1, wherein the control unit comprises a first sampling sub-unit adapted to sample the dim reference signal and cause the dim reference signal to be in a low frequency range, and a second sampling sub-unit adapted to sample the feedback signal and cause the feedback signal to be in a low frequency range.

3. The driver according to claim 1, wherein the dim reference signal is approximately a flat voltage signal.

4. The driver according to claim 1, wherein the feedback signal is kept in a voltage waveform in accordance with a current waveform of the output current to the LED array.

5. The driver according to claim 1, wherein the cross-over frequency of the control unit is lower than 50HZ.

6. The driver according to claim 5, wherein the cross-over frequency is lower than 15HZ.

7. The driver according to claim 1, wherein the switching power unit is arranged in a single-stage configuration and comprises a flyback transformer.

8. The driver according to claim 1, wherein the control unit comprises a third sampling sub-unit adapted to sample a voltage signal reflecting a voltage waveform of the AC power, and wherein the control unit is adapted to implement a power factor correction in response to the voltage signal.

9. A lighting device comprising at least one LED array, wherein the lighting device further comprises a driver according to any one of claims 1 to 8.

10. A method of providing variable power to at least one LED array, the method comprising the steps of:

- supplying current to the LED array by means of a power supply; and

- adjusting the current in accordance with a dimming demand signal at an input side of the power supply, by performing a comparison between a dim reference signal representing phase-modulating information at the input side of the power supply and a feedback signal representing an average value of the current to the LED array.

11. The method according to claim 10, wherein the adjusting step comprises a first sub-step of sampling and low-pass filtering the dim reference signal, and a second sub-step of sampling and low-pass filtering the feedback signal.

12. The method according to claim 10, wherein the adjusting step is further based on a voltage signal reflecting the voltage waveform at the input side of the power supply for acquiring a power factor correction.

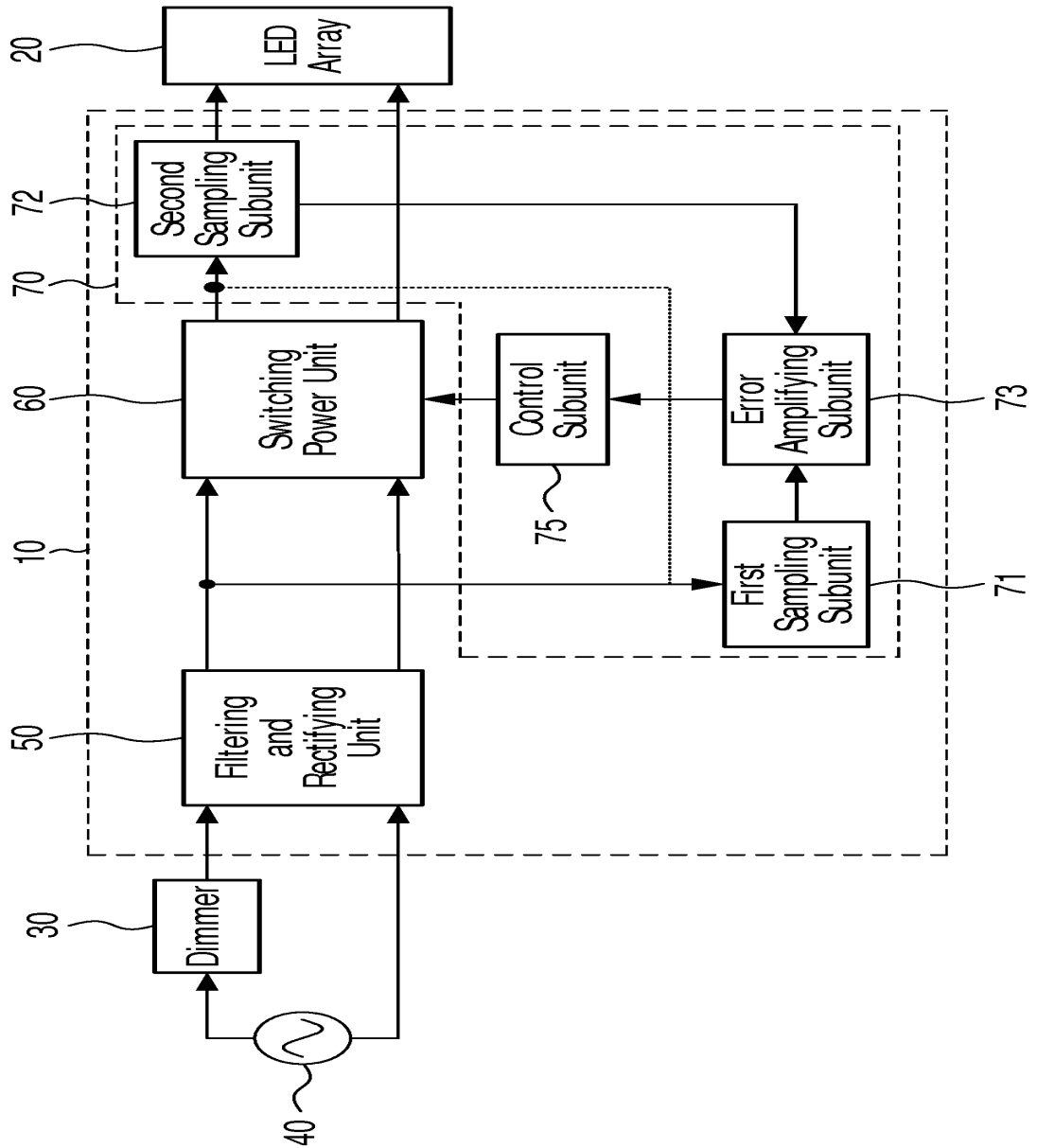


FIG. 1

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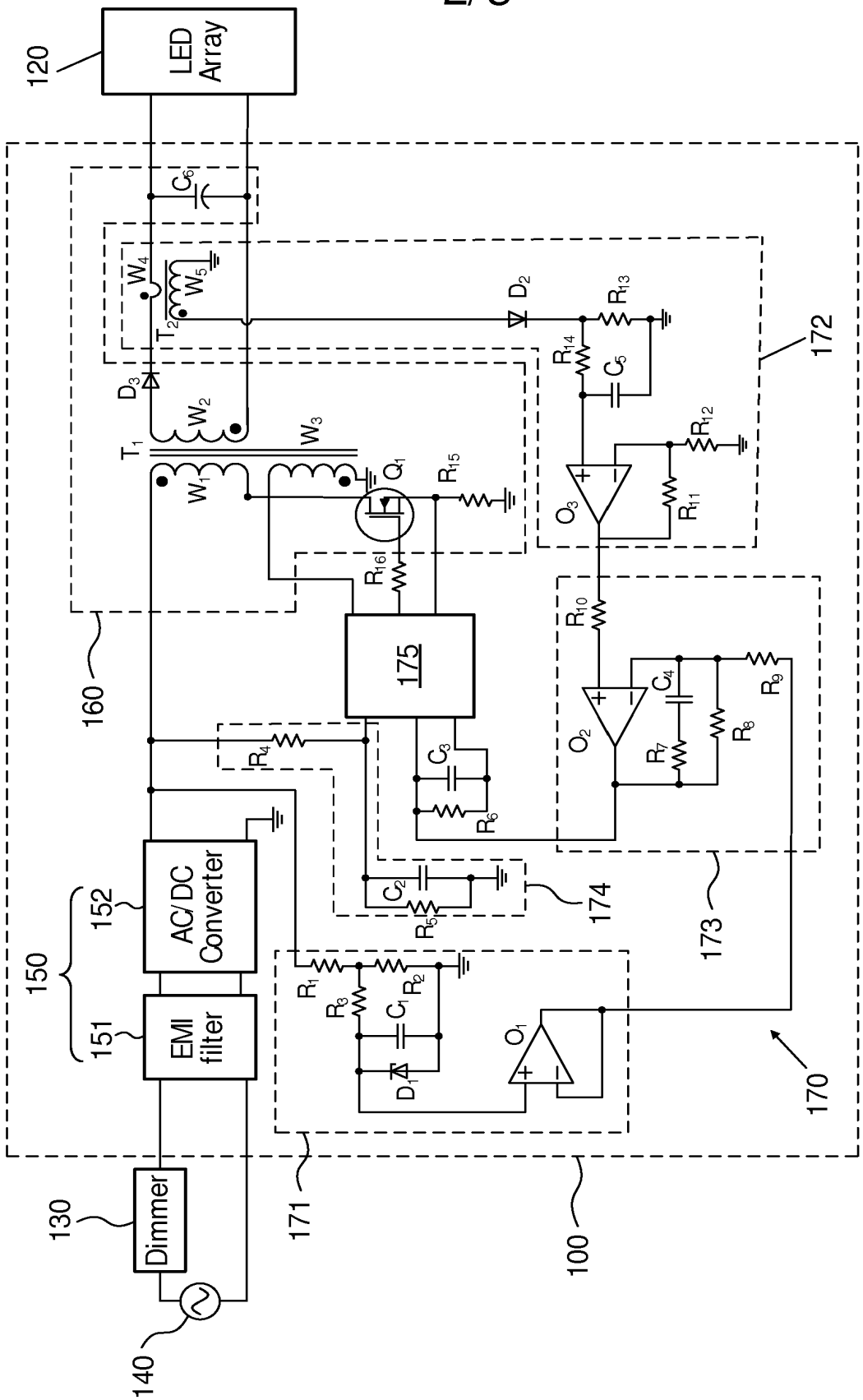

120
LED Array
160
175
172
173
174
171
170
100
150
152
AC/DC Converter
151
EMI filter
130
Dimmer
140
C_6
W_4
W_5
T_2
D_2
R_{13}
R_{14}
C_5
D_3
W_2
W_3
T_1
W_1
Q_1
R_{15}
R_{16}
O_3
R_{12}
R_{11}
R_{10}
O_2
C_4
R_9
R_8
R_7
R_4
C_3
R_6
C_2
R_5
R_1
R_3
C_1
R_2
D_1
O_1

FIG. 2

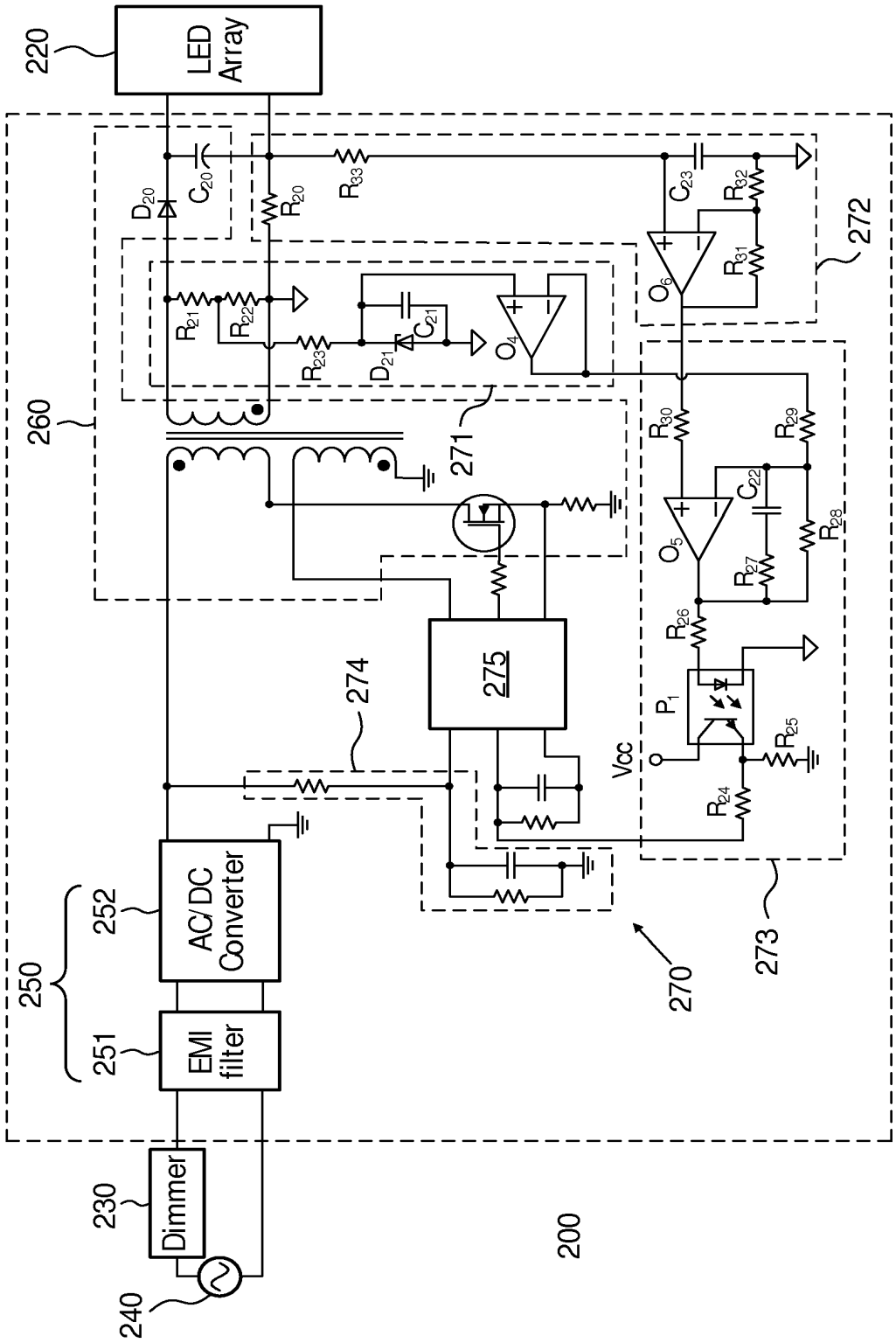

220
LED Array
260
271
272
273
274
275
270
200
250
252
AC/DC Converter
251
EMI filter
230
Dimmer
240
Vcc
D_{20}
C_{20}
R_{20}
R_{33}
C_{23}
R_{32}
R_{31}
O_6
R_{21}
R_{22}
R_{23}
D_{21}
C_{21}
O_4
R_{30}
R_{29}
C_{22}
R_{28}
O_5
R_{27}
R_{26}
P_1
R_{25}
R_{24}

FIG. 3

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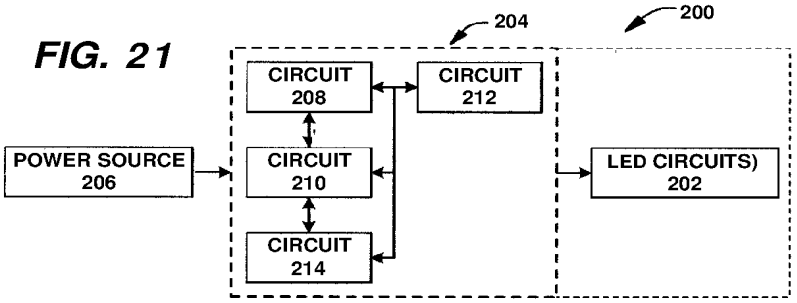
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(54) Title: LED LIGHTING SYSTEM

FIG. 21



(57) Abstract: An LED lighting system having at least one LED circuit and at least two circuits or drivers capable of receiving an AC voltage at a first frequency and having an output capable of driving the at least one LED circuit, wherein the output of each circuit or driver capable of driving the at least one LED circuit is provided to the at least one LED circuit through a circuit or sensor capable of permitting only a single output from the at least two circuits or drivers be provided to the at least one LED circuit.

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LED LIGHTING SYSTEM

RELATED APPLICATIONS

[Para 1] The application is a continuation-in-part of International Application No. PCT/US20 10/062235 filed December 28, 2010 which claims priority to U.S. Provisional Application No. 61/284,927 filed December 28, 2009 and U.S. Provisional Application No. 61/335,069 filed December 31, 2009 and is a continuation-in-part of U.S. Patent Application No. 12/287,267, filed October 6, 2008, which claims priority to U.S. Provisional Application No. 60/997,771, filed October 6, 2007; U.S. Patent Application No. 12/364,890 filed February 3, 2009 which is a continuation of U.S. Application No. 11/066,414 (now U.S. Patent No. 7,489,086) filed February 25, 2005 which claims priority to U.S. Provisional Application No. 60/547,653 filed February 25, 2004 and U.S. Provisional Application No. 60/559,867 filed April 6, 2004; International Application No. PCT/US201 0/001 597 filed May 28, 2010 which is a continuation-in-part of U.S. Application No. 12/287,267, and claims priority to U.S. Provisional Application No. 61/217,215, filed May 28, 2009; International Application No. PCT/US20 10/00 1269 filed April 30, 2010 which is a continuation-in-part of U.S. Application **No.** 12/287,267, and claims priority to U.S. Provisional Application No. 61/215,144, filed May 1, 2009; this application also claims priority to U.S. Provisional Application No. 61/333,963 filed May 12, 2010; the contents of each of these applications are expressly incorporated herein by reference.

TECHNICAL FIELD

[Para 2] The present invention relates to an LED lighting system having multiple circuits or drivers capable of providing an output to at least one LED circuit.

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FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

[Para 3] **None.**

BACKGROUND **OF THE INVENTION**

[Para 4] Description of the Related Art

[Para 5] LEDs are semiconductor devices that produce light when a current is supplied to them. LEDs are intrinsically DC devices that only pass current in one polarity and historically have been driven by DC voltage sources using resistors, current regulators and voltage regulators to limit the voltage and current delivered to the LED. Some LEDs have resistors built into the LED package providing a higher voltage LED typically driven with 5V DC or 12V DC.

[Para 6] Some standard AC voltages in the world include 12VAC, 24VAC, 100VAC, 110VAC, 120VAC, 220VAC, 230VAC, 240VAC and 277VAC. Therefore, it would be advantageous to have a single chip LED or multi-chip single LED packages and/or devices that could be easily configured to operate at multiple voltage levels and/or multiple brightness levels by simply selecting a voltage and/or current level when packaging the multi-voltage and/or multi-current single chip LEDs or by selecting a specific voltage and/or current level when integrating the LED package onto a printed circuit board or within a finished lighting product. It would also be advantageous to have multi-current LED chips and/or packages for LED lamp applications in order to provide a means of increasing brightness in LED lamps by switching in additional circuits just as additional filaments are switched in for standard incandescent lamps.

[Para 7] US 7,525,248 discloses a *chip-scale* LED lamp including discrete LEDs capable of being built upon electrically insulative, electrically conductive, or electrically semi

conductive substrates. Further, the construction of the LED lamp enables the lamp to be configured for high voltage AC or DC power operation. The LED based solid-state light emitting device or lamp is built upon an electrically insulating layer that has been formed onto a support surface of a substrate. Specifically, the insulating layer may be epitaxially grown onto the substrate, followed by an LED buildup of an n-type semiconductor layer, an optically active layer, and a p-type semiconductor layer, in succession. Isolated mesa structure of individual, discrete LEDs are formed by etching specific portions of the LED buildup down to the insulating layer, thereby forming trenches between adjacent LEDs. Thereafter, the individual LEDs are electrically coupled together through conductive elements or traces being deposited for connecting the n-type layer of one LED and the p-type layer of an adjacent LED, continuing across all of the LEDs to form the solid-state light emitting device. The device may therefore be formed as an integrated AC/DC light emitter with a positive and negative lead for supplied electrical power. For instance, the LED lamp may be configured for powering by high voltage DC power (e.g., 12V, 24V, etc.) or high voltage AC power (e.g., 110/120V, 220/240V, etc.).

[Para 8] US 7,213,942 discloses a single-*cAip* LED device through the use of integrated circuit technology, which can be used for standard high AC voltage (110 volts for North America, and 220 volts for Europe, Asia, etc.) operation. The ***single-chip*** *A C LED* device integrates many smaller LEDs, which are connected in series. The integration is done during the LED fabrication process and the final product is a single-c/iip device that can be plugged directly into house or building power outlets or directly screwed into incandescent lamp sockets that are powered by standard AC voltages. The series connected smaller LEDs are patterned by photolithography, etching (such as plasma dry etching), and metallization on a single *chip*. The electrical insulation between small LEDs within a *single-chip* is achieved by etching light emitting materials into the insulating substrate so that no light emitting

material is present between small LEDs. The voltage crossing each one of the small LEDs is about the same as that in a conventional DC operating LED fabricated from the same type of material (e.g., about 3.5 volts for blue LEDs).

[Para 9] Accordingly, single chip LEDs have been limited and have not been integrated circuits beyond being fixed series, fixed parallel or series parallel circuit configurations until the development of AC LEDs. The AC LEDs have still however been single circuit or parallel circuit fixed single voltage designs.

[Para 10] LED packages have historically not been integrated circuits beyond being fixed series, fixed parallel or fixed series parallel LED circuit configurations.

[Para 11] The art is deficient in that it does not provide a multi-voltage and/or multi-current circuit monolithically integrated on a single substrate which would be advantageous.

[Para 12] It would further be advantageous to have a multi-voltage and/or multi-brightness circuit that can provide options in voltage level, brightness level and/or AC or DC powering input power preference.

[Para 13] It would further be advantageous to provide multiple voltage level and/or multiple brightness level light emitting LED circuits, chips, packages and lamps "multi-voltage and/or multi-brightness LED devices" that can easily be electrically configured for at least two forward voltage drive levels with direct AC voltage coupling, bridge rectified AC voltage coupling or constant voltage DC power source coupling. For example, it would be advantageous to provide a device that can be driven with more than one AC or DC forward voltage "multi-voltage" at 6V or greater based on a selectable desired operating voltage level that is achieved by electrically connecting the LED circuits in a series or parallel circuit configuration and/or more than one level of brightness "multi-brightness" based on a switching means that connects and/or disconnects at least one additional LED circuit to and/or from a first LED circuit. It would be advantageous if the desired operating voltage

level and/or the desired brightness level electrical connection was achieved and/or completed at the LED packaging level when the multi-voltage and/or multi-brightness circuits and/or single chips are integrated into the LED package, or the LED package may have external electrical contacts that match the integrated multi-voltage and/or multi-brightness circuits and/or single chips within, allowing the drive voltage level and/or the brightness level select-ability to be passed on through to the exterior of the LED package and allowing the voltage level or brightness level to be selected at the LED package user, or the PCB assembly facility, or the end product manufacturer.

[Para 14] It would further be advantageous to provide at least two integrated circuits having a forward voltage of at least 12VAC or 12VDC or greater on a single chip or within a single LED package that provide a means of selecting a forward voltage when packaging a multi-voltage and/or multi-brightness circuit using discrete die (one LED chip at a time) and wire bonding them into a circuit at the packaging level or when packaging one or more multi-voltage and/or multi-brightness level single chips within a LED package.

[Para IS] It would further be advantageous to provide multi-voltage and/or multi-brightness level devices that can provide electrical connection options for either AC or DC voltage operation at preset forward voltage levels of 6V or greater.

[Para 16] It would further be advantageous to provide multi-brightness LED devices that can be switched to different levels of brightness by simply switching additional circuits on or off in addition to a first operating circuit within a single chip and or LED package. This would allow LED lamps to switch to higher brightness levels just like 2-way or 3-way incandescent lamps do today.

[Para 17] The benefits of providing multi-voltage circuits of 6V or greater on a single chip is that an LED packager can use this single chip as a platform to offer more than one LED packaged product with a single chip that addresses multiple voltage levels for various

end customer design requirements. This would also increase production on a single product for the chip maker and improves inventory control. This also improves buying power and inventory control for the LED packager when using one chip.

[Para 18] It would further be advantageous to have a LED lighting assembly which includes LED circuitry for AC or DC drive and a high frequency AC voltage transformer or inverter that could be used to convert low frequency voltages, like for example mains voltage or some other low voltage at 50/60 Hz, to a high frequency without a change in the voltage provided. For example, it would be advantageous to have a LED lighting power supply and/or driver capable of receiving 120 VAC at 60 Hz and be able to provide a high frequency AC output directly to an AC driven LED circuit(s), or alternatively to a DC driven LED circuit(s) through an AC-to-DC rectifier at a voltage equal to or different from the original input voltage to the power supply and/or driver.

[Para 19] It would be further advantageous to combine multiple-voltage LED chips, packages, circuits, lamps, etc., high frequency AC voltage power supplies and/or transformers to drive LEDs by either directly connecting a high frequency transformer or inverter to an AC driven LED circuit(s), or by operably connecting an AC-to-DC rectifier between the high frequency transformer or inveter and a DC driven LED circuit. With proper design considerations LEDs may be driven more efficiently with direct AC or rectified AC than with constant voltage or constant current DC drive schemes. High frequency AC transformers or inverters can be made smaller and more cost effective than constant current or constant voltage DC drivers or power supplies currently being used to power LEDs. The higher the frequency, the smaller the transformer can be made. With proper design consideration and based on the wattage and the frequency of the AC voltage output of the power supply, a high frequency AC voltage transformer can be made small enough to be mounted directly onto a LED lighting PCB assembly.

[**Para** 20] It would be further advantageous to provide an LED lighting system capable of operating after a circuit or driver through which power is supplied to LEDs fails.

[**Para** 21] The present invention provides for these advantages and solves the deficiencies in the art.

SUMMARY OF THE INVENTION

[**Para** 22] According to one aspect of the invention at least two single voltage AC LED circuits are formed on a single chip or on a substrate providing a multi-voltage AC LED device for direct AC power operation. Each single voltage AC LED circuit has at least two LEDs connected to each other in opposing parallel relation.

[**Para** 23] According to another aspect of the invention, each single voltage AC LED circuit is designed to be driven with a predetermined forward voltage of at least 6VAC and preferably each single voltage AC LED circuit has a matching forward voltage of 6VAC, 12VAC, 24VAC, 120VAC, or other AC voltage levels for each single voltage AC LED circuit.

[**Para** 24] According to another aspect of the invention, each multi-voltage AC LED device would be able to be driven with at least two different AC forward voltages resulting in a first forward voltage drive level by electrically connecting the two single voltage AC LED circuits in parallel and a second forward voltage drive level by electrically connecting the at least two single voltage level AC LED circuits in series. By way of example, the second forward voltage drive level of the serially connected AC LED circuits would be approximately twice the level of the first forward voltage drive level of the parallel connected AC LED circuits. The at least two parallel connected AC LED circuits would be twice the current of the at least two serially connected AC LED circuits. In either circuit configuration,

the brightness would be approximately the same with either forward voltage drive selection of the multi-voltage LED device.

[Para 25] According to another aspect of the invention, at least two single voltage series LED circuits, each of which have at least two serially connected LEDs, are formed on a single chip or on a substrate providing a multi-voltage AC or DC operable LED device.

[Para 26] According to another aspect of the invention, each single voltage series LED circuit is designed to be driven with a predetermined forward voltage of at least 6V AC or DC and preferably each single voltage series LED circuit has a matching forward voltage of 6V, 12V, 24V, 120V, or other AC or DC voltage levels. By way of example, each multi-voltage AC or DC LED device would be able to be driven with at least two different AC or DC forward voltages resulting in a first forward voltage drive level by electrically connecting the two single voltage series LED circuits in parallel and a second forward voltage drive level by electrically connecting the at least two single voltage level series LED circuits in series. The second forward voltage drive level of the serially connected series LED circuits would be approximately twice the level of the first forward voltage drive level of the parallel connected series LED circuits. The at least two parallel connected series LED circuits would be twice the current of the at least two serially connected series LED circuits. In either circuit configuration, the brightness would be approximately the same with either forward voltage drive selection of the multi-voltage series LED device.

[Para 27] According to another aspect of the invention, at least two single voltage AC LED circuits are formed on a single chip or on a substrate providing a multi-voltage and/or multi-brightness AC LED device for direct AC power operation.

[Para 28] According to another aspect of the invention, each single voltage AC LED circuit has at least two LEDs connected to each other in opposing parallel relation. Each single voltage AC LED circuit is designed to be driven with a predetermined forward voltage

of at least 6VAC and preferably each single voltage AC LED circuit has a matching forward voltage of 6VAC, 12VAC, 24VAC, 120VAC, or other AC voltage levels for each single voltage AC LED circuit. The at least two AC LED circuits within each multi-voltage and/or multi current AC LED device would be able to be driven with at least two different AC forward voltages resulting in a first forward voltage drive level by electrically connecting the two single voltage AC LED circuits in parallel and a second forward voltage drive level by electrically connecting the at least two single voltage level AC LED circuits in series. The second forward voltage drive level of the serially connected AC LED circuits would be approximately twice the level of the first forward voltage drive level of the parallel connected AC LED circuits. The at least two parallel connected AC LED circuits would be twice the current of the at least two serially connected AC LED circuits. In either circuit configuration, the brightness would be approximately the same with either forward voltage drive selection of the multi-voltage LED device.

[Para 29] According to another aspect of the invention at least two single voltage LED circuits are formed on a single chip or on a substrate, and at least one bridge circuit made of LEDs is formed on the same single chip or substrate providing a multi-voltage and/or multi-brightness LED device for direct DC power operation. Each single voltage LED circuit has at least two LEDs connected to each other in series. Each single voltage LED circuit is designed to be driven with a predetermined forward voltage and preferably matching forward voltages for each circuit such as 12VDC, 24VDC, 120VDC, or other DC voltage levels for each single voltage LED circuit. Each multi-voltage and/or multi-brightness LED device would be able to be driven with at least two different DC forward voltages resulting in a first forward voltage drive level when the two single voltage LED circuits are connected in parallel and a second forward voltage drive level that is twice the level of the first forward voltage drive level when the at least two LED circuits are connected in series.

[Para 30] According to another aspect of the invention at least two single voltage LED circuits are formed on a single chip or on a substrate providing a multi-voltage and/or multi-brightness LED device for direct DC power operation. Each single voltage LED circuit has at least two LEDs connected to each other in series. Each single voltage LED circuit is designed to be driven with a predetermined forward voltage and preferably matching forward voltages for each circuit such as 12VAC, 24VAC, 120VAC, or other DC voltage levels for each single voltage LED circuit. Each multi-voltage and/or multi-brightness LED device would be able to be driven with at least two different DC forward voltages resulting in a first forward voltage drive level when the two single voltage LED circuits are connected in parallel and a second forward voltage drive level that is twice the level of the first forward voltage drive level when the at least two LED circuits are connected in series.

[Para 31] According to another aspect of the invention at least two single voltage LED circuits are formed on a single chip or on a substrate, and at least one bridge circuit made of standard diodes, LEDs or some combination thereof is provided separate of the LED circuit or formed on the same single chip or substrate providing a multi-voltage and/or multi-brightness LED device for direct DC power operation. Each single voltage LED circuit has at least two LEDs connected to each other in series. Each single voltage LED circuit is designed to be driven with a predetermined forward voltage and preferably matching forward voltages for each circuit such as 12VDC, 24VDC, 120VDC, or other DC voltage levels for each single voltage LED circuit. Each multi-voltage and/or multi-brightness LED device would be able to be driven with at least two different DC forward voltages resulting in a first forward voltage drive level when the two single voltage LED circuits are connected in parallel and a second forward voltage drive level that is twice the level of the first forward voltage drive level when the at least two LED circuits are connected in series.

[Para 32] According to another aspect of the invention a multi-voltage and/or multi-

current AC LED circuit is integrated within a single chip LED. Each multi-voltage and/or multi-current single chip AC LED comprises at least two single voltage AC LED circuits. Each single voltage AC LED circuit has at least two LEDs in anti-parallel configuration to accommodate direct AC voltage operation. Each single voltage AC LED circuit may have may have at least one voltage input electrical contact at each opposing end of the circuit or the at least two single voltage AC LED circuits may be electrically connected together in series on the single chip and have at least one voltage input electrical contact at each opposing end of the two series connected single voltage AC LED circuits and one voltage input electrical contact at the center junction of the at least two single voltage AC LED circuits connected in series. The at least two single voltage AC LED circuits are integrated within a single chip to form a multi-voltage and/or multi-current single chip AC LED.

[Para 33] According to another aspect of the invention, at least one multi-voltage and/or multi-brightness LED devices may be integrated within a LED lamp. The at least two individual LED circuits within the multi-voltage and/or multi-brightness LED device(s) may be wired in a series or parallel circuit configuration by the LED packager during the LED packaging process thus providing for at least two forward voltage drive options, for example 12VAC and 24VAC or 120VAC and 240VAC that can be selected by the LED packager.

[Para 34] According to another aspect of the invention a multi-voltage and/or multi-current AC LED package is provided, comprising at least one multi-voltage and/or multi-current single chip AC LED integrated within a LED package. The multi-voltage and/or multi-current AC LED package provides matching electrical connectivity pads on the exterior of the LED package to the electrical connectivity pads of the at least one multi-voltage and/or multi-current single chip AC LED integrated within the LED package thus allowing the LED package user to wire the multi-voltage and/or multi-current AC LED package into a series or parallel circuit configuration during the PCB assembly process or final product integration

process and further providing a AC LED package with at least two forward voltage drive options.

[Para 35] According to another aspect of the invention multiple individual discrete LED chips are used to form at least one multi-voltage and/or multi-current AC LED circuit within a LED package thus providing a multi-voltage and/or multi current AC LED package. Each multi-voltage and/or multi-current AC LED circuit within the package comprises at least two single voltage AC LED circuits. Each single voltage AC LED circuit has at least two LEDs in anti-parallel configuration to accommodate direct AC voltage operation The LED package provides electrical connectivity pads on the exterior of the LED package that match the electrical connectivity pads of the at least two single voltage AC LED circuits integrated within the multi-voltage and/or multi-current AC LED package thus allowing the LED package to be wired into a series or parallel circuit configuration during the PCB assembly process and further providing a LED package with at least two forward voltage drive options.

[Para 36] According to another aspect of the invention a multi-voltage and/or multi-current single chip AC LED and/or multi-voltage and/or multi current AC LED package is integrated within an LED lamp. The LED lamp having a structure that comprises a heat sink, a lens cover and a standard lamp electrical base. The multi-voltage and/or multi-current single chip AC LED and/or package is configured to provide a means of switching on at least one additional single voltage AC LED circuit within multi-voltage and/or multi-current AC LED circuit to provide increased brightness from the LED lamp.

[Para 37] According to anther broad aspect of the invention at least one multi-current AC LED single chip is integrated within a LED package.

[Para 38] According to another aspect of the invention, at least one single chip multi-current bridge circuit having standard diodes, LEDs, or some combination thereof is integrated within a LED lamp having a standard lamp base. The single chip multi-current

bridge circuit may be electrically connected together in parallel configuration but left open to accommodate switching on a switch to the more than one on the single chip and have at least one accessible electrical contact at each opposing end of the two series connected circuits and one accessible electrical contact at the center junction of the at least two individual serially connected LED circuits. The at least two individual circuits are integrated within a single chip.

[Para 39] According to another aspect of the invention when the at least two circuits are left unconnected on the single chip and provide electrical pads for connectivity during the packaging process, the LED packager may wire them into series or parallel connection based on the desired voltage level specification of the end LED package product offering.

[Para 40] According to another aspect of the invention, a high frequency transformer or inverter may provide power to at least one multi-voltage and/or multi-brightness LED device or chip. The high frequency transformer or inverter may be either packaged with the LED device or chip and may provide direct AC voltage to the LED device or chip, or as a separate driver or power supply for the LED device or chip capable of being electrically connected to the LED device or chip. The high frequency transformer or inverter is designed to receive a voltage at a low frequency, like for example a voltage at 50/60 Hz like a mains voltage, and output a voltage at a high frequency. The high frequency transformer or inverter may also be configured to step-up or step-down the voltage provided to the transformer or inverter from a source voltage.

[Para 41] According to another aspect of the invention, a high-frequency transformer or inverter may provide power to a DC driven-LED circuit, chip, or device or an LED circuit, chip or device containing one or more series strings of LEDs through a rectifier having standard diodes, LEDs, or some combination thereof may be electrically connected between the high-frequency transformer or inverter and. The rectifier may be provided independently

from the high-frequency transformer or inverter and the LED circuit, chip, or device and electrically connected at its input to the high-frequency transformer or inverter and at its output to the LED circuit, chip or device. Alternatively, the rectifier may be packaged with the high-frequency transformer or inverter forming a power supply or driver for the LED circuit, chip, or device. The rectifier may likewise be packaged directly with, or as part of, an LED circuit, chip, or device. As should be appreciated by those having skill in the art, packaging the rectifier directly with the LED circuit, chip, or device allows for an LED package containing a DC-driven LED circuit, chip, or device, or one or more series strings of LEDs, to be directly plugged into any power supply or driver providing an AC voltage output and operate. As a further alternative, a high-frequency inverter, rectifier, and LED circuit, chip, or device may be packaged into a single lighting device capable of being directly incorporated into a lighting element, or may be incorporated directly into a lamp or other OEM product utilizing LED light.

[Para 42] According to another aspect of the invention, a two-way or three-way switch may be provided directly between a high-frequency inverter providing power to a LED circuits, chip, or device and the LED circuits, chip or device, or in the alternative between a LED circuits, chip, or device and a rectifier having standard diodes, LEDs, or some combination thereof electrically connected to a high-frequency transformer or inverter.

[Para 43] According to another aspect of the invention, an LED lighting system having multiple circuits or drivers capable of receiving an AC voltage input at a first frequency, like for example a mains input, and providing an output capable of driving at least one LED circuit is provided. The LED lighting system includes a sensor capable of sensing the output of each circuit or driver capable of driving the LED circuit, and permitting only a single output to be provided. The sensor may be further capable of switching between circuits or drivers capable of driving the LED circuit if any circuit or driver currently being utilized

fails.

[Para 44] Other aspects and features of the invention will become apparent to those having ordinary skill in the art upon review of the following Description, Claims, and associated Drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[Para 45] FIG. 1 shows a schematic view of a preferred embodiment of the invention;

[Para 46] FIG. 2 shows a schematic view of a preferred embodiment of the invention;

[Para 47] FIG. 3 shows a schematic view of a preferred embodiment of the invention;

[Para 48] FIG. 4 shows a schematic view of a preferred embodiment of the invention;

[Para 49] FIG. 5 shows a schematic view of a preferred embodiment of the invention;

[Para 50] FIG. 6a shows a schematic view of a preferred embodiment of the invention;

[Para 51] FIG. 6b shows a schematic view of a preferred embodiment of the invention;

[Para 52] FIG. 7a shows a schematic view of a preferred embodiment of the invention;

[Para 53] FIG. 7b shows a schematic view of a preferred embodiment of the invention;

[Para 54] FIG. 8 shows a schematic view of a preferred embodiment of the invention;

[Para 55] FIG. 9 shows a schematic view of a preferred embodiment of the invention;

[Para 56] FIG. 10 shows a schematic view of a preferred embodiment of the invention;

[Para 57] FIG. 11 shows a schematic view of a preferred embodiment of the invention;

[Para 58] FIG. 12 shows a schematic view of a preferred embodiment of the invention;

[Para 59] FIG. 13 shows a schematic view of a preferred embodiment of the invention;

[Para 60] FIG. 14 shows a schematic view of a preferred embodiment of the invention;

[Para 61] FIG. 15 shows a schematic view of a preferred embodiment of the invention;

[Para 62] FIG. 16 shows a block diagram of a preferred embodiment of the invention;

[Para 63] FIG. 17 shows a block diagram of a preferred embodiment of the invention;

[Para 64] **FIG.** 18 shows a block diagram of a preferred embodiment of the invention;

[Para 65] **FIG.** 19 shows a block diagram of a preferred embodiment of the invention; and,

[Para 66] **FIG.** 20 shows a block diagram of a preferred embodiment of the invention.

[Para 67] **FIG.** 21 shows a block diagram of an embodiment of an LED system as contemplated by the invention.

[Para 68] **FIG.** 22 shows a block diagram of an embodiment of an LED system as contemplated by the invention.

[Para 69] **FIG.** 23 shows a schematic diagram of a circuit or driver as contemplated by the invention.

[Para 70] **FIG.** 24 shows a schematic diagram of an LED circuit as contemplated by the invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

[Para 71] While the present invention is susceptible of embodiment in many different forms, there is shown in the drawings and will herein be described in detail preferred embodiments of the invention with the understanding that the present disclosure is to be considered as an exemplification of the principles of the invention and is not intended to limit the broad aspect of the invention to the embodiments illustrated.

[**Para** 72] **FIG.** 1 discloses a schematic diagram of a multi-voltage and/or multi-brightness LED lighting device 10. The multi-voltage and/or multi-brightness LED lighting device 10 comprises at least two AC LED circuits 12 configured in an imbalanced bridge circuit, each of which have at least two LEDs 14. The at least two AC LED circuits have electrical contacts 16a, 16b, 16c, and 16d at opposing ends to provide various connectivity options for an AC voltage source input. For example, if 16a and 16c are electrically

connected together and 16b and 16d are electrically connected together and one side of the AC voltage input is applied to 16a and 16c and the other side of the AC voltage input is applied to 16b and 16d, the circuit becomes a parallel circuit with a first operating forward voltage. If only 16a and 16c are electrically connected and the AC voltage inputs are applied to electrical contacts 16b and 16d, a second operating forward voltage is required to drive the single chip 18. The single chip 18 may also be configured to operate at more than one brightness level "multi-brightness" by electrically connecting for example 16a and 16b and applying one side of the line of an AC voltage source to 16a ad 16b and individually applying the other side of the line from the AC voltage source a second voltage to 26b and 26c.

[Para 73] FIG. 2 discloses a schematic diagram of a multi-voltage and/or multi-brightness LED lighting device 20 similar to the multi-voltage and/or multi-brightness LED lighting device 10 described above in FIG. 1 . The at least two AC LED circuits 12 are integrated onto a substrate 22. The at least two AC LED circuits 12 configured in a imbalanced bridge circuit, each of which have at least two LEDs 14. The at least two AC LED circuits have electrical contacts 16a, 16b, 16c, and 16d on the exterior of the substrate 22 and can be used to electrically configure and/or control the operating voltage and/or brightness level of the multi-voltage and/or multi-brightness LED lighting device.

[Para **74]** FIG. 3 discloses a schematic diagram of a multi-voltage and/or multi-brightness LED lighting device 30 similar to the multi-voltage and/or multi-brightness LED lighting device 10 and 20 described in FIGs. 1 and 2. The multi-voltage and/or multi-brightness LED lighting device 30 comprises at least two AC LED circuits 32 having at least two LEDs 34 connected in series and anti-parallel configuration. The at least two AC LED circuits 32 have electrical contacts 36a, 36b, 36c, and 36d at opposing ends to provide various connectivity options for an AC voltage source input. For example, if 36a and 36c are electrically connected together and 36b and 36d are electrically connected together and one

side of the AC voltage input is applied to 36a and 36c and the other side of the AC voltage input is applied to 36b and 36d, the circuit becomes a parallel circuit with a first operating forward voltage. If only 36a and 36c are electrically connected and the AC voltage inputs are applied to electrical contacts 36b and 36d, a second operating forward voltage is required to drive the multi-voltage and/or multi-brightness lighting device 30. The multi-voltage and/or multi-brightness lighting device 30 may be a monolithically integrated single chip 38, a monolithically integrated single chip integrated within a LED package 38 or a number of individual discrete die integrated onto a substrate 38 to form a multi-voltage and/or multi-brightness lighting device 30.

[Para **75]** FIG. 4 discloses a schematic diagram of the same multi-voltage and/or multi-brightness LED device 30 as described in FIG. 3 having the at least two AC LED circuits 32 connected in parallel configuration to an AC voltage source and operating at a first forward voltage. A resistor 40 may be used to limit current to the multi-voltage and/or multi-brightness LED lighting device 30.

[Para 76] FIG. 5 discloses a schematic diagram of the same multi-voltage and/or multi-brightness LED device 30 as described in FIG. 3 having the at least two AC LED circuits 32 connected in series configuration to an AC voltage source and operating at a second forward voltage that is approximately two times greater than the first forward voltage of the parallel circuit as described in FIG. 4. A resistor may be used to limit current to the multi-voltage and/or multi-brightness LED lighting device.

[Para 77] FIGs. 6a and 7a disclose schematic diagrams of a multi-voltage and/or multi-brightness LED lighting devices 50. The multi-voltage and/or multi-brightness LED lighting devices 50 comprises at least two AC LED circuits 52, each of which have at least two LEDs 54 in series and anti-parallel relation. The at least two AC LED circuits 52 have at least three electrical contacts 56a, 56b and 56c, and in the case of FIG. 7a a fourth electrical contact 56d.

The at least two AC LED circuits 52 are electrically connected together in parallel at one end 56a and left unconnected at the opposing ends of the electrical contacts 56b and 56c, and in the case of FIG. 7a, 56d. One side of an AC voltage source line is electrically connected to 56a and the other side of an AC voltage source line is individually electrically connected to 56b, 56c, and 56d with either a fixed connection or a switched connection thereby providing a first brightness when AC voltage is applied to 56a and 56b and a second brightness when an AC voltage is applied to 56a, 56b and 56c, and a third brightness when an AC voltage is applied to 56a, 56b, 56c, and 56d. It is contemplated that the multi-voltage and/or multi-brightness LED lighting devices 50 are a single chip, an LED package, an LED assembly or an LED lamp.

[Para 78] FIGs. 6b and 7b disclose a schematic diagram similar to the multi-voltage and/or multi-brightness LED device 50 shown in FIGs. 6a and 7a integrated within a lamp 58 and connected to a switch 60 to control the brightness level of the multi-voltage and/or multi-brightness LED lighting device 50.

[Para 79] FIG. 8 discloses a schematic diagram of a multi-brightness LED lighting device 62 having at least two bridge rectifiers 68 in series with LED circuits 69. Each of the at least two bridge rectifiers 68 in series with LED circuits 69 comprise four LEDs 70 configured in a bridge circuit 68. LED circuits 69 have at least two LEDs 71 connected in series and electrical contacts 72a, 72b and 72c. When one side of an AC voltage is applied to 72a and the other side of an AC voltage line is applied to 72b and 72c individually, the brightness level of the multi-brightness LED lighting device 62 can be increased and/or decreased in a fixed manner or a switching process.

[Para 80] FIG. 9 discloses a schematic diagram the multi-brightness LED lighting device 62 as shown above in FIG. 8 with a switch 74 electrically connected between the multi-brightness LED lighting device 62 and the AC voltage source 78.

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[Para 81] FIG. 9 discloses a schematic diagram of at least two single voltage LED circuits integrated with a single chip or within a substrate and forming a multi-voltage and/or multi-brightness LED device.

[Para 82] FIG. 10 discloses a schematic diagram of a single chip LED bridge circuit 80 having four LEDs 81 configured into a bridge circuit and monolithically integrated on a substrate 82. The full wave LED bridge circuit has electrical contacts 86 to provide for AC voltage input connectivity and DC voltage output connectivity.

[Para 83] FIG. 11 discloses a schematic diagram of another embodiment of a single chip multi-voltage and/or multi-brightness LED lighting device 90. The multi-voltage and/or multi-brightness LED lighting device 90 has at least two series LED circuits 92 each of which have at least two LEDs 94 connected in series. The at least two series LED circuits 92 have electrical contacts 96 at opposing ends to provide a means of electrical connectivity. The at least two series LED circuits are monolithically integrated into a single chip 98. The electrical contacts 96 are used to wire the at least two series LEDs circuit 92 into a series circuit, a parallel circuit or an AC LED circuit all within a single chip.

[Para 84] FIG. 12 discloses a schematic diagram of the same multi-voltage and/or multi-brightness LED lighting device 90 as shown above in FIG. 11. The multi-voltage and/or multi-brightness LED lighting device 90 has at least two series LED circuits 92 each of which have at least two LEDs 94 connected in series. The at least two series LED circuits can be monolithically integrated within a single chip or discrete individual die can be integrated within a substrate to form an LED package 100. The LED package 100 has electrical contacts 102 that are used to wire the at least two series LEDs circuit into a series circuit, a parallel circuit or in anti-parallel to form an AC LED circuit all within a single LED package.

[Para 85] As seen in FIGs. 13-15, a single rectifier 110 may be provided for two or more

LED circuits 92, each containing at least two LEDs 94 connected in series. The single rectifier 110 comprises standard diodes 112 connected to an AC voltage source 116, or in the alternative may be connected to a driver or power supply which ultimately provides an AC voltage, like for example a high frequency AC driver 118. The single rectifier 110 is electrically connected to the LED circuits 92. Specifically, the rectifier 110 connects to a common junction of an anode of at least one LED 94 in each LED circuit 92, and to the cathode of at least one LED 94 in each LED circuit 92. As shown in FIG. 15, the rectifier may instead be connected to a switch, allowing for either one or both of LED circuits 92 to be operative at any given time.

[Para 86] It is contemplated by the invention that diodes 112 in FIGs. 13-15 are interchangeable with LEDs 70 in rectifiers 68 in FIGs. 8 and 9 and vice versa. As should be appreciated by those having skill in the art, any combination of LEDs 70 and diodes 112 can be used in rectifiers 68 and 110, so long as rectifiers 68 and 110 provide DC power from an AC source.

[Para 87] As shown in FIGs. 13 and 14, and further shown in FIGs. 16-20, any lighting devices, chips, or AC LED or DC LED circuits contemplated by the present invention may be powered through a high-frequency AC driver 118. As shown in FIG. 13, any AC source 116 may be connected to the high-frequency driver or inverter or transformer 118, however, as shown in Figs. 16-20 it is contemplated that low frequency voltage 124, like for example a mains voltage, is provided to the high-frequency driver or transformer or inverter 118.

[Para 88] FIGs. 16 and 17 show two embodiments of an AC LED lighting system 140 wherein a high-frequency AC driver, inverter, or transformer 118 for provides a high-frequency voltage to an AC LED circuit, lighting device, or chip 126. AC LED circuit, lighting device, or chip 126 may be any of the devices, circuits, or chips shown and described in FIGs. 1-7, like for example LED lighting devices 10, 20, 30 and/or AC LED circuits 12,

32, or any combination thereof. When multiple AC LED circuits, lighting devices, or chips are connected to the high-frequency driver in combination, such AC LED circuit(s), lighting device(s), or chip(s) may be connected together in either a series relationship, a parallel relationship, or a series-parallel relationship.

[Para 89] As shown in FIG. 16, the high-frequency AC driver, inverter or transformer 118 may be packaged separately from an (or multiple) AC LED circuit, device, or chip 126. In such embodiments a power source 128 provides voltage to the high-frequency AC driver, inverter or transformer 118 which steps up the frequency of the voltage to a higher frequency and provides the higher-frequency voltage to the AC LED circuit(s), device(s), or chip(s) 126. High-frequency AC driver, inverter, or transformer 118 may further include necessary circuitry, for example a transformer, for stepping-up or stepping-down the AC voltage provided by the power source 128.

[Para 90] As shown in FIG. 17, high-frequency AC driver 118 may be packaged with AC LED circuit(s), device(s), or chip(s) 126 in a unitary AC LED light bulb, lighting element 130. It is contemplated by the invention that a switch may be configured between the high-frequency driver 118 and the AC LED circuit(s), device(s), or chip(s) 126 for selectively operating one or more AC LED circuit, lighting device, or chip. For example, as shown in FIGS. 6A, 6B, 7A, and 7B a 2-way or 3-way switch may be attached at the input side of the AC LED circuit(s), lighting device(s), or chip(s). Such a switch may be located between the high-frequency AC driver, inverter, or transformer 118, and the AC LED circuit(s), lighting device(s), or chip(s).

[Para 91] FIGs. 14 and 18-20 show a DC LED lighting system 142 having a DC LED circuit(s), device(s), or chip(s) 92, 132 being powered by a high-frequency AC driver, inverter, or transformer 118 through a rectifier 110. In operation, the combination of AC sources 116, 128, high-frequency AC driver, inverter or transformer 118, and DC LED

circuit, device, or chip 92, 132 operate in substantially the same manner as that described with respect to FIGs. 16 and 17. However, in each system shown in FIGs. 14 and 18-20, rectifier 110 rectifies the high-frequency AC voltage output of the high-frequency AC driver before a voltage is provided to the DC LED circuit(s), device(s), or chip(s) 92, 132. DC LED circuit(s), device(s), or chip(s) 132 are not limited in form to just circuit 92, and instead may take the form of any of the lighting devices, circuits, or chips shown and described, for example, in FIGs. 8-12. When multiple DC LED circuits, lighting devices, or chips are connected to the high-frequency driver in combination, such DC LED circuit(s), lighting device(s), or chip(s) may be connected together in either a series relationship, a parallel relationship, or a series-parallel relationship. Additionally, as shown in FIG. 15, a switch, like for example a 2-way switch or a 3-way switch, may also be attached at the input side of DC LED circuit(s), device(s), or chip(s).

[Para 92] As shown in FIGs. 18-20, like in an AC embodiment, AC driver 118, rectifier 110, and DC LED circuit(s), device(s), or chip(s) 132 may be packaged in any number of ways. As shown in FIG. 18, each element may be packaged separately and electrically connected together in series. Alternatively, as shown in FIG. 19, a DC LED driver 134 may be formed by combining the high-frequency AC driver 118 with rectifier 110. As shown in FIG. 20, an additional alternative contemplated by the invention is forming a DC LED lighting element 136, which may be embodied as a light bulb, lighting system, lamp, etc., wherein the DC LED lighting element 136 includes each of a high-frequency AC driver 118, a rectifier 110, and a DC LED circuit(s), lighting device(s), or chip(s) 132. It should be appreciated by those having skill in the art that a lighting element containing only rectifier 110 and a DC LED circuit(s), lighting device(s), or chip(s) 132 may also be designed. Such lighting elements have the advantage of being able to be plugged into any AC source, whether it is a high-frequency AC driver, inverter, or transformer, or a simple mains voltage,

and provide a light output in the same manner as the imbalanced circuit shown in, for example FIGs. 1-7.

[**Para** 93] FIGs. 2 1 and 22 show embodiments of a lighting system which may be used to incorporate any of the AC LED or DC LED drivers, lighting devices, circuits, chips or the like discussed herein.

[**Para** 94] FIG. 2 1 shows lighting system 200 having at least one LED circuit 202 connected as a load to driver 204. LED circuit 202 has at least two LEDs connected in series and may be configured in any manner shown and discussed in any of figures, like for example, FIGs. 1-9, 11, and 12, or as shown and discussed later in FIG. 24. As should be appreciated by those having ordinary skill in the art, it is contemplated that lighting system 200 may include two or more LED circuits 202 connected in series, parallel, or series parallel wherein each LED circuit 202 has at least two LEDs connected in series.

[**Para** 95] Driver 204 in lighting system 200 has an input, like for example a plug, power cord, or other adapter capable of connecting to a power source, for receiving a first AC voltage and frequency from power source 206, which may be any AC power source including a mains power source, and includes at least first circuit 208 and second circuit 2 10 which are each capable of receiving the first AC voltage and first frequency. Circuits 208, 210 each have an output capable of being connected the at least one LED circuit 202 for driving the at least two LEDs connected therein. As seen in FIG. 21, driver 204 may additionally include circuit 214 which is substantially similar to circuits 208, 210. As should be appreciated by those having ordinary skill in the art, any number of circuits may be included in driver 204 so long as each additional circuit is capable of receiving the first AC voltage and first frequency, and having an output capable of being connected the at least one LED circuit 202 for driving the at least two LEDs connected therein.

[**Para** 96] Driver 204 further includes a sensor in the form of circuit 212 which is

configured to sense and permit the output of only one of first circuit 208 or second circuit 210 to be provided to the at least one LED circuit 202. For example, circuit 212 may be configured to sense the output from both first circuit 208 and second circuit 210 and allow only the output of first circuit 208 to be provided to at least one LED circuit 202 while the output of circuit 210 is blocked or not provided to at least one LED circuit 202. If circuit 212 no longer senses an output from circuit 208, because for example circuit 208 has failed, circuit 212 may disconnect or block the output of circuit 208 from at least one LED circuit 202, and connect the output of circuit 210 to at least one LED circuit 202 so that circuit 210 drives at least one LED circuit 202. As should be appreciated by those having ordinary skill in the art, in embodiments including circuit 214 or any additional circuits capable of receiving the first AC voltage and first frequency and having an output capable driving at least one LED circuit 202, circuit 212 may be configured to allow only a single output through and connect a new circuit output each time the circuit providing an output to at least one LED circuit 202 fails.

[Para 97] In order to achieve this function, circuit 212 may include any sensor and/or switch combination known to those of ordinary skill in the art capable of detecting or sensing the output of circuits 208 and 210, and blocking the outputs so only a single output is provided to at least one LED circuit 202 at all times so long as one of circuit 208 and 210 are operational. Examples of circuits which may be used as circuit 212 include a relay circuit, a micro-controller IC, or a voltage level sensing circuit connected between the output of circuits 208 and 210 and at least one LED circuit 202.

[Para 98] In alternative embodiments, circuit 212 may include a logic gate and multiple circuits, each of the multiple circuits including an RMS converter and a window voltage comparator controlling an analog switch. Each RMS converter would receive the output of circuit 208 or circuit 210 and convert the output voltages to an RMS voltage. The RMS

voltage may then be provided to a respective window voltage comparator, and be compared to high and low reference voltages stored in the each window voltage comparator. If the measured RMS voltage is within the high or low reference range, the comparator may then close an analog switch, allowing the output of circuit 208 or 210 to proceed to the logic gate. The logic gate may then be configured to allow only one received output from circuit 208 or 210 to pass through and be provided to at least one LED circuit 202. If the allowed output from either of circuit 208 or 210 fails and is not provided, the logic gate may then allow the non-allowed output from 208 or 210 to be provided to at least one LED circuit 202. Utilizing a logic gate receiving multiple inputs and an RMS converter and window voltage comparator has the added benefit of blocking the output from either of circuit 208 or 210 if the output is too high or too low, insuring maximum efficiency when driving at least one LED circuit 202.

[Para 99] Regardless of what is used for circuit 212, it should be appreciated by those having ordinary skill in the art that a two-way or three-way switch like that shown and described in FIGS. 6A and 6B or 7A and 7B may be provided on the back end of circuit 212 wherein the two-way or three-way switch may connect additional LED circuits formed as part of at least one LED circuit 202. Utilizing a switch may allow for additional LED circuits to be turned on and off, adjusting the brightness of system 200.

[Para 100] As should be appreciated by those having ordinary skill in the art, any two-way or three-way switch may also be utilized to join the output of circuits 208 and 210, as well as any additional similar circuits included in driver 204, to provide additional power to at least one LED circuit 202. For example, the switch may be used to combine the outputs of circuits 208 and 210 into a single output before reaching circuit 212, or alternatively may alter the logic of a logic gate used in circuit 212, allowing the output of both circuits 208 and 210 to be provided to at least one LED circuit 202.

[Para **101]** FIG. 22 shows an alternative embodiment to FIG. 21 wherein lighting system

300 contains at least one LED circuit 302,which is substantially similar to LED circuit 202, drivers 304 and 306 and sensor 308. In operation, drivers 304 and 306 function in a similar manner as circuits 208 and 210 and sensor 308 may function in substantially the same manner as circuit 212. In the embodiment shown in FIG. 22, however, drivers 304 and 306 may be packaged separately from sensor 308. Packaging each driver 304 and 306 separately may also allow for either driver to be easily replaced within system 300 if either driver 304 or 306 fails.

[Para 102] Drivers 304 and 306 each have a first input for receiving a first AC voltage and frequency and each contain an output capable of being connected to the at least one LED circuit 302 through sensor 308. In embodiments where multiple drivers are used, lighting system 300 may include a single input for power from power source 310, like for example a plug, power cord, or other adapter capable of connecting to and transmitting an AC voltage.

[Para 103] As with the embodiment described in FIG. 21, in embodiments where multiple drivers are used, sensor 308 may be configured to receive the output of the drivers 304 and 306, sense the voltages, and allow only a single output to be provided to at least one LED circuit 302. Sensor 308 may include a relay circuit, a micro-controller IC, or a voltage level sensing circuit connected between the output of circuits 208 and 210 and at least one LED circuit 202.

[Para 104] In alternative embodiments, sensor 308 may include a logic gate and multiple circuits, each of the multiple circuits including an RMS converter and a window voltage comparator controlling an analog switch. Each RMS converter would receive the output of driver 304 or driver 306 and convert the output voltages to an RMS voltage. The RMS voltage may then be provided to a respective window voltage comparator, and be compared to high and low reference voltages stored in the each window voltage comparator. If the measured RMS voltage is within the high or low range, the comparator may then close an

analog switch, allowing the output of driver 304 or 306 to proceed to the logic gate. The logic gate may then be configured to allow only one received output from drivers 304 or 306 to pass through and be provided to at least one LED circuit 302. If the allowed output from either of driver 304 or 306 fails and is not provided, the logic gate may then allow the non-allowed output from drivers 304 or 306 to be provided to at least one LED circuit 302. Utilizing a logic gate receiving multiple inputs and an RMS converter and window voltage comparator has the added benefit of blocking the output from either of drivers 304 and 306 if the output is too high or too low, insuring maximum efficiency when driving at least one LED circuit 302.

[Para 105] While circuits 208, 2 10 and drivers 304, 306 may be any of the drivers or circuits discussed herein capable of driving LED circuits, FIG. 23 shows one embodiment of circuits 208, 210 and a configuration for drivers 304, 306 as contemplated by the invention. As should be appreciated by those having ordinary skill in the art, each of the circuit shown in FIG. 23 may be packaged separately forming drivers 304, 306, or packaged together in a single driver forming driver 204. As such, it should be understood when referring to FIG. 23, the terms circuits 208, 210 may be used interchangeably with the terms driver 304, 306.

[Para 106] As seen in FIG. 23, circuits 208, 210 each contain AC input 400, connected in series with fuse 402, resistor 404, and bridge rectifier 406 which provides DC output 408 from circuits 208, 210 to a sensor or circuit and at least one LED circuit. Circuits 208, 210 may also include a voltage suppressor 4 10 connected in series with fuse 402 and resistor 404, while being connected in parallel with rectifier 406. Voltage suppressor 410 may be a transient voltage suppressor used to protect rectifier 406 and any sensor or circuit or LED circuits connected to the output of the circuit 208 or 210. Circuits 208, 210 and drivers 304, 306 may further include a transformer for stepping the provided AC voltage up or down and/or to adjust the provided AC frequency up or down.

[**Para** 107] Driver 204 may further include further include at least two capacitors connected to a fourth circuit wherein the fourth circuit only allows one of the at least two capacitors to connect to the first or second circuit or any additional circuits included in driver 204 which are providing an output to LED circuit 202. The fourth circuit may be configured to disconnect the one of the at least two capacitors connected to the first or second circuit if the one capacitor fails and then connect at least one other capacitor from the at least two capacitors to circuits 208, 210. The fourth circuit may be configured to connect any one of the at least two capacitors anywhere within the first or second circuit, and preferably in parallel with bridge rectifier 406.

[**Para** 108] In embodiments like that shown in FIG. 22 wherein multiple drivers are provided for lighting system 300, each driver 304, 306 may contain at least two capacitors and an internal sensor wherein the internal sensor only one of the at least two capacitors to form a portion of the driver, *i.e.* form a portion of the circuit shown in FIG. 23.

[**Para** 109] A resistor may be connected in series with the at least two LEDs forming at least one LED circuit 202, 302 in order to suppress the current provided by driver 204 or drivers 304, 306 to further protect the at least two LEDs. FIG. 24 shows an embodiment of at least one LED circuit 202, 302 for use in conjunction with circuits 208, 210 and drivers 304, 306 shown in FIG. 23, wherein at least two LEDs 500 are connected in series with resistor 502. As seen in FIG. 24, LED circuit 202, 302 may further include a capacitor 504 connected in series with LEDs 502 and in parallel with resistor 502 for smoothing the received output from driver 204 or drivers 304, 306. LED circuit 202, 302 finally may also include a fuse 506 to further protect LED circuit 202, 302 from any surge currents.

[**Para** 110] In embodiments where mains power is directly rectified and provided to LED circuit 202, 302 through circuit 212 or sensor 308, LEDs 500 may be high voltage LEDs having a forward voltage of at least 36V. However, it should be appreciated that LEDs

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having any forward voltage may be utilized, so long as the total forward voltage across each LED is satisfied by the provided output from driver 204 or drivers 304, 306.

[Para 111] It is to be understood that additional embodiments of the invention described herein may be contemplated by one of ordinary skill in the art, and the scope of the present invention is not limited to the embodiments disclosed. While specific embodiment s of the present invention have been illustrated described, numerous modifications come to mind without significantly departing from the spirit of the invention, and the scope of protection is only limited by the scope of the accompanying claims.

CLAIMS

What is claimed is:

1. An LED lighting system comprising:

at least one LED circuit comprising at least two LEDs connected in series;

a driver having an input for receiving a first AC voltage and frequency from an AC power source, the driver having

a first circuit capable of receiving the first AC voltage and first frequency and having an output capable of being connected to the at least one LED circuit to drive the at least two LEDs;

a second circuit capable of receiving the first AC voltage and first frequency and having an output capable of being connected to the at least one LED circuit to drive the at least two LEDs; and,

a third circuit which senses and permits the output of only one of the first or second circuits to be provided to the at least one LED circuit.

2. The LED lighting system of claim 1 wherein the third circuit is configured to sense and provide the output of the first circuit to the at least one LED circuit.

3. The LED lighting system of claims 1 or 2 wherein the third circuit is configured to sense and provide to the output of the second circuit to the at least one LED circuit if no output is sensed from the first circuit.

4. The LED lighting system of any of claims 1-3 wherein the AC voltage source is mains power.

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5. The LED lighting system of any of claims 1-4 further comprising at least two LED circuits each having at least two LEDs connected in series.

6. The LED lighting system of any of claims 1-5 wherein each of the first and second circuit includes a resistor, a fuse and a bridge rectifier connected in series with the received AC voltage and current such that the output of the second and third circuits is a DC voltage and current.

7. The LED lighting system of claim 6 wherein the first and second circuit further include a voltage suppressor connected in parallel with the bridge rectifier, the voltage suppressor being connected in series with the resistor and the fuse.

8. The LED lighting system of claim 7 wherein the voltage suppressor is a transient voltage suppressor.

9. The LED lighting system of any of claims 1-8 wherein the at least one LED circuit includes a resistor connected in series with the two or more LED circuits.

10. The LED lighting system of claim 9 wherein the at least one LED circuit includes a capacitor connected in parallel with the resistor.

11. The LED lighting system of any of claims 1-10 further comprising at least one additional circuit capable of receiving the first AC voltage and first frequency and having an output capable of being connected to the at least one LED circuit to drive the at least two LEDs.

12. The LED lighting system of claim 11 wherein the third circuit is configured to switch to the at least one additional circuit if no output is sensed from the first circuit or the second circuit.

13. The system of any of claims 1-12 wherein the first and second circuits include a transformer connected to the AC power source for stepping the input AC voltage up or down.

14. The system of any of claims 1-13 wherein the first and second circuits include a transformer connected to the AC power source for stepping the frequency of the input AC voltage up or down.

15. The LED lighting system of any of claims 1-14 wherein the forward voltage of each of the at least two LEDs is at least 36V.

16. The LED lighting system of any of claims 1-15 wherein the driver further includes at least two capacitors connected to a fourth circuit wherein the fourth circuit only allows one of the at least two capacitors to connect to the first or second circuit.

17. The LED lighting system of claim 16 wherein the fourth circuit is configured to disconnect the one of the at least two capacitors connected to the first or second circuit if the one capacitor fails.

18. The LED lighting system of claim 17 wherein the fourth circuit connects a different capacitor from the at least two capacitors to the first or second circuit if the one of the at least two capacitors fails.

19. An LED lighting system comprising:

at least one LED circuit comprising at least two LEDs connected in series;

a first driver having an input for receiving a first AC voltage and frequency from an AC power source, the first driver having an output capable of being connected to the at least one LED circuit to drive the at least two LEDs;

a second driver having an input for receiving the first AC voltage and frequency from the AC power source, the second driver having an output capable of being connected to the at least one LED circuit to drive the at least two LEDs; and,

a sensor for sensing the output of the first and second drivers, the sensor being configured to provide the output of only the first or second driver to the at least one LED circuit.

20. The LED lighting system of claim 19 wherein the sensor is configured to sense and provide the output of the first driver to the at least one LED circuit.

21. The LED lighting system of claims 19 or 20 wherem the sensor is configured to provide the output of the second driver to the at least one LED circuit if the output of the first driver is not sensed.

22. The LED lighting system of claims 19-21 wherein the AC power source is mains power.

23. The LED lighting system of any of claims 19-22 wherein each of the first and second drivers include a resistor, a fuse, and a bridge rectifier connected in series such that the output of the first and second drivers is a DC voltage and current.

24. The LED lighting system of claim 23 wherein each of the first and second drivers include a voltage suppressor.

25. The LED lighting system of claim 23 wherein the voltage suppressor is a transient voltage suppressor.

26. The LED lighting system of any of claims 19-25 wherein the first and second drivers each include a transformer capable of stepping the first AC voltage up or down.

27. The LED lighting system of any of claims 19-26 wherein the first and second drivers each include a transformer capable of stepping the first AC frequency up or down.

28. The LED lighting system of claims 19-26 further comprising at least two LED circuits comprising at least two LEDs connected in series wherein the at least two LED circuits are connected to each other in parallel and are capable of receiving the output from either of the first or second drivers.

29. The LED lighting system of claim 28 wherein the at least two LED circuits each include a resistor connected in series with the at least two LEDs.

30. The LED lighting system of claims 28 or 29 wherein the at least two LED circuits each include a capacitor connected in series with the at least two LEDs.

31. The LED lighting system of claim 30 wherein the capacitor is connected in parallel to the resistor.

32. The LED lighting system of any of claims 19-31 further comprising at least one additional driver having an input for receiving a first AC voltage and frequency from

an AC power source, the third driver having an output capable of being connected to the at least one LED circuit to drive the at least two LEDs.

33. The LED lighting system of claim 32 further wherein the sensor is capable of providing the output of the at least one additional driver to the at least one LED circuit if an output is not sensed from either of the first or second driver.

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FIG. 2

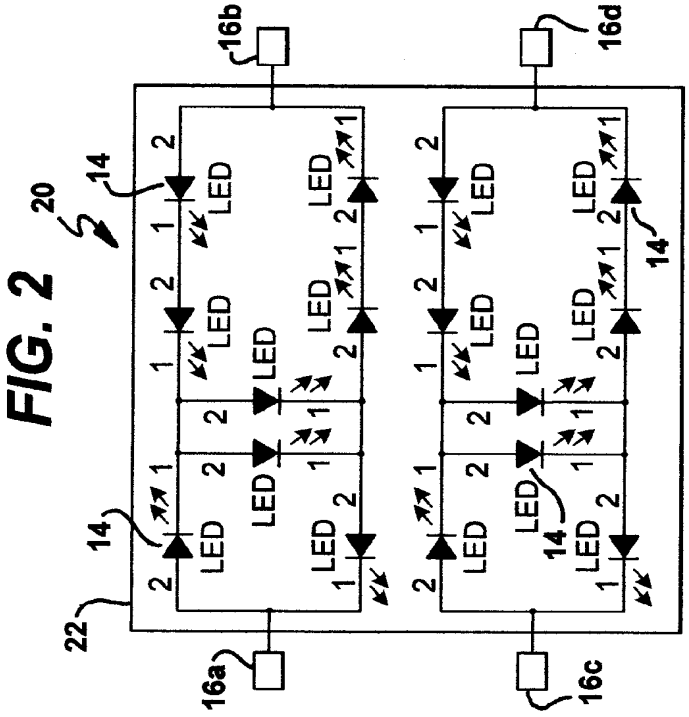
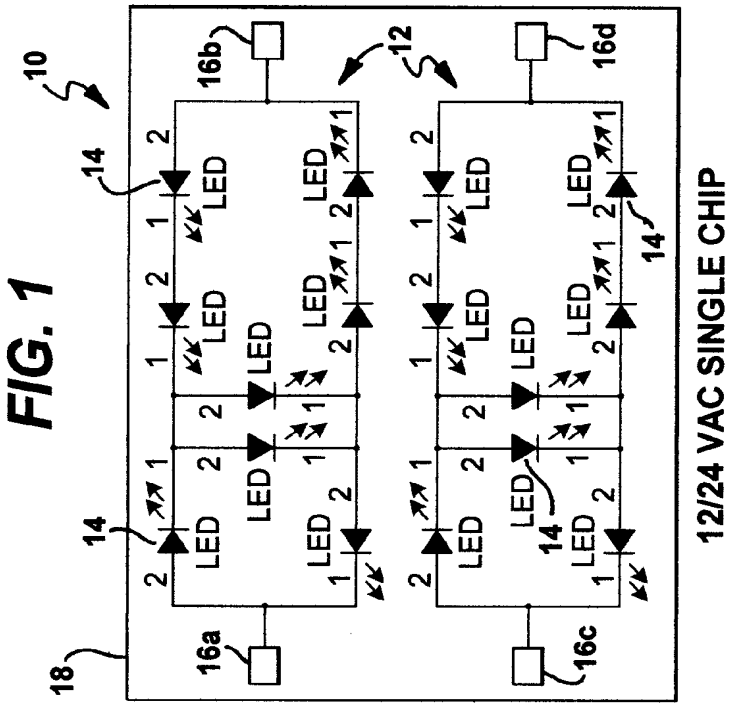

16b
16d
20
14
LED
22
16a
16c

FIG. 1


10
12
16b
16d
14
LED
18
16a
16c
12/24 VAC SINGLE CHIP

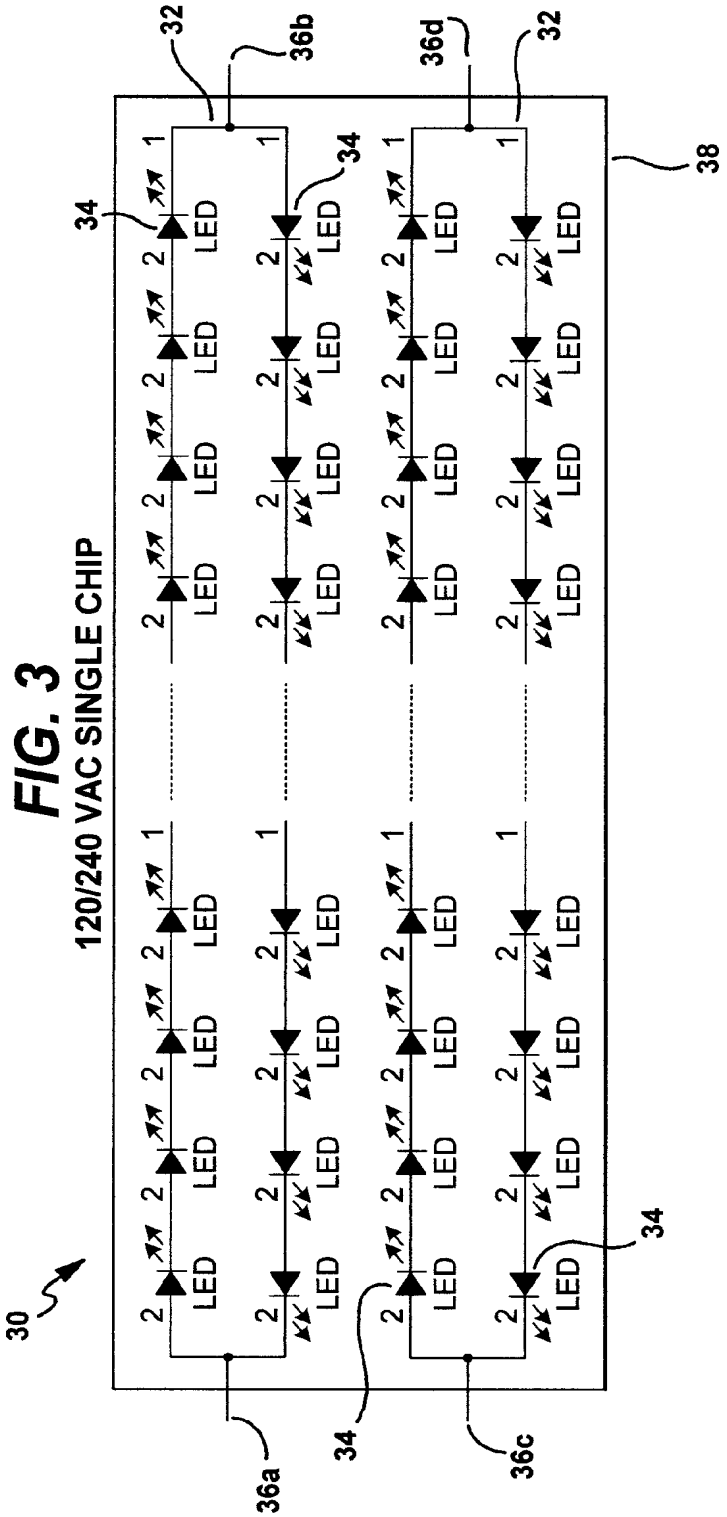
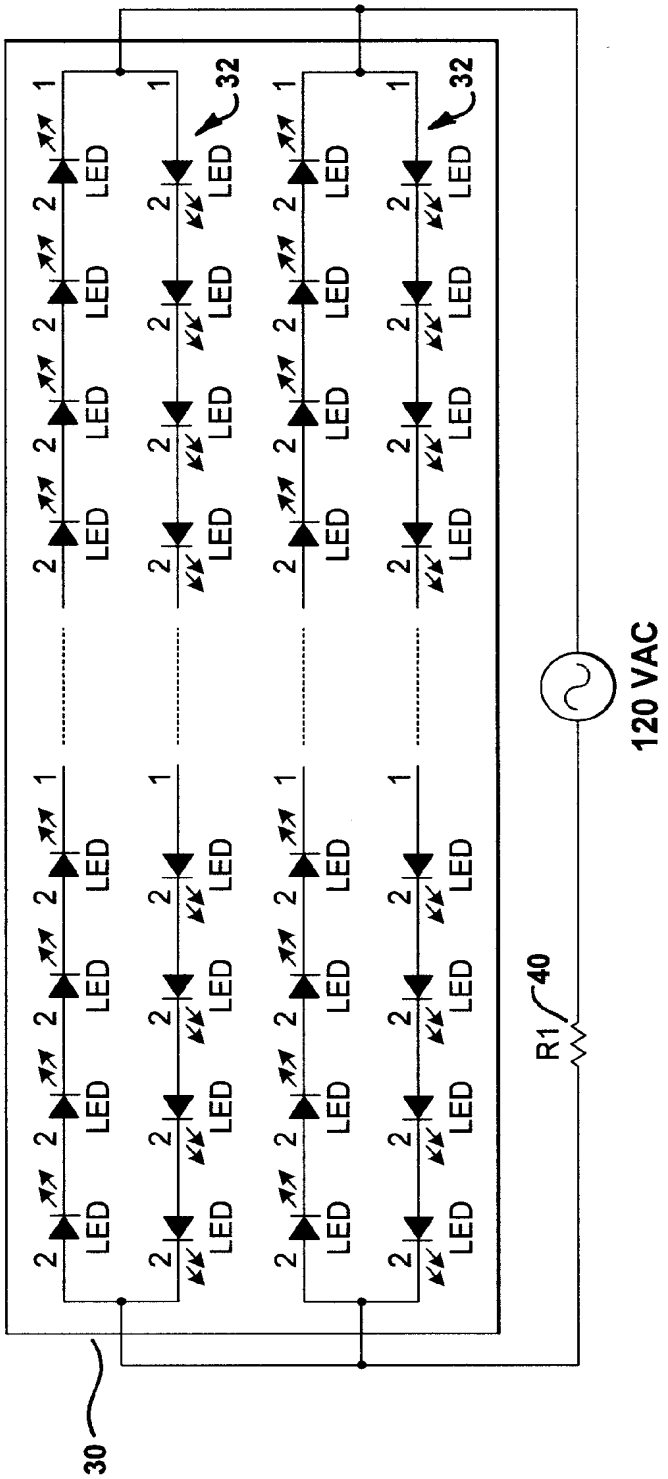

120/240 VAC SINGLE CHIP
30
32
36b
36d
32
38
34
34
34
36a
34
36c
LED
1
2

FIG. 3

FIG. 4



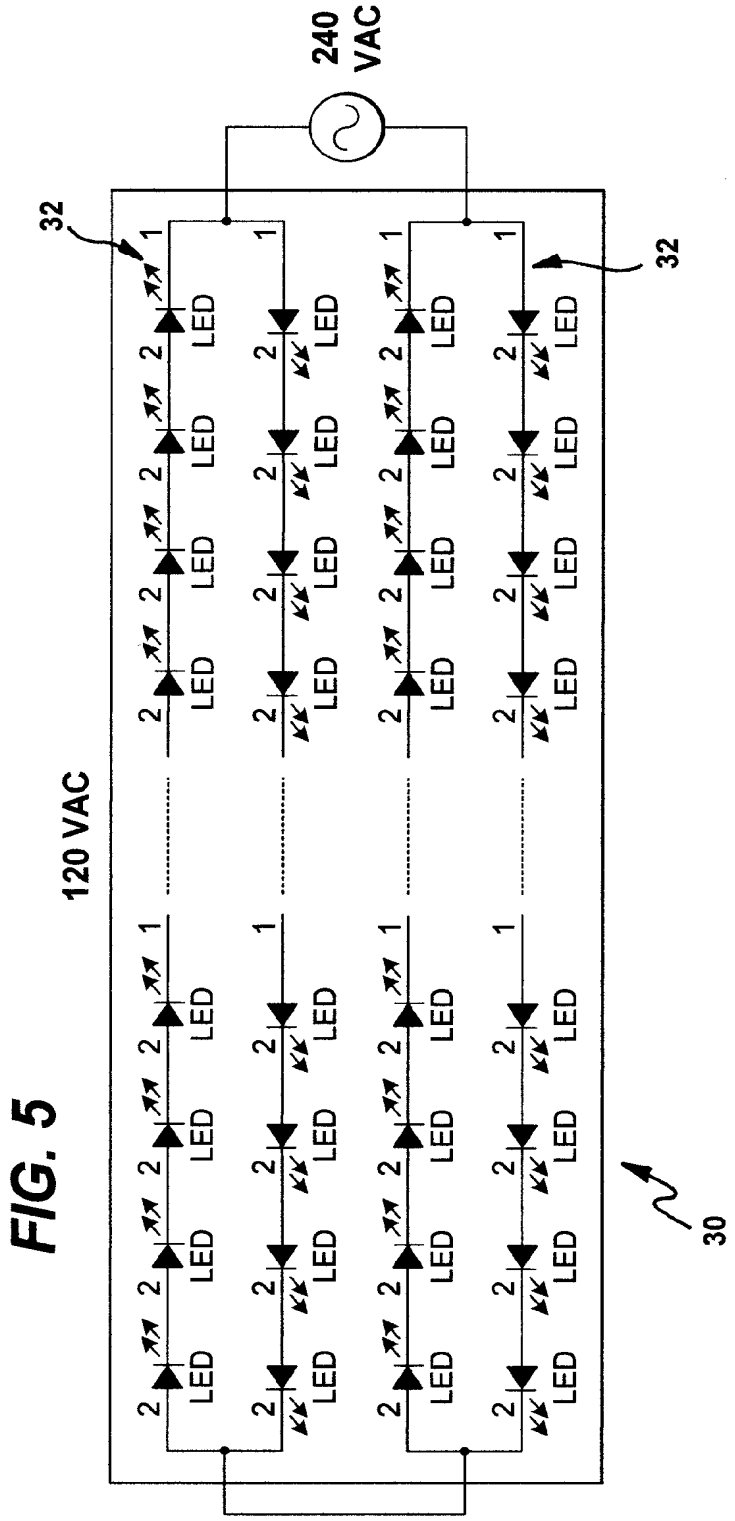


FIG. 5

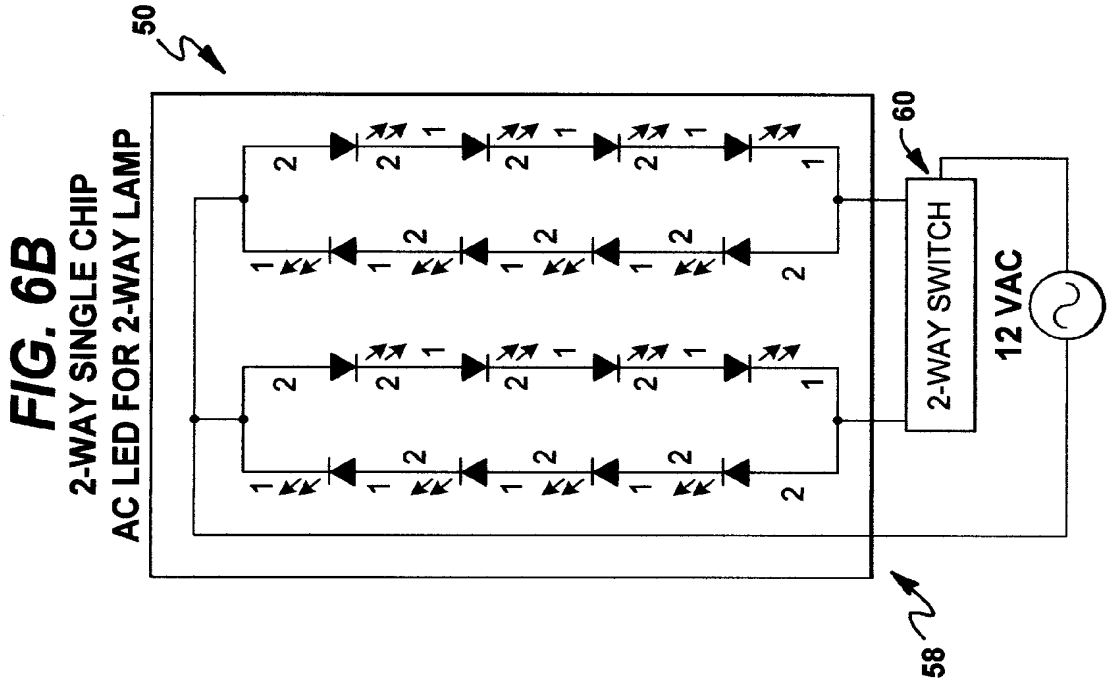


FIG. 6B
2-WAY SINGLE CHIP
AC LED FOR 2-WAY LAMP

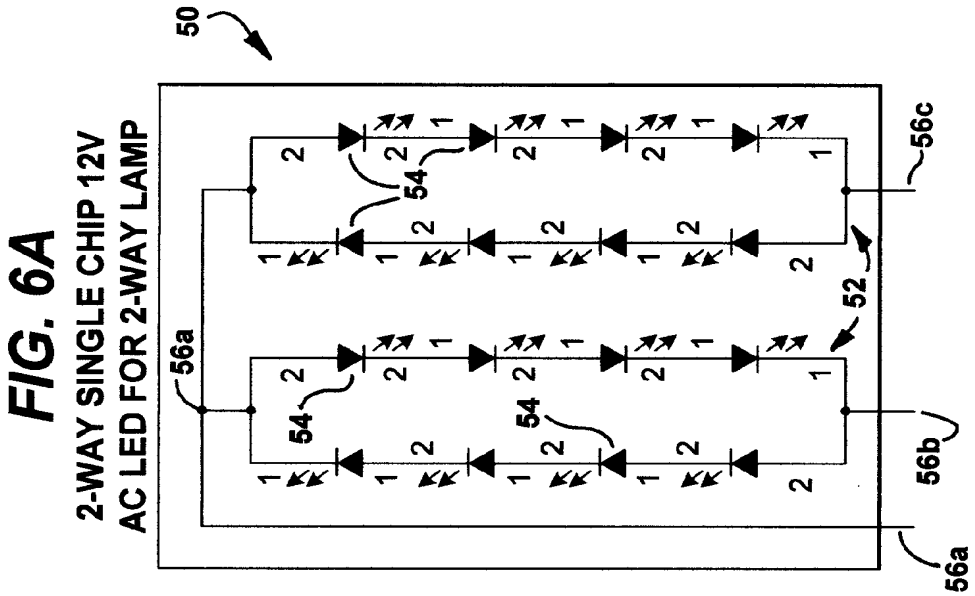


FIG. 6A
2-WAY SINGLE CHIP 12V
AC LED FOR 2-WAY LAMP

FIG. 7A

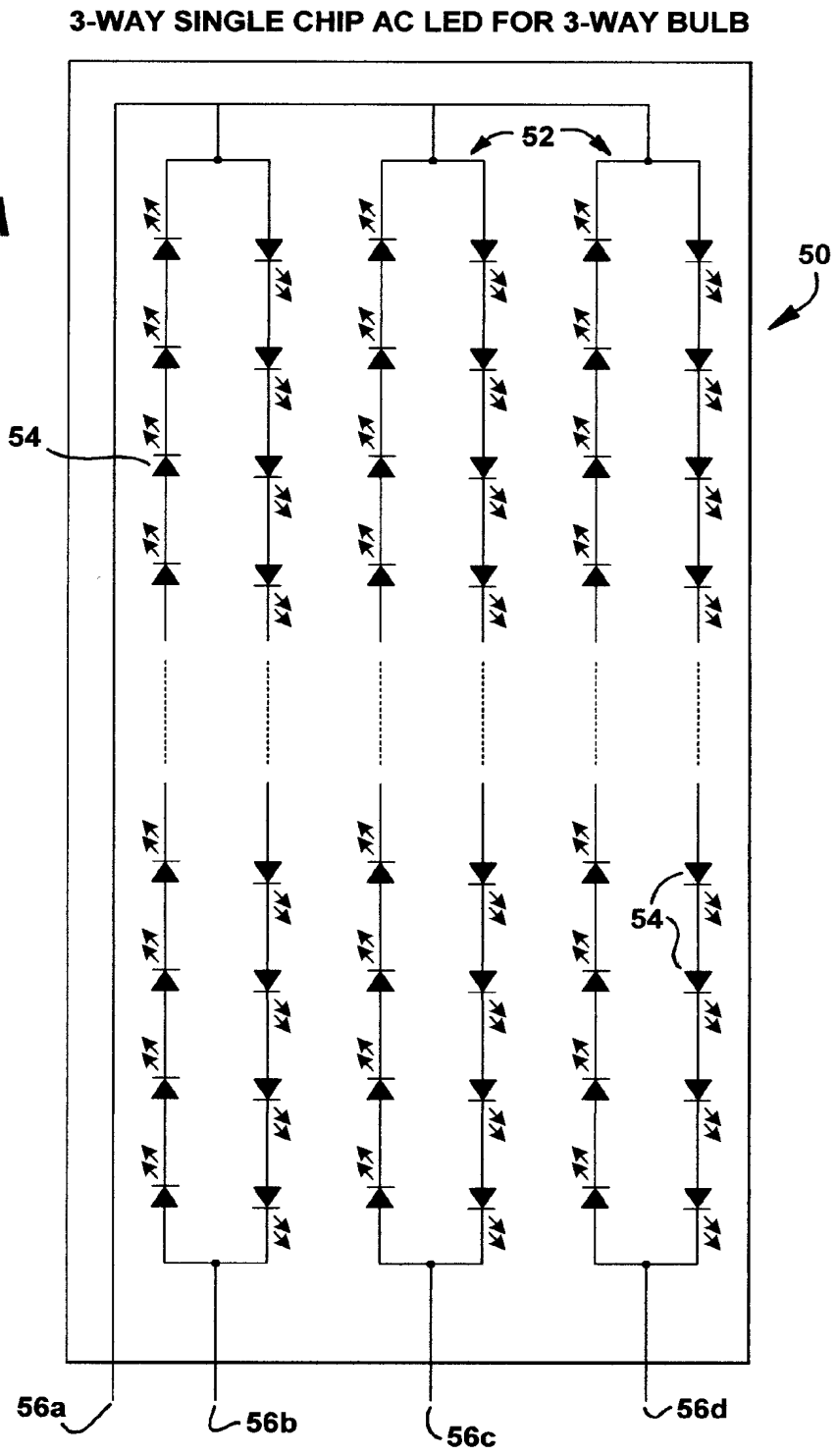
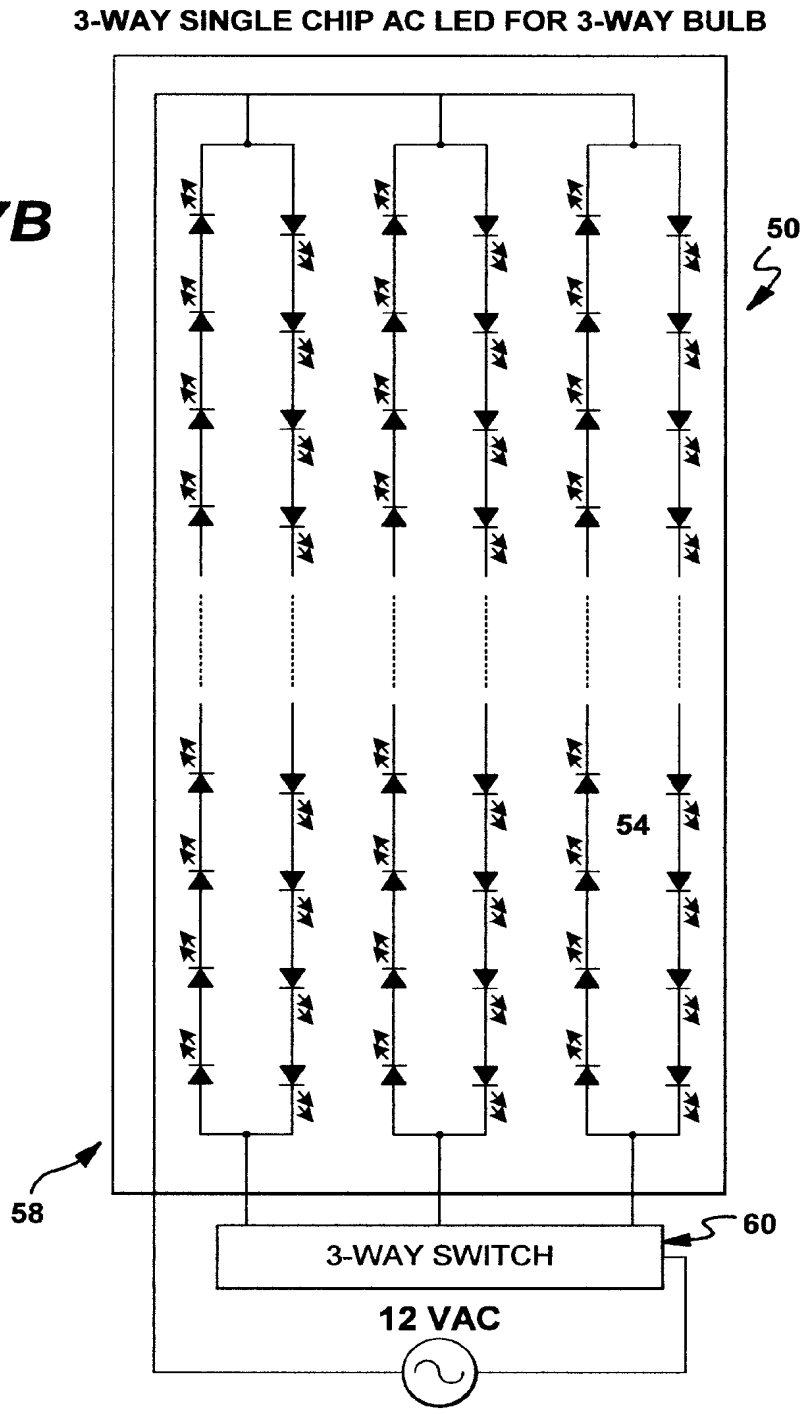

3-WAY SINGLE CHIP AC LED FOR 3-WAY BULB
52
50
54
54
56a
56b
56c
56d

FIG. 7B


3-WAY SINGLE CHIP AC LED FOR 3-WAY BULB
50
54
58
60
3-WAY SWITCH
12 VAC