US006788011B2

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

(10) **Patent No.:** **US 6,788,011 B2**
(45) **Date of Patent:** **Sep. 7, 2004**

(54) **MULTICOLORED LED LIGHTING METHOD AND APPARATUS**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **09/971,367**

(22) Filed: **Oct. 4, 2001**

(65) **Prior Publication Data**

US 2002/0057061 A1 May 16, 2002

Related U.S. Application Data

(63) Continuation of application No. 09/669,121, filed on Sep. 25, 2000, which is a continuation of application No. 09/425,770, filed on Oct. 22, 1999, now Pat. No. 6,150,774, which is a continuation of application No. 08/920,156, filed on Aug. 26, 1997, now Pat. No. 6,016,038.

(51) **Int. Cl.**[7] **G05F 1/00**

(52) **U.S. Cl.** **315/294**; 315/292; 315/312; 315/316; 315/362

(58) **Field of Search** 315/291, 292, 315/295, 294, 308, 312, 318, 314, 76, 360, 362, 316, 324; 362/800

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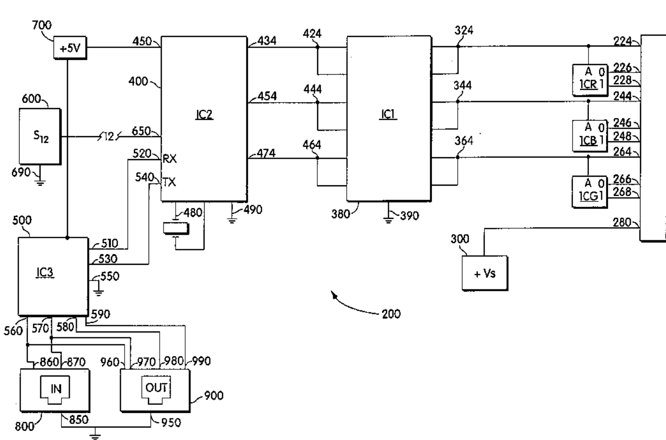
(57) **ABSTRACT**

The systems and methods described herein relate to LED systems capable of generating light, such as for illumination or display purposes. The light-emitting LEDs may be controlled by a processor to alter the brightness and/or color of the generated light, e.g., by using pulse-width modulated signals. Thus, the resulting illumination may be controlled by a computer program to provide complex, predesigned patterns of light in virtually any environment.

144 Claims, 7 Drawing Sheets



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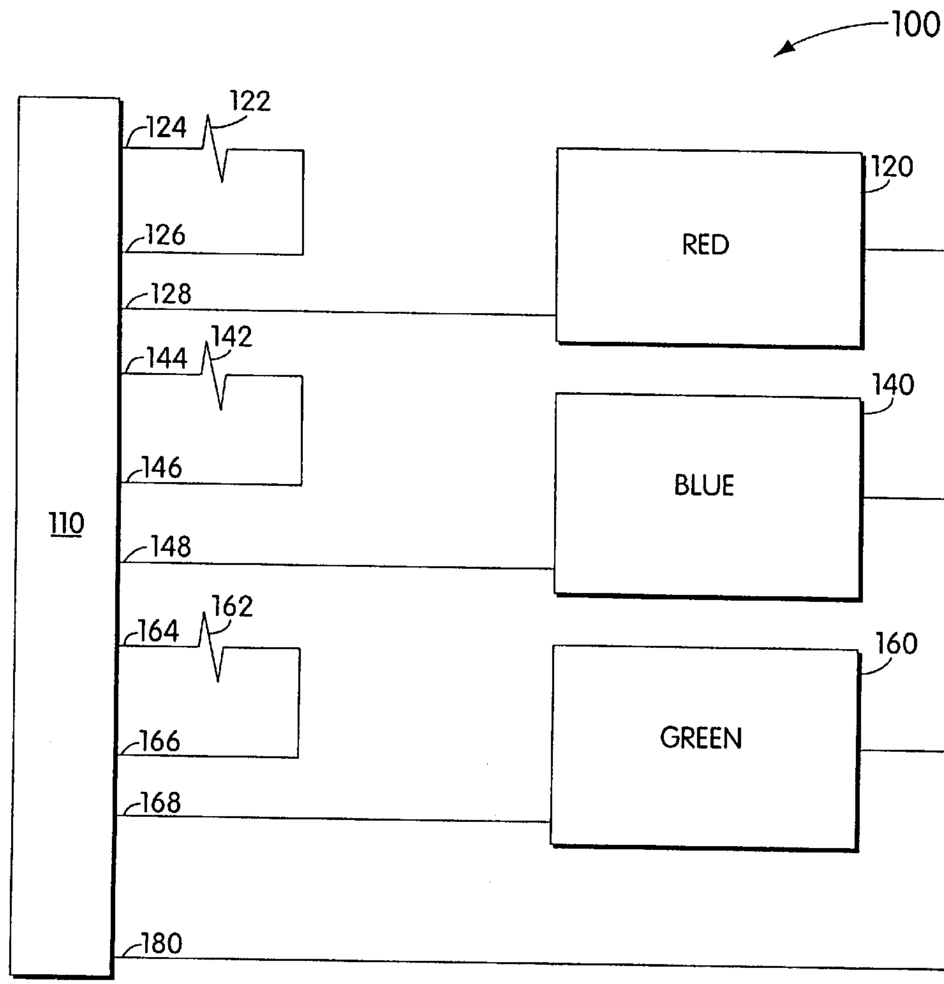
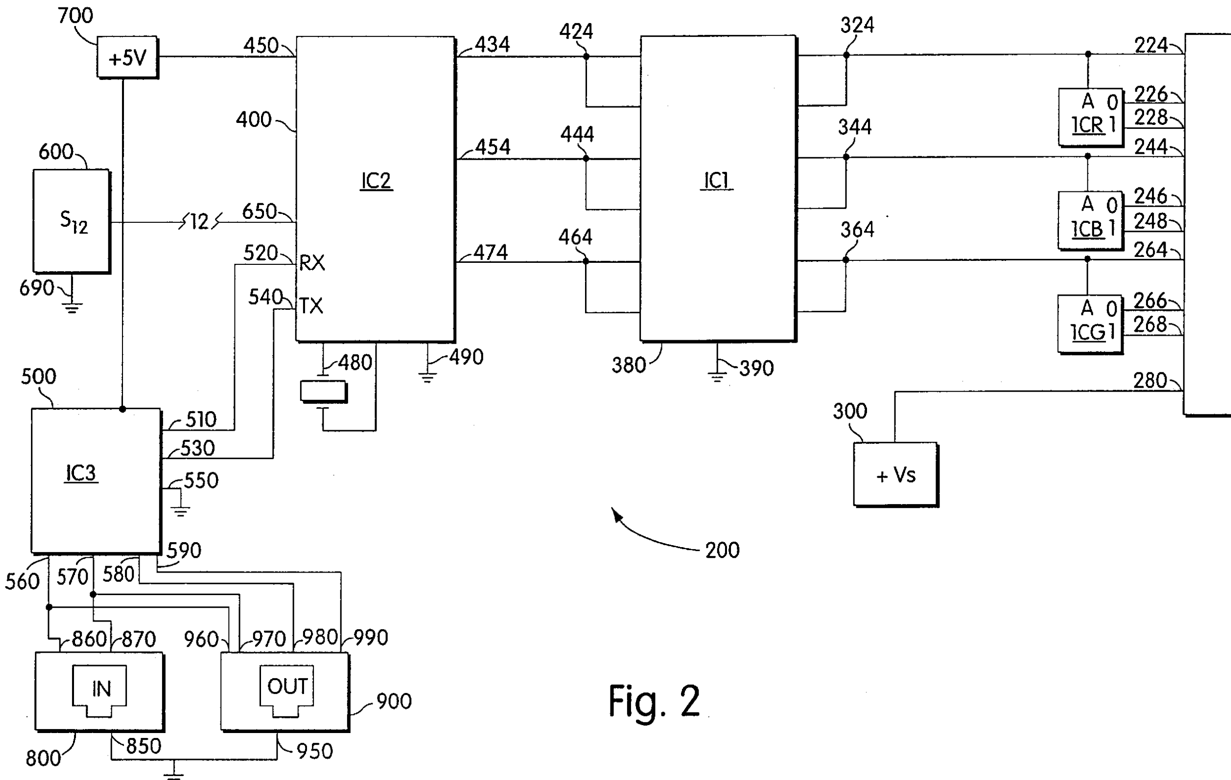

100
122
124
126
128
142
144
146
148
162
164
166
168
180
110
120
RED
140
BLUE
160
GREEN

Fig. 1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+5V
450
434
424
324
224
400
IC2
IC1
ICR
226
228
454
444
344
244
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12
650
ICB
246
248
210
474
464
364
264
520
RX
540
TX
690
ICG
266
268
480
490
380
390
500
280
300
+ Vs
IC3
510
530
550
200
590
560
570
580
860
870
960
970
980
990
IN
OUT
900
800
850
950

Fig. 2

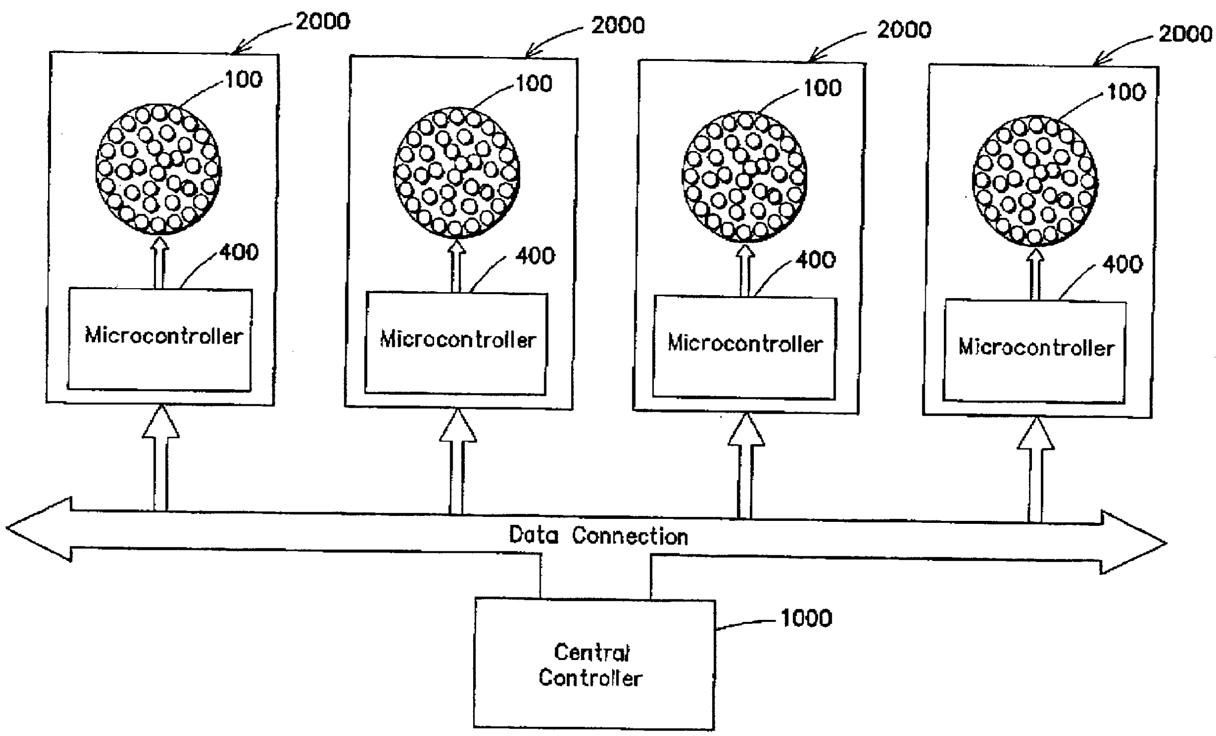
2000
2000
2000
2000
100
100
100
100
400
400
400
400
Microcontroller
Microcontroller
Microcontroller
Microcontroller
Data Connection
Central Controller
1000

Fig. 2A

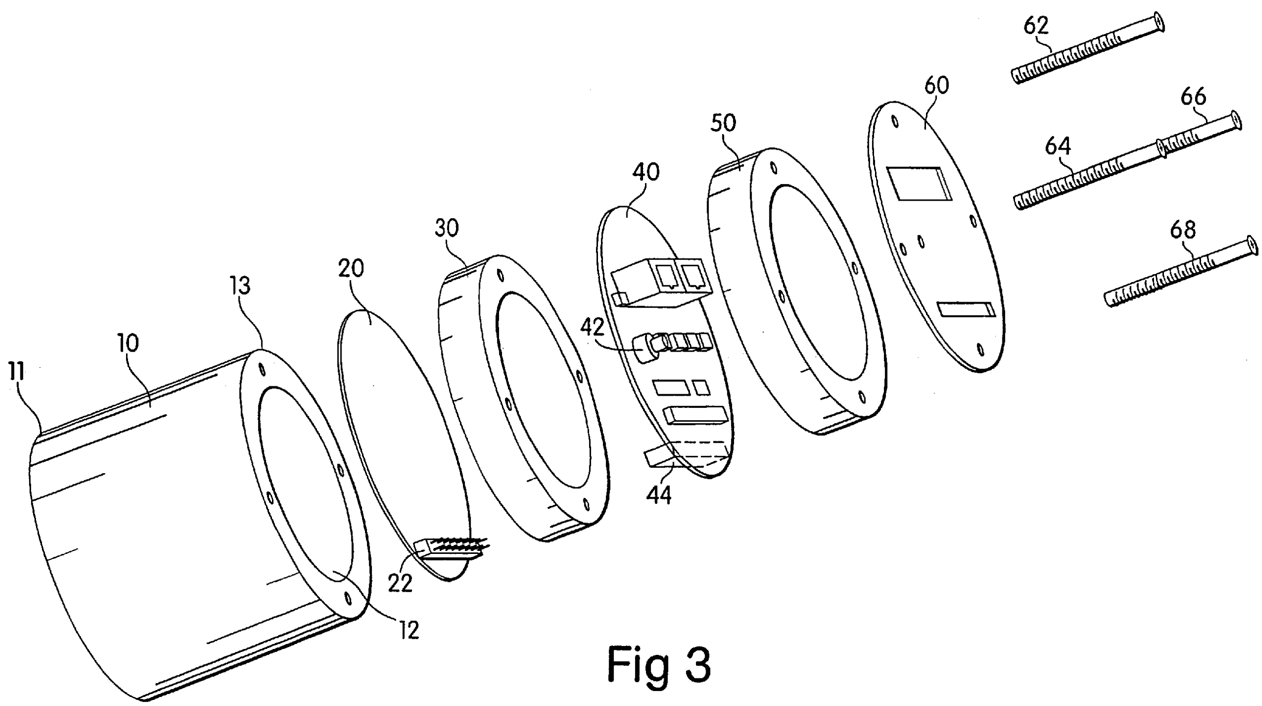

Fig 3

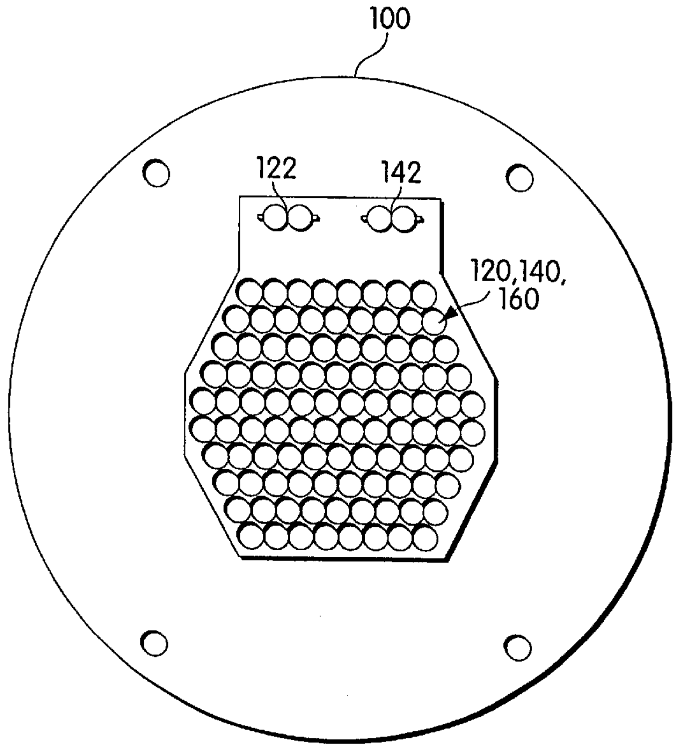

Fig. 4

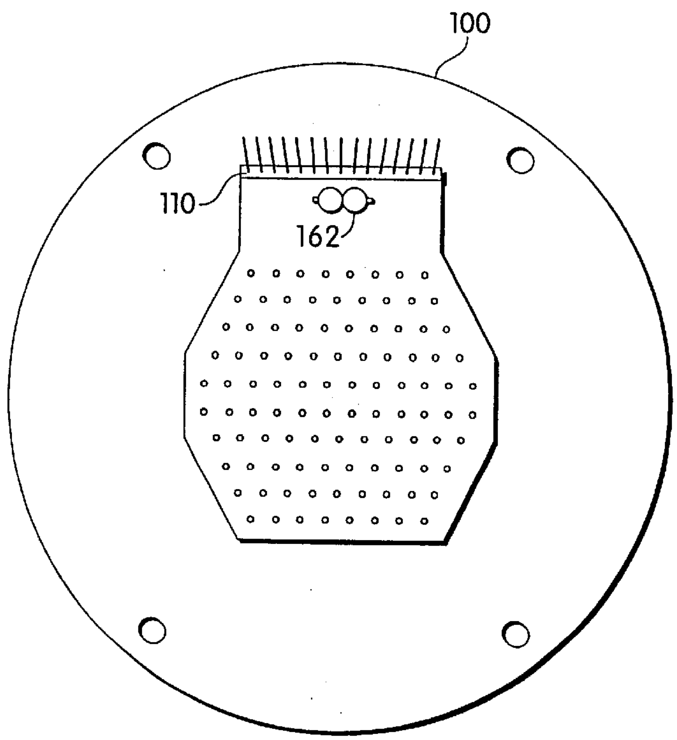

Fig. 5

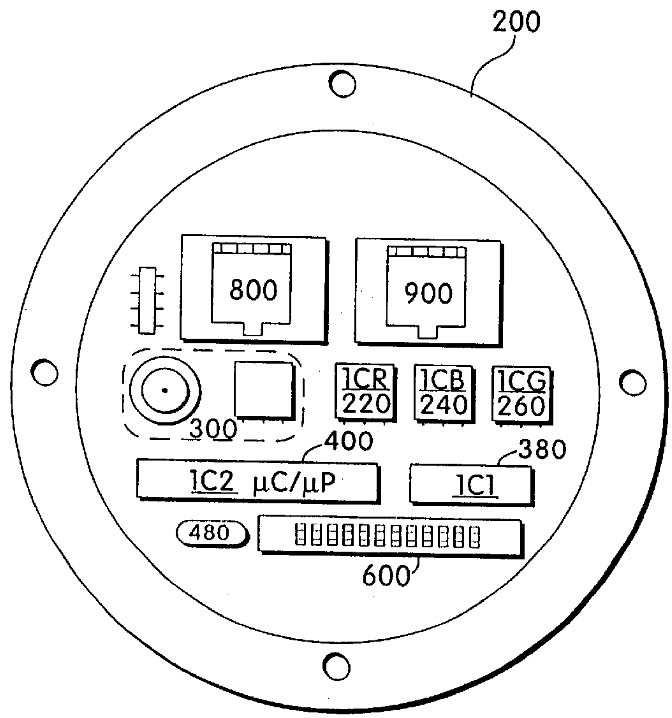
200
800
900
1CR
220
1CB
240
1CG
260
300
400
380
1C2 μC/μP
1C1
480
600

Fig. 6

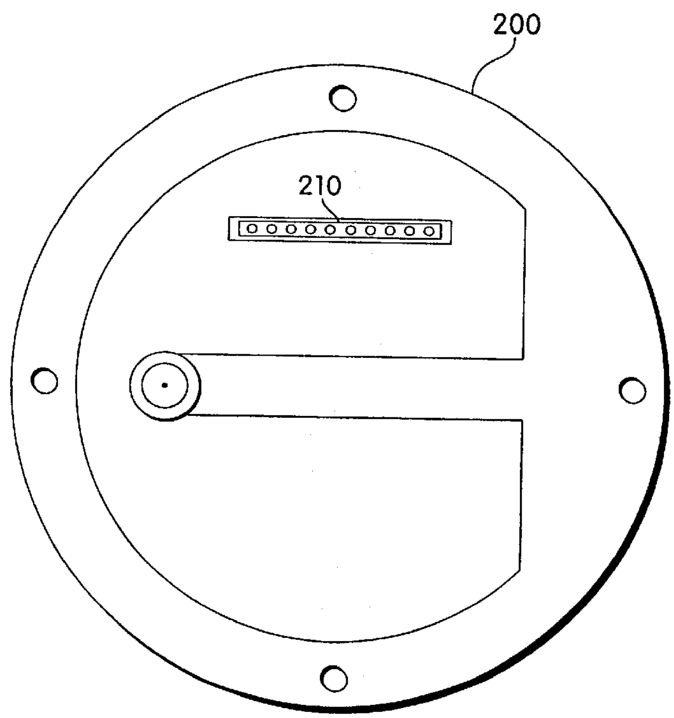
200
210

Fig. 7

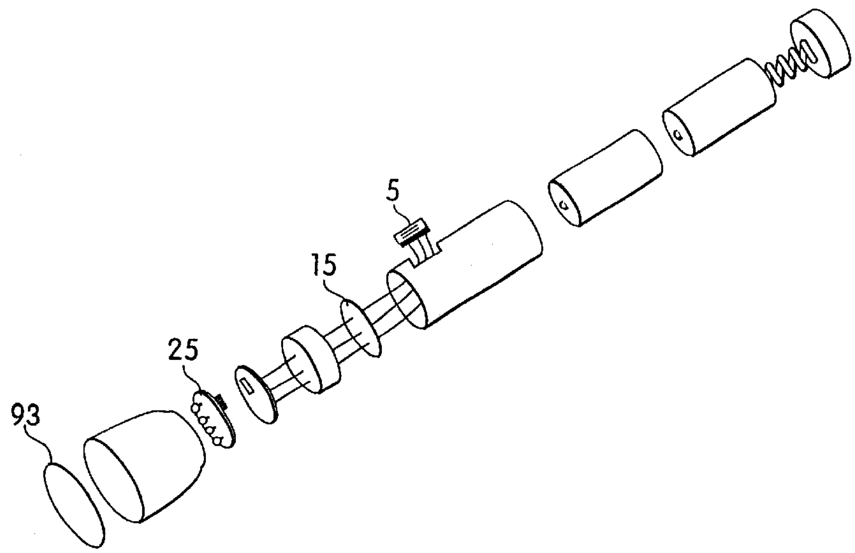
5
15
25
93

Fig. 8

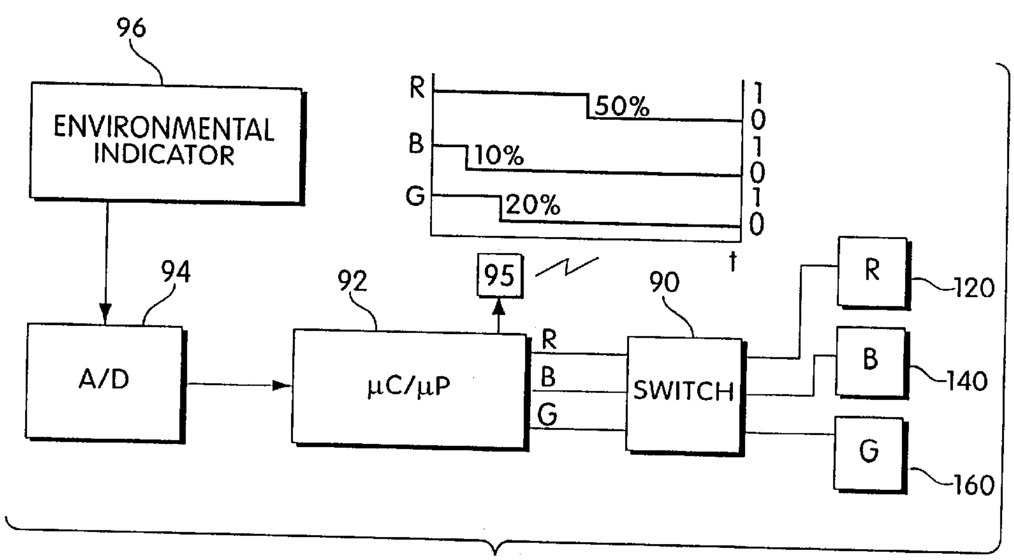
96
ENVIRONMENTAL INDICATOR
94
A/D
92
μC/μP
95
R
B
G
50%
10%
20%
1
0
1
0
1
0
t
90
SWITCH
R
B
G
120
140
160

Fig. 9

MULTICOLORED LED LIGHTING METHOD AND APPARATUS

CROSS REFERENCES TO RELATED APPLICATIONS

This application is a continuation of application Ser. No. 09/669,121, filed on Sep. 25, 2000, which is a continuation of application Ser. No. 09/425,770, filed Oct. 22, 1999, now U.S. Pat. No. 6,150,774, which is a continuation of application Ser. No. 08/920,156, filed Aug. 26, 1997, now U.S. Pat. No. 6,016,038.

BACKGROUND OF THE INVENTION

The present invention relates to providing light of a selectable color using LEDs. More particularly, the present invention is a method and apparatus for providing multicolored illumination. More particularly still, the present invention is an apparatus for providing a computer controlled multicolored illumination network capable of high performance and rapid color selection and change.

It is well known that combining the projected light of one color with the projected light of another color will result in the creation of a third color. It is also well known that the three most commonly used primary colors—red, blue and green—can be combined in different proportions to generate almost any color in the visible spectrum. The present invention takes advantage of these effects by combining the projected light from at least two light emitting diodes (LEDs) of different primary colors.

Computer lighting networks are not new. U.S. Pat. No. 5,420,482, issued to Phares, describes one such network that uses different colored LEDs to generate a selectable color. Phares is primarily for use as a display apparatus. However, the apparatus has several disadvantages and limitations. First, each of the three color LEDs in Phares is powered through a transistor biasing scheme in which the transistor base is coupled to a respective latch register through biasing resistors. The three latches are all simultaneously connected to the same data lines on the data bus. This means it is impossible in Phares to change all three LED transistor biases independently and simultaneously. Also, biasing of the transistors is inefficient because power delivered to the LEDs is smaller than that dissipated in the biasing network. This makes the device poorly suited for efficient illumination applications. The transistor biasing used by Phares also makes it difficult, if not impossible, to interchange groups of LEDs having different power ratings, and hence different intensity levels.

U.S. Pat. No. 4,845,481, issued to Havel, is directed to a multicolored display device. Havel addresses some, but not all of the switching problems associated with Phares. Havel uses a pulse width modulated signal to provide current to respective LEDs at a particular duty cycle. However, no provision is made for precise and rapid control over the colors emitted. As a stand alone unit, the apparatus in Havel suggests away from network lighting, and therefore lacks any teaching as to how to implement a pulse width modulated computer lighting network. Further, Havel does not appreciate the use of LEDs beyond mere displays, such as for illumination.

U.S. Pat. No. 5,184,114, issued to Brown, shows an LED display system. But Brown lacks any suggestion to use LEDs for illumination, or to use LEEDs in a configurable computer network environment. U.S. Pat. No. 5,134,387, issued to Smith et al., directed to an LED matrix display, contains similar problems. Its rudimentary cur-rent control scheme severely limits the possible range of colors that can be displayed.

It is an object of the present invention to overcome the limitations of the prior art by providing a high performance computer controlled multicolored LIED lighting network.

It is a further object of the present invention to provide a unique LED lighting network structure capable of both a linear chain of nodes and a binary tree configuration.

It is still another object of the present invention to provide a unique heat-dissipating housing to contain the lighting units of the lighting network.

It is yet another object of the present invention to provide a current regulated LED lighting apparatus, wherein the apparatus contains lighting modules each having its own maximum current rating and each conveniently interchangeable with one another.

It is a still further object of the present invention to provide a unique computer current-controlled LED lighting assembly for use as a general illumination device capable of emitting multiple colors in a continuously programmable 24-bit spectrum.

It is yet a still further object of the present invention to provide a unique flashlight, inclinometer, thermometer, general environmental indicator and lightbulb, all utilizing the general computer current-control principles of the present invention.

Other objects of the present invention will be apparent from the detailed description below.

SUMMARY OF THE INVENTION

In brief, the invention herein comprises a pulse width modulated current control for an LED lighting assembly, where each current-controlled unit is uniquely addressable and capable of receiving illumination color information on a computer lighting network. In a further embodiment, the invention includes a binary tree network configuration of lighting units (nodes). In another embodiment, the present invention comprises a heat dissipating housing, made out of a heat-conductive material, for housing the lighting assembly. The heat dissipating housing contains two stacked circuit boards holding respectively the power module and the light module. The light module is adapted to be conveniently interchanged with other light modules having programmable current, and hence maximum light intensity ratings. Other embodiments of the present invention involve novel applications for the general principles described herein.

DESCRIPTION OF THE DRAWINGS

FIG. **1** is a stylized electrical circuit schematic of the light module of the present invention.

FIG. **2** is a stylized electrical circuit schematic of the power module of the present invention.

FIG. **2**A illustrates a network of addressable LED-based lighting units according to one embodiment of the invention.

FIG. **3** is an exploded view of the housing of one of the embodiments of the present invention.

FIG. **4** is a plan view of the LED-containing side of the light module of the present invention.

FIG. **5** is a plan view of the electrical connector side of the light module of the present invention.

FIG. **6** is a plan view of the power terminal side of the power module of the present invention.

FIG. **7** is a plan view of the electrical connector side of the power module of the present invention.

FIG. **8** is an exploded view of a flashlight assembly containing the LED lighting module of the present invention.

FIG. **9** is a control block diagram of the environmental indicator of the present invention.

DETAILED DESCRIPTION

The structure and operation of a preferred embodiment will now be described. It should be understood that many other ways of practicing the inventions herein are available, and the embodiments described herein are exemplary and not limiting. Turning to FIG. **1**, shown is an electrical schematic representation of a light module **100** of the present invention. FIGS. **4** and **5** show the LED-containing side and the electrical connector side of light module **100**. Light module **100** is self-contained, and is configured to be a standard item interchangeable with any similarly constructed light module. Light module **100** contains a ten-pin electrical connector **110** of the general type. In this embodiment, the connector **110** contains male pins adapted to fit into a complementary ten-pin connector female assembly, to be described below. Pin **180** is the power supply. A source of DC electrical potential enters module **100** on pin **180**. Pin **180** is electrically connected to the anode end of light emitting diode (LED) sets **120, 140** and **160** to establish a uniform high potential on each anode end.

LED set **120** contains red LEDs, set **140** contains blue and set **160** contains green, each obtainable from the Nichia America Corporation. These LEDs are primary colors, in the sense that such colors when combined in preselected proportions can generate any color in the spectrum. While three primary colors is preferred, it will be understood that the present invention will function nearly as well with only two primary colors to generate any color in the spectrum. Likewise, while the different primary colors are arranged herein on sets of uniformly colored LEDs, it will be appreciated that the same effect may be achieved with single LEDs containing multiple color-emitting semiconductor dies. LED sets **120**, **140** and **160** each preferably contains a serial/parallel array of LEDs in the manner described by Okuno in U.S. Pat. No. 4,298,869, incorporated herein by reference. In the present embodiment, LED set **120** contains three parallel connected rows of nine red LEDs (not shown), and LED sets **140** and **160** each contain five parallel connected rows of five blue and green LEDs, respectively (not shown). It is understood by those in the art that, in general, each red LED drops the potential in the line by a lower amount than each blue or green LED, about 2.1 V, compared to 4.0 V, respectively, which accounts for the different row lengths. This is because the number of LEDs in each row is determined by the amount of voltage drop desired between the anode end at the power supply voltage and the cathode end of the last LED in the row. Also, the parallel arrangement of rows is a fail-safe measure that ensures that the light module **100** will still function even if a single LED in a row fails, thus opening the electrical circuit in that row. The cathode ends of the three parallel rows of nine red LEDs in LED set **120** are then connected in common, and go to pin **128** on connector **110**. Likewise, the cathode ends of the five parallel rows of five blue LEDs in LED set **140** are connected in common, and go to pin **148** on connector **110**. The cathode ends of the five parallel rows of five green LEDs in LED set **160** are connected in common, and go to pin **168** on connector **110**. Finally, on light module **100**, each LED set is associated with a programming resistor that combines with other components, described below, to program the maximum current through each set of LEDs. Between pin **124** and **126** is resistor **122**, 6.2 Ω. Between pin **144** and **146** is resistor **142**, 4.7 Ω. Between pin **164** and **166** is resistor **162**, 4.7 Ω. Resistor **122** programs maximum current through red LED set **120**, resistor **142** programs maximum current through blue LED set **140**, and resistor **162** programs maximum current through green LED set **160**. The values these resistors should take are determined empirically, based on the desired maximum light intensity of each LED set. In the present embodiment, the resistances above program red, blue and green currents of 70, 50 and 50 μA, respectively.

With the electrical structure of light module **100** described, attention will now be given to the electrical structure of power module **200**, shown in FIG. **2**. FIGS. **6** and **7** show the power terminal side and electrical connector side of an embodiment of power module **200**. Like light module **100**, power module **200** is self contained. Interconnection with male pin set **110** is achieved through complementary female pin set **210**. Pin **280** connects with pin **180** for supplying power, delivered to pin **280** from supply **300**. Supply **300** is shown as a functional block for simplicity. In actuality, supply **300** can take numerous forms for generating a DC voltage. In the present embodiment, supply **300** provides 24 Volts through a connection terminal (not shown), coupled to pin **280** through transient protection capacitors (not shown) of the general type. It will be appreciated that supply **300** may also supply a DC voltage after rectification and/or voltage transformation of an AC supply, as described more fully in U.S. Pat. No. 4,298,869.

Also connected to pin connector **210** are three current programming integrated circuits, ICR **220**, ICB **240** and ICG **260**. Each of these is a three terminal adjustable regulator, preferably part number LM317B, available from the National Semiconductor Corporation, Santa Clara, Calif. The teachings of the LM317 datasheet are incorporated herein by reference. Each regulator contains an input terminal, an output terminal and an adjustment terminal, labeled I, O and A, respectively. The regulators function to maintain a constant maximum current into the input terminal and out of the output terminal. This maximum current is pre-programmed by setting a resistance between the output and the adjustment terminals. This is because the regulator will cause the voltage at the input terminal to settle to whatever value is needed to cause 1.25 V to appear across the fixed current set resistor, thus causing constant current to flow. Since each functions identically, only ICR **220** will now be described. First, current enters the input terminal of ICR **220** from pin **228**. Of course, pin **228** in the power module is coupled to pin **128** in the light module, and receives current directly from the cathode end of the red LED set **120**. Since resistor **122** is ordinarily disposed between the output and adjustment terminals of ICR **220** through pins **224**/**124** and **226**/**126**, resistor **122** programs the amount of current regulated by ICR **220**. Eventually, the current output from the adjustment terminal of ICR **220** enters a Darlington driver. In this way, ICR **220** and associated resistor **122** program the maximum current through red LED set **120**. Similar results are achieved with ICB **240** and resistor **142** for blue LED set **140**, and with ICG **260** and resistor **162** for green LED set **160**.

The red, blue and green LED currents enter another integrated circuit, IC1 **380**, at respective nodes **324**, **344** and **364**. IC1 **380** is preferably a high current/voltage Darlington driver, part no. DS2003 available from the National Semiconductor Corporation, Santa Clara, Calif. IC1 **380** is used as a current sink, and functions to switch current between respective LED sets and ground **390**. As described in the DS2003 datasheet, incorporated herein by reference, IC1 contains six sets of Darlington transistors with appropriate on-board biasing resistors. As shown, nodes **324**, **344** and **364** couple the current from the respective LED sets to three pairs of these Darlington transistors, in the well known manner to take advantage of the fact that the current rating of IC**1** **380** may be doubled by using pairs of Darlington transistors to sink respective currents. Each of the three on-board Darlington pairs is used in the following manner as a switch. The base of each Darlington pair is coupled to signal inputs **424**, **444** and **464**, respectively. Hence, input **424** is the signal input for switching current through node **324**, and thus the red LED set **120**. Input **444** is the signal input for switching current through node **344**, and thus the blue LED set **140**. Input **464** is the signal input for switching current through node **364**, and thus the green LED set **160**. Signal inputs **424**, **444** and **464** are coupled to respective signal outputs **434**, **454** and **474** on microcontroller IC**2** **400**, as described below. In essence, when a high frequency square wave is incident on a respective signal input, IC**1** **380** switches current through a respective node with the identical frequency and duty cycle. Thus, in operation, the states of signal inputs **424**, **444** and **464** directly correlate with the opening and closing of the power circuit through respective LED sets **120**, **140** and **160**.

The structure and operation of microcontroller IC**2** **400** will now be described. Microcontroller IC**2** **400** is preferably a MICROCHIP brand PIC 16C63, although almost any properly programmed microcontroller or microprocessor can perform the software functions described herein. The main function of microcontroller IC**2** **400** is to convert numerical data received on serial Rx pin **520** into three independent high frequency square waves of uniform frequency but independent duty cycles on signal output pins **434**, **454** and **474**. The FIG. **2** representation of microcontroller IC**2** **400** is partially stylized, in that persons of skill in the art will appreciate that certain of the twenty-eight standard pins have been omitted or combined for greatest clarity.

Microcontroller IC**2** **400** is powered through pin **450**, which is coupled to a 5 Volt source of DC power **700**. Source **700** is preferably driven from supply **300** through a coupling (not shown) that includes a voltage regulator (not shown). An exemplary voltage regulator is the LM340 3-terminal positive regulator, available from the National Semiconductor Corporation, Santa Clara, Calif. The teachings of the LM340 datasheet are hereby incorporated by reference. Those of skill in the art will appreciate that most microcontrollers, and many other independently powered digital integrated circuits, are rated for no more than a 5 Volt power source. The clock frequency of microcontroller IC**2** **400** is set by crystal **480**, coupled through appropriate pins. Pin **490** is the microcontroller IC**2** **400** ground reference.

Switch **600** is a twelve position dip switch that may be alterably and mechanically set to uniquely identify the microcontroller IC**2** **400**. When individual ones of the twelve mechanical switches within dip switch **600** are closed, a path is generated from corresponding pins **650** on microcontroller IC**2** **400** to ground **690**. Twelve switches create 2^{12} possible settings, allowing any microcontroller IC**2** **400** to take on one of 4096 different IDs, or addresses. In the preferred embodiment, only nine switches are actually used because the DMX-512 protocol, discussed below, is employed.

Once switch **600** is set, microcontroller IC**2** **400** "knows" its unique address ("who am I"), and "listens" on serial line **520** for a data stream specifically addressed to it. A high speed network protocol, preferably a DMX protocol, is used to address network data to each individually addressed microcontroller IC**2** **400** from a central network controller **1000**, as shown for example in FIG. **2A**. The DMX protocol is described in a United States Theatre Technology, Inc. publication entitled "DMX512/1990 Digital Data Transmission Standard for Dimmers and Controllers," incorporated herein by reference. Basically, in the network protocol used herein, a central controller creates a stream of network data consisting of sequential data packets. Each packet first contains a header, which is checked for conformance to the standard and discarded, followed by a stream of sequential bytes representing data for sequentially addressed devices. For instance, if the data packet is intended for light number fifteen, then fourteen bytes from the data stream will be discarded, and the device will save byte number fifteen. If as in the preferred embodiment, more than one byte is needed, then the address is considered to be a starting address, and more than one byte is saved and utilized. Each byte corresponds to a decimal number 0 to 255, linearly representing the desired intensity from Off to Full. (For simplicity, details of the data packets such as headers and stop bits are omitted from this description, and will be well appreciated by those of skill in the art.) This way, each of the three LED colors is assigned a discrete intensity value between 0 and 255. These respective intensity values are stored in respective registers within the memory of microcontroller IC**2** **400** (not shown). Once tile central controller exhausts all data packets, it starts over in a continuous refresh cycle. The refresh cycle is defined by the standard to be a minimum of 1196 microseconds, and a maximum of 1 second.

Microcontroller IC**2** **400** is programmed continually to "listen" for its data stream. When microcontroller IC**2** **400** is "listening," but before it detects a data packet intended for it, it is running a routine designed to create the square wave signal outputs on pins **434**, **454** and **474**. The values in the color registers determine the duty cycle of the square wave. Since each register can take on a value from 0 to 255, these values create 256 possible different duty cycles in a linear range from 0% to 100%. Since the square wave frequency is uniform and determined by the program running in the microcontroller IC**2** **400**, these different discrete duty cycles represent variations in the width of the square wave pulses. This is known as pulse width modulation (PWM).

The PWM interrupt routine is implemented using a simple counter, incrementing from 0 to 255 in a cycle during each period of the square wave output on pins **434**, **454** and **474**. When the counter rolls over to zero, all three signals are set high. Once the counter equals the register value, signal output is changed to low. When microcontroller IC**2** **400** receives new data, it freezes the counter, copies the new data to the working registers, compares the new register values with the current count and updates the output pins accordingly, and then restarts the counter exactly where it left off. Thus, intensity values may be updated in the middle of the PWM cycle. Freezing the counter and simultaneously updating the signal outputs has at least two advantages. First, it allows each lighting unit to quickly pulse/strobe as a strobe light does. Such strobing happens when the central controller sends network data having high intensity values alternately with network data having zero intensity values at a rapid rate. If one restarted the counter without first updating the signal outputs, then the human eye would be able to perceive the staggered deactivation of each individual color LED that is set at a different pulse width. This feature is not of concern in incandescent lights because of the integrating effect associated with the heating and cooling cycle of the illumination element. LEDs, unlike incandescent elements, activate and deactivate essentially instantaneously in the present application. The second advantage is that one can "dim" the LEDs without the flickering that would otherwise occur if the counter were reset to zero. The central controller can send a continuous dimming signal when it creates a sequence of intensity values representing a uniform and proportional decrease in light intensity for each color LED. If one did not update the output signals before restarting the counter, there is a possibility that a single color LED will go through nearly two cycles without experiencing the zero current state of its duty cycle. For instance, assume the red register is set at 4 and the counter is set at 3 when it is frozen. Here, the counter is frozen just before the "off" part of the PWM cycle is to occur for the red LEDs. Now assume that the network data changes the value in the red register from 4 to 2 and the counter is restarted without deactivating the output signal. Even though the counter is greater than the intensity value in the red register, the output state is still "on", meaning that maximum current is still flowing through the red LEDs. Meanwhile, the blue and green LEDs will probably turn off at their appropriate times in the PWM cycle. This would be perceived by the human eye as a red flicker in the course of dimming the color intensities. Freezing the counter and updating the output for the rest of the PWM cycle overcomes these disadvantages, ensuring the flicker does not occur.

The network interface for microcontroller IC2 **400** will now be described. Jacks **800** and **900** are standard RJ-8 network jacks. Jack **800** is used as an input jack, and is shown for simplicity as having only three inputs: signal inputs **860**, **870** and ground **850**. Network data enters jack **800** and passes through signal inputs **860** and **870**. These signal inputs are then coupled to IC3 **500**, which is an RS-485/RS-422 differential bus repeater of the standard type, preferably a DS96177 from the National Semiconductor Corporation, Santa Clara, Calif. The teachings of the DS96177 datasheet are hereby incorporated by reference. The signal inputs **860**, **870** enter IC3 **500** at pins **560**, **570**. The data signal is passed through from pin **510** to pin **520** on microcontroller IC2 **400**. The same data signal is then returned from pin **540** on IC2 **400** to pin **530** on IC3 **500**. Jack **900** is used as an output jack and is shown for simplicity as having only five outputs: signal outputs **960**, **970**, **980**, **990** and ground **950**. Outputs **960** and **970** are split directly from input lines **860** and **870**, respectively. Outputs **980** and **990** come directly from IC3 **500** pins **580** and **590**, respectively. It will be appreciated that the foregoing assembly enables two network nodes to be connected for receiving the network data. Thus, a network may be constructed as a daisy chain, if only single nodes are strung together, or as a binary tree, if two nodes are attached to the output of each single node.

From the foregoing description, one can see that an addressable network of LED illumination or display units **2000** as shown in FIG. **2**A can be constructed from a collection of power modules each connected to a respective light module. As long as at least two primary color LEDs are used, any illumination or display color may be generated simply by preselecting the light intensity that each color emits. Further, each color LED can emit light at any of 255 different intensities, depending on the dug cycle of PWM square wave, with a full intensity pulse generated by passing maximum current through the LED. Further still, the maximum intensity can be conveniently programmed simply by adjusting the ceiling for the maximum allowable current using programming resistances for the current regulators residing on the light module. Light modules of different maximum current ratings may thereby be conveniently interchanged.

The foregoing embodiment may reside in any number of different housings. A preferred housing for an illumination unit is described. Turning now to FIG. **3**, there is shown an exploded view of an illumination unit of the present invention comprising a substantially cylindrical body section **10**, a light module **20**, a conductive sleeve **30**, a power module **40**, a second conductive sleeve **50** and an enclosure plate **60**. It is to be assumed here that the light module **20** and the power module **40** contain the electrical structure and software of light module **100** and power module **200**, described above. Screws **62**, **64**, **66**, **68** allow the entire apparatus to be mechanically connected. Body section **10**, conductive sleeves **30** and **50** and enclosure plate **60** are preferably made from a material that conducts heat, most preferably aluminum. Body section **10** has an open end **10**, a reflective interior portion **12** and an illumination end **13**, to which module **20** is mechanically affixed. Light module **20** is disk shaped and has two sides. The illumination side (not shown) comprises a plurality of LEDs of different primary colors. The connection side holds an electrical connector male pin assembly **22**. Both the illumination side and the connection side are coated with aluminum surfaces to better allow the conduction of heat outward from the plurality of LEDs to the body section **10**. Likewise, power module **40** is disk shaped and has every available surface covered with aluminum for the same reason. Power module **40** has a connection side holding an electrical connector female pin assembly **44** adapted to fit the pins from assembly **22**. Power module **40** has a power terminal side holding a terminal **42** for connection to a source of DC power. Any standard AC or DC jack may be used, as appropriate.

Interposed between light module **20** and power module **40** is a conductive aluminum sleeve **30**, which substantially encloses the space between modules **20** and **40**. As shown, a disk-shaped enclosure plate **60** and screws **62**, **64**, **66** and **68** sad all of the components together, and conductive sleeve **50** is thus interposed between enclosure plate **60** and power module **40**. Once sealed together as a unit, the illumination apparatus may be connected to a data network as described above and mounted in any convenient manner to illuminate an area. In operation, preferably a light diffusing means will be inserted in body section **10** to ensure that the LEDs on light module **20** appear to emit a single uniform frequency of light.

From the foregoing, it will be appreciated that PWM current control of LEDs to produce multiple colors may be incorporated into countless environments, with or without networks. For instance, FIG. **8** shows a hand-held flashlight can be made to shine any conceivable color using an LED assembly of the present invention. The flashlight contains an external adjustment means **5**, that may be for instance a set of three potentiometers coupled to an appropriately programmed microcontroller **92** through respective A/D conversion means **15**. Each potentiometer would control the current duty cycle, and thus the illumination intensity, of an individual color LED on LED board **25**. With three settings each capable of generating a different byte from 0 to 255, a computer-controlled flashlight may generate twenty-four bit color. Of course, three individual potentiometers can be incorporated into a single device such as a track ball or joystick, so as to be operable as a single adjuster. Further, it is not necessary that the adjustment means must be a potentiometer. For instance, a capacitive or resistive thumb plate may also be used to program the two or three registers necessary to set the color. A lens assembly **93** may be provided for reflecting the emitted light. A non-hand held embodiment of the present invention may be used as an underwater swimming pool light. Since the present invention can operate at relatively low voltages and low current, it is uniquely suited for safe underwater operation.

Similarly, the present invention may be used as a general indicator of any given environmental condition. FIG. **9** shows the general functional block diagram for such an apparatus. Shown within FIG. **9** is also an exemplary chart showing the duty cycles of the three color LEDs during an exemplary period. As one example of an environmental indicator **96**, the power module can be coupled to an inclinometer. The inclinometer measures general angular orientation with respect to the earth's center of gravity. The inclinometer's angle signal can be converted through an A/D converter **94** and coupled to the data inputs of the microcontroller **92** in the power module. The microcontroller **92** can then be programmed to assign each discrete angular orientation a different color through the use of a lookup table associating angles with LED color register values. A current switch **90**, coupled to the microcontroller **92**, may be used to control the current supply to LEDs **120**, **140**, and **160** of different colors. The microcontroller **92** may be coupled to a transceiver **95** for transmitting and receiving signals. The "color inclinometer" may be used for safety, such as in airplane cockpits, or for novelty, such as to illuminate the sails on a sailboat that sways in the water. Another indicator use is to provide an easily readable visual temperature indication. For example, a digital thermometer can be connected to provide the microcontroller a temperature reading Each temperature will be associated with a particular set of register values, and hence a particular color output A plurality of such "color thermometers" can be located over a large space, such as a storage freezer, to allow simple visual inspection of temperature over three dimensions.

Another use of the present invention is as a lightbulb. Using appropriate rectifier and voltage transformation means, the entire power and light modules may be placed in an Edison-mount (screw-type) lightbulb housing. Each bulb can be programmed with particular register values to deliver a particular color bulb, including white. The current regulator can be pre-programmed to give a desired current rating and thus preset light intensity. Naturally, the lightbulb will have a transparent or translucent section that allows the passage of light into the ambient.

While the foregoing has been a detailed description of the preferred embodiment of the invention, the claims which follow define more freely the scope of invention to which applicant is entitled. Modifications or improvements which may not come within the explicit language of the claims described in the preferred embodiments should be treated as within the scope of invention insofar as they are equivalent or otherwise consistent with the contribution over the prior art and such contribution is not to be limited to specific embodiments disclosed.

What is claimed is:

1. An illumination apparatus, comprising:

at least one first LED adapted to output at least first radiation having a first spectrum;

at least one second LED adapted to output second radiation having a second spectrum different than the first spectrum; and

at least one controller coupled to the at least one first LED and the at least one second LED and configured to respond to user operation of at least one user interface in communication with the at least one controller, the at least one controller further configured to independently control at least a first intensity of the first radiation and a second intensity of the second radiation in response to the user operation,

wherein the at least one controller is configured 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.

2. The illumination apparatus of claim **1**, wherein the at least one controller is configured as an addressable controller capable of receiving at least one network signal including address information and lighting information.

3. The illumination apparatus of claim **1**, wherein the at least one controller is configured to independently control at least the first intensity of the first radiation and the second intensity of the second radiation so as to controllably vary an overall color generated by the apparatus as perceived by an observer.

4. The illumination apparatus of claim **1**, wherein the at least one controller is configured to independently control at least the first intensity of the first radiation and the second intensity of the second radiation such that an overall color generated by the illumination apparatus represents a single observable color at a given time.

5. The illumination apparatus of claim **1**, wherein the at least one controller is configured to independently control at least the first intensity of the first radiation and the second intensity of the second radiation so as to controllably vary an overall intensity of illumination generated by the apparatus as perceived by an observer.

6. The illumination apparatus of claim **1**, wherein the at least one controller is configured to independently control at least the first intensity of the first radiation and the second intensity of the second radiation so as to produce a dynamic lighting effect as perceived by an observer.

7. The illumination apparatus of claim **1**, further comprising at least one third LED adapted to output third radiation having a third spectrum different than the first spectrum and the second spectrum, wherein the at least one controller is further adapted to independently control a third intensity of the third radiation in response to the user operation of the at least one user interface.

8. The illumination apparatus of claim **7**, wherein at least one of the at least one first LED, the at least one second LED, and the at least one third LED includes at least one blue LED.

9. The illumination apparatus of claim **8**, wherein the at least one first LED, the at least one second LED, and the at least one third LED respectively include at least one red LED, at least one green LED, and at least one blue LED.

10. The illumination apparatus of claim **1**, further comprising at least one optical element disposed in a path of at least the first radiation and the second radiation to optically process at least the first radiation and the second radiation.

11. The illumination apparatus of claim **10**, wherein the at least one optical element is configured to receive at least the first and second radiation and to display a color that is a combination of at least the first and second radiation.

12. The illumination apparatus of claim **1**, further including at least one sensor to monitor at least one detectable condition, wherein the at least one controller is configured to further control the at least one first LED and the at least one second LED in response to the at least one detectable condition.

13. The illumination apparatus of claim **1**, further including at least one transceiver coupled to the at least one controller and configured to communicate at least one IR signal or at least one electromagnetic signal.

14. The illumination apparatus of claim **1**, wherein:

the at least one controller includes at least one first register associated with the at least one first LED and at least one second register associated with the at least one second LED; and the at least one controller is configured to program the at least one first register and the at least one second register based on the user operation.

15. The illumination apparatus of claim **1**, wherein the at least one controller includes at least one adjustable regulator configured to variably regulate power to at least one of the at least one first LED and the at least one second LED.

16. The illumination apparatus of claim **1**, wherein:

the at least one controller includes a first switch and a second switch respectively associated with the at least one first LED and the at least one second LED; and

the at least one controller is configured to control the at least one first LED and the at least one second LED by turning the first and second switches on and off at high speeds.

17. The illumination apparatus of claim **2**, wherein:

the addressable controller includes a first switch and a second switch respectively associated with the at least one first LED and the at least one second LED; and

the addressable controller is configured to control the at least one first LED and the at least one second LED by turning the first and second switches on and off at high speeds.

18. The illumination apparatus of claim **1**, wherein the at least one controller is configured to implement the PWM technique such that at least one potentially observable artifact in at least the first radiation and the second radiation is reduced.

19. The illumination apparatus of claim **18**, wherein the at least one potentially observable artifact includes a flicker effect, and wherein the at least one controller is configured to implement the PWM technique such that the flicker effect is reduced.

20. The illumination apparatus of claim **19**, wherein the at least one controller is configured to be capable of varying an overall intensity of illumination generated by the apparatus with essentially no perceivable flicker effect.

21. The illumination apparatus of claim **18**, wherein the at least one controller includes:

at least one first register associated with the at least one first LED to store a first intensity value representing a first PWM control signal;

at least one second register associated with the at least one second LED to store a second intensity value representing a second PWM control signal; and

at least one PWM counter,

wherein:

the at least one controller is configured to program at least the at least one first register and the at least one second register with the first and second intensity values, respectively, based on the user operation; and

the at least one controller is configured to generate the first and second PWM control signals based on a comparison of the at least one PWM counter to the first and second intensity values, respectively.

22. The illumination apparatus of claim **21**, wherein the first and second intensity values represent respective duty cycles of the first and second PWM control signals.

23. The illumination apparatus of claim **21**, wherein the at least one controller is configured to freeze the at least one PWM counter when at least one of the at least one first register and the at least one second register is programmed with a new intensity value.

24. The illumination apparatus of claim **23**, wherein the at least one controller is configured to update at least one of the first PWM control signal and the second PWM control signal based on the new intensity value after the at least one PWM counter is frozen, and then restart the at least one PWM counter where it left off after the at least one of the first PWM control signal and the second PWM control signal is updated.

25. The illumination apparatus of claim **1**, wherein the at least one controller includes at least one modular connection to facilitate coupling of the at least one controller to the at least one first LED and the at least one second LED.

26. The illumination apparatus of claim **25**, wherein:

the at least one first LED and the at least one second LED are supported by a first substrate;

the at least one controller is supported by a second substrate; and

the at least one modular connection facilitates mechanical and electrical coupling of the first substrate and the second substrate.

27. The illumination apparatus of claim **1**, further comprising the at least one user interface.

28. The illumination apparatus of claim **27**, wherein the at least one user interface comprises at least one external adjustment means.

29. The illumination apparatus of claim **27**, wherein the at least one user interface consists of a single user-operated device to control the at least one controller.

30. The illumination apparatus of claim **27**, wherein:

the at least one controller includes at least one first register associated with the at least one first LED and at least one second register associated with the at least one second LED; and

the at least one user interface and the at least one controller are configured to program the at least one first register and the at least one second register based on the user operation.

31. The illumination apparatus of claim **30**, wherein:

the at least one user interface and the at least one controller are configured to program, based on the user operation, the at least one first register and the at least one second register with intensity values representing duty cycles of PWM control signals.

32. The illumination apparatus of claim **27**, wherein the at least one user interface comprises at least one of at least one potentiometer, a thumb plate, a trackball, a joystick, a switch, and a network interface.

33. The illumination apparatus of claim **1**, further comprising a voltage converter to convert an AC potential to a DC power source to supply DC power to at least the at least one controller.

34. The illumination apparatus of claim **33**, wherein the DC power source supplies DC power to the at least one first LED and the at least one second LED.

35. The illumination apparatus of claim **2**, in combination with a central network controller that is configured to generate the at least one network signal.

36. The illumination apparatus of claim **33**, wherein:

the at least one controller includes a first switch and a second switch respectively associated with the at least one first LED and the at least one second LED; and

the at least one controller is configured to control the at least one first LED and the at least one second LED by turning the first and second switches on and off at high speeds.

37. The illumination apparatus of claim **1**, further comprising a housing to support the at least one controller, the at least one first LED, and the at least one second LED.

38. The illumination apparatus of claim **37**, wherein the housing includes at least one electrically conductive portion.

39. The illumination apparatus of claim **37**, wherein the housing includes at least one heat conductive portion.

40. The illumination apparatus of claim **37**, wherein the housing includes at least one light diffuser disposed in the path of the first radiation and the second radiation.

41. The illumination apparatus of claim **37**, wherein the housing is configured such that the apparatus is a hand-held illumination device.

42. The illumination apparatus of claim **37**, wherein the housing is configured such that the apparatus is an underwater swimming pool light.

43. The illumination apparatus of claim **37**, wherein the housing is configured such that the at least one controller, the at least one first LED, and the at least one second LED are substantially enclosed by the housing.

44. The illumination apparatus of claim **37**, wherein the housing is configured to resemble a conventional light bulb.

45. The illumination apparatus of claim **37**, wherein the housing includes at least one power connection coupled to the at least one controller, the at least one power connection configured to engage mechanically and electrically with a conventional light socket.

46. The illumination apparatus of claim **37**, further comprising the at least one user interface.

47. The illumination apparatus of claim **46**, wherein the at least one user interface is integrated with the housing.

48. The illumination apparatus of claim **2**, wherein the addressable controller has an alterable address.

49. The illumination apparatus of claim **2**, wherein the at least one network signal is formatted using a DMX protocol, and wherein the addressable controller is configured to control the at least one first LED and the at least one second LED based at least in part on the DMX protocol.

50. The illumination apparatus of claim **2**, wherein the addressable controller is configured to control the at least one first LED and the at least one second LED based at least in part on the user operation of the at least one user interface and the lighting information.

51. The illumination apparatus of claim **2**, wherein the at least one network signal is provided to the addressable controller based at least in part on the user operation of the at least one user interface.

52. The illumination apparatus of claims **2**, wherein the network signal includes address information and lighting information for a plurality of illumination apparatus, wherein the lighting information includes intensity values for LEDs of the plurality of illumination apparatus, and wherein the addressable controller is configured to process the network signal based on an address of the addressable controller and the address information in the network signal to recover from the lighting information the intensity values for at least the first and second LEDs of the illumination apparatus.

53. In an illumination apparatus comprising at least one first LED adapted to output at least first radiation having a first spectrum and at least one second LED adapted to output second radiation having a second spectrum different than the first spectrum, an illumination control method, comprising an act of:

a) independently controlling at least a first intensity of the first radiation and a second intensity of the second radiation in response to user operation of at least one user interface,

wherein the act a) includes an act of:

b) implementing 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.

54. The illumination method of claim **53**, wherein the act a) includes acts of:

a1) receiving at least one addressed network signal including lighting information; and

a2) controlling at least the first intensity and the second intensity based at least in part on the lighting information.

55. The illumination method of claim **54**, wherein the act a1) includes an act of:

receiving the at least one addressed network signal based at least in part on the user operation of the at least one user interface.

56. The illumination method of claim **54**, wherein the at least one addressed network signal includes address information and lighting information for a plurality of illumination apparatus, wherein the lighting information includes intensity values for LEDs of the plurality of illumination apparatus, wherein the illumination apparatus has an address, and wherein the act a2) includes an act of:

processing the at least one addressed network signal based on the address of the illumination apparatus and the address information in the network signal to recover the intensity values for at least the first and second LEDs of the illumination apparatus.

57. The illumination method of claim **54**, wherein the act a1) includes an act of:

receiving the at least one addressed network signal from a central network controller.

58. The illumination method of claim **54**, wherein the at least one addressed network signal is formatted using a DMX protocol, and wherein the act a2) includes an act of:

controlling the at least one first LED and the at least one second LED based at least in part on the DMX protocol.

59. The illumination method of claim **53**, wherein the act a) includes an act of:

independently controlling at least the first intensity of the first radiation and the second intensity of the second radiation so as to controllably vary an overall color generated by the apparatus as perceived by an observer.

60. The illumination method of claim **53**, wherein the act a) includes an act of:

independently controlling at least the first intensity of the first radiation and the second intensity of the second radiation such that an overall color generated by the illumination apparatus represents a single observable color at a given time.

61. The illumination method of claim **53**, wherein the act a) includes an act of:

independently controlling at least the first intensity of the first radiation and the second intensity of the second radiation so as to controllably vary an overall intensity of illumination generated by the apparatus as perceived by an observer.

62. The illumination method of claim **53**, wherein the act a) includes an act of:

independently controlling at least the first intensity of the first radiation and the second intensity of the second radiation so as to produce a dynamic lighting effect as perceived by an observer.

63. The illumination method of claim **53**, wherein the illumination apparatus further comprises at least one third LED adapted to output third radiation having a third spectrum different than the first spectrum and the second spectrum, wherein the act a) includes an act of:

independently controlling a third intensity of the third radiation in response to the user operation of the at least one user interface.

64. The illumination method of claim **63**, wherein at least one of the at least one first LED, the at least one second LED, and the at least one third LED includes at least one blue LED.

65. The illumination method of claim **63**, wherein the at least one first LED, the at least one second LED, and the at least one third LED respectively include at least one red LED, at least one green LED, and at least one blue LED.

66. The illumination method of claim **53**, further comprising an act of:

optically processing at least the first radiation and the second radiation.

67. The illumination method of claim **66**, wherein the act of optically processing includes an act of:

optically processing at least the first and second radiation so as to display a color that is a combination of at least the first and second radiation.

68. The illumination method of claim **53**, wherein the illumination apparatus further includes at least one sensor to monitor at least one detectable condition, and wherein the method further includes an act of:

controlling the at least one first LED and the at least one second LED in response to the at least one detectable condition.

69. The illumination method of claim **53**, further including an act of:

communicating with the illumination apparatus via at least one IR signal or at least one electromagnetic signal.

70. The illumination method of claim **53**, wherein the illumination apparatus includes at least one first register associated with the at least one first LED and at least one second register associated with the at least one second LED, and wherein the act a) includes an act of:

programming the at least one first register and the at least one second register based on the user operation of the at least one user interface.

71. The illumination method of claim **53**, wherein the act a) includes an act of:

variably regulating power to at least one of the at least one first LED and the at least one second LED.

72. The illumination method of claim **53**, wherein each of the at least one first LED and the at least one second LED is associated with a switch, and wherein the act a) includes an act of:

controlling the at least one first LED and the at least one second LED by turning the respective switches on and off at high speeds.

73. The illumination method of claim **58**, wherein each of the at least one first LED and the at least one second LED is associated with a switch, and wherein the act a2) further includes an act of:

controlling the at least one first LED and the at least one second LED by turning the respective switches on and off at high speeds.

74. The illumination method of claim **53**, wherein the act b) includes an act of:

c) implementing the PWM technique such that at least one potentially observable artifact in at least the first radiation and the second radiation is reduced.

75. The illumination method of claim **74**, wherein the at least one potentially observable artifact includes a flicker effect, and wherein the act c) includes an act of:

implementing the PWM technique such that the flicker effect is reduced.

76. The illumination method of claim **75**, wherein the act c) includes an act of:

varying an overall intensity of illumination generated by the apparatus with essentially no perceivable flicker effect.

77. The illumination method of claim **74**, wherein the illumination apparatus includes:

at least one first register associated with the at least one first LED to store a first intensity value representing a first PWM control signal;

at least one second register associated with the at least one second LED to store a second intensity value representing a second PWM control signal; and

at least one PWM counter,

and wherein the act c) includes acts of:

d) programming at least the at least one first register and the at least one second register with the first and second intensity values, respectively, based on the user operation; and

e) generating the first and second PWM control signals based on a comparison of the at least one PWM counter to the first and second intensity values, respectively.

78. The illumination method of claim **77**, wherein the first and second intensity values represent respective duty cycles of the first and second PWM control signals.

79. The illumination method of claim **77**, wherein the act e) includes an act of:

f) freezing the at least one PWM counter when at least one of the at least one first register and the at least one second register is programmed with a new intensity value.

80. The illumination method of claim **79**, wherein the act e) further includes acts of:

g) updating at least one of the first PWM control signal and the second PWM control signal based on the new intensity value after the at least one PWM counter is frozen in the act f); and

h) restarting the at least one PWM counter where it left off after the at least one of the first PWM control signal and the second PWM control signal is updated in the act g).

81. In an illumination apparatus comprising at least one first LED adapted to output at least first radiation having a first spectrum and at least one second LED adapted to output second radiation having a second spectrum different than the first spectrum, an illumination control method, comprising an act of:

a) implementing 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 such that at least one potentially observable artifact in at least the first radiation and the second radiation is reduced.

82. The illumination method of claim **81**, wherein the at least one potentially observable artifact includes a flicker effect, and wherein the act a) includes an act of:

implementing the PWM technique such that the flicker effect is reduced.

83. The illumination method of claim **82**, wherein the act a) includes an act of:

varying an overall intensity of illumination generated by the apparatus with essentially no perceivable flicker effect.

84. The illumination method of claim **81**, wherein the illumination apparatus further includes:

at least one first register associated with the at least one first LED to store a first intensity value representing a first PWM control signal;

at least one second register associated with the at least one second LED to store a second intensity value representing a second PWM control signal; and

at least one PWM counter,

and wherein the act a) includes acts of:

b) programming at least the at least one first register and the at least one second register with the first and second intensity values, respectively; and

c) generating the first and second PWM control signals based on a comparison of the at least one PWM counter to the first and second intensity values, respectively.

85. The illumination method of claim **84**, wherein the first and second intensity values represent respective duty cycles of the first and second PWM control signals.

86. The illumination method of claim **84**, wherein the act c) includes an act of:

d) freezing the at least one PWM counter when at least one of the at least one first register and the at least one second register is programmed with a new intensity value.

87. The illumination method of claim **86**, wherein the act c) further includes acts of:

e) updating at least one of the first PWM control signal and the second PWM control signal based on the new intensity value after the at least one PWM counter is frozen in the act d); and

f) restarting the at least one PWM counter where it left off after the at least one of the first PWM control signal and the second PWM control signal is updated in the act e).

88. An illumination apparatus, comprising:

at least one first LED adapted to output at least first radiation having a first spectrum;

at least one second LED adapted to output second radiation having a second spectrum different than the first spectrum;

at least one controller coupled to the at least one first LED and the at least one second LED and configured to respond to user operation of at least one user interface in communication with the at least one controller, the at least one controller further configured to independently control at least a first intensity of the first radiation and a second intensity of the second radiation in response to the user operation; and

at least one sensor to monitor at least one detectable condition,

wherein the at least one controller is configured to further control the at least one first LED and the at least one second LED in response to the at least one detectable condition.

89. An illumination apparatus, comprising:

at least one first LED adapted to output at least first radiation having a first spectrum;

at least one second LED adapted to output second radiation having a second spectrum different than the first spectrum;

at least one controller coupled to the at least one first LED and the at least one second LED and configured to respond to user operation of at least one user interface in communication with the at least one controller, the at least one controller further configured to independently control at least a first intensity of the first radiation and a second intensity of the second radiation in response to the user operation; and

at least one transceiver coupled to the at least one controller and configured to communicate at least one IR signal or at least one electromagnetic signal.

90. An illumination apparatus, comprising:

at least one first LED adapted to output at least first radiation having a first spectrum;

at least one second LED adapted to output second radiation having a second spectrum different than the first spectrum; and

at least one controller coupled to the at least one first LED and the at least one second LED and configured to respond to user operation of at least one user interface in communication with the at least one controller, the at least one controller further configured to independently control at least a first intensity of the first radiation and a second intensity of the second radiation in response to the user operation,

wherein:

the at least one controller includes at least one first register associated with the at least one first LED and at least one second register associated with the at least one second LED; and

the at least one controller is configured to program the at least one first register and the at least one second register based on the user operation.

91. An illumination apparatus, comprising:

at least one first LED adapted to output at least first radiation having a first spectrum;

at least one second LED adapted to output second radiation having a second spectrum different than the first spectrum; and

at least one controller coupled to the at least one first LED and the at least one second LED and configured to respond to user operation of at least one user interface in communication with the at least one controller, the at least one controller further configured to independently control at least a first intensity of the first radiation and a second intensity of the second radiation in response to the user operation,

wherein the at least one controller includes at least one adjustable regulator configured to variably regulate power to at least one of the at least one first LED and the at least one second LED.

92. An illumination apparatus, comprising:

at least one first LED adapted to output at least first radiation having a first spectrum;

at least one second LED adapted to output second radiation having a second spectrum different than the first spectrum; and

at least one controller coupled to the at least one first LED and the at least one second LED and configured to respond to user operation of at least one user interface in communication with the at least one controller, the at least one controller further configured to independently control at least a first intensity of the first radiation and a second intensity of the second radiation in response to the user operation,

wherein:

the at least one controller includes a first switch and a second switch respectively associated with the at least one first LED and the at least one second LED; and

the at least one controller is configured to control the at least one first LED and the at least one second LED by turning the first and second switches on and off at high speeds.

93. In an illumination apparatus comprising at least one first LED adapted to output at least first radiation having a first spectrum and at least one second LED adapted to output second radiation having a second spectrum different than the first spectrum, an illumination control method, comprising acts of:

a) receiving at least one signal formatted at least in part using a DMX protocol and including lighting information based at least in part on user operation of at least one user interface; and

b) controlling at least the first intensity and the second intensity based at least in part on the lighting information.

94. The illumination method of claim **93**, wherein the at least one user interface includes a central network controller, and wherein the act a) includes an act of:

receiving the at least one signal from the central network controller.

95. The illumination method of claim **93**, wherein the act a) includes an act of:

a1) receiving at least one network signal formatted at least in part using the DMX protocol and including lighting information for a plurality of illumination apparatus.

96. The illumination method of claim **95**, wherein the act a1) includes an act of:

receiving the at least one network signal based at least in part on the user operation of the at least one user interface.

97. The illumination method of claim **95**, wherein the at least one network signal includes address information, wherein the lighting information includes intensity values for LEDs of the plurality of illumination apparatus, wherein the illumination apparatus has an address, and wherein the act a1) includes an act of:

a2) processing the at least one network signal based on the address of the illumination apparatus and the address information in the at least one network signal to recover the intensity values for at least the first and second LEDs of the illumination apparatus.

98. The illumination method of claim **97**, wherein the address information relates to an arrangement of data packets in the at least one network signal, and wherein the act a2) includes an act of:

processing the at least one network signal based on the address of the illumination apparatus and the arrangement of data packets in the at least one network signal to recover the intensity values for at least the first and second LEDs of the illumination apparatus.

99. The illumination method of claim **97**, wherein the at least one user interface includes a central network controller, and wherein the act a) includes an act of:

receiving the at least one signal from the central network controller.

100. The illumination method of claim **93**, wherein the act b) further includes an act of:

implementing a pulse width modulation technique to control at least the first intensity of the first radiation and the second intensity of the second radiation.

101. The illumination method of claim **93**, wherein each of the at least one first LED and the at least one second LED is associated with a switch, and wherein the act a) further includes an act of:

controlling the at least one first LED and the at least one second LED by turning the respective switches on and off at high speeds.

102. An illumination apparatus, comprising:

at least one first LED adapted to output at least first radiation having a first spectrum;

at least one second LED adapted to output second radiation having a second spectrum different than the first spectrum;

at least one user interface; and

at least one controller coupled to the at least one first LED and the at least one second LED and configured to respond to user operation of the at least one user interface, the at least one controller further configured to independently control at least a first intensity of the first radiation and a second intensity of the second radiation in response to the user operation,

wherein the at least one user interface comprises at least one external adjustment means.

103. An illumination apparatus, comprising:

at least one first LED adapted to output at least first radiation having a first spectrum;

at least one second LED adapted to output second radiation having a second spectrum different than the first spectrum; and

at least one controller coupled to the at least one first LED and the at least one second LED and configured to respond to user operation of at least one user interface in communication with the at least one controller, the at least one controller further configured to independently control at least a first intensity of the first radiation and a second intensity of the second radiation in response to the user operation,

wherein the at least one controller is configured as an addressable controller capable of receiving at least one network signal including lighting information for a plurality of illumination apparatus.

104. The illumination apparatus of claim **103**, wherein the addressable controller is configured to control the at least one first LED and the at least one second LED based at least in part on the user operation of the at least one user interface and the lighting information.

105. The illumination apparatus of claim **103**, wherein the at least one network signal is provided to the addressable controller based at least in part on the user operation of the at least one user interface.

106. The illumination apparatus of claim **103**, wherein the lighting information includes intensity values for LEDs of the plurality of illumination apparatus, and wherein the addressable controller is configured to process the at least one network signal based on an address of the addressable controller to recover from the lighting information the intensity values for at least the first and second LEDs of the illumination apparatus.

107. The illumination apparatus of claim **106**, wherein the at least one network signal includes address information.

108. The illumination apparatus of claim **107**, wherein the address information relates to an arrangement of data packets in the at least one network signal.

109. The illumination apparatus of claim **103**, wherein the addressable controller has an alterable address.

110. The illumination apparatus of claim **103**, wherein the at least one network signal is formatted using a DMX protocol, and wherein the addressable controller is configured to control the at least one first LED and the at least one second LED based at least in part on the DMX protocol.

111. The illumination apparatus of claim **103**, in combination with the at least one user interface, wherein the at least one user interface is a central network controller that is configured to generate the at least one network signal.

112. The illumination apparatus of claim **103**, wherein the addressable controller is configured to implement a pulse width modulation technique to control at least the first intensity of the first radiation and the second intensity of the second radiation.

113. The illumination apparatus of claim **103**, wherein:

the addressable controller includes a first switch and a second switch respectively associated with the at least one first LED and the at least one second LED; and

the addressable controller is configured to control the at least one first LED and the at least one second LED by turning the first and second switches on and off at high speeds.

114. The illumination apparatus of claim **103**, further including at least one modular connection to facilitate coupling of the at least one controller to the at least one first LED and the at least one second LED.

115. The illumination apparatus of claim **103**, further including at least one modular connection to facilitate coupling of the at least one controller to the at least one first LED and the at least one second LED.

116. The illumination apparatus of claim **115**, wherein:

the at least one first LED and the at least one second LED are supported by a first substrate;

the at least one controller is supported by a second substrate; and the at least one modular connection is configured to facilitate at least one of a mechanical coupling and an electrical coupling of the first substrate and the second substrate.

117. In an illumination apparatus comprising at least one first LED adapted to output at least first radiation having a first spectrum, at least one second LED adapted to output second radiation having a second spectrum different than the first spectrum, and at least one sensor to monitor at least one detectable condition, an illumination control method, comprising acts of:

independently controlling at least a first intensity of the first radiation and a second intensity of the second radiation in response to user operation of at least one user interface; and

controlling the at least one first LED and the at least one second LED in response to the at least one detectable condition.

118. In an illumination apparatus comprising at least one first LED adapted to output at least first radiation having a first spectrum and at least one second LED adapted to output second radiation having a second spectrum different than the first spectrum, an illumination control method, comprising acts of:

independently controlling at least a first intensity of the first radiation and a second intensity of the second radiation in response to user operation of at least one user interface; and

communicating with the illumination apparatus via at least one IR signal or at least one electromagnetic signal.

119. In an illumination apparatus comprising at least one first LED adapted to output at least first radiation having a first spectrum and at least one second LED adapted to output second radiation having a second spectrum different than the first spectrum, an illumination control method, comprising an act of:

a) independently controlling at least a first intensity of the first radiation and a second intensity of the second radiation in response to user operation of at least one user interface, wherein the illumination apparatus includes at least one first register associated with the at least one first LED and at least one second register associated with the at least one second LED, and wherein the act a) includes an act of:

programming the at least one first register and the at least one second register based on the user operation of the at least one user interface.

120. In an illumination apparatus comprising at least one first LED adapted to output at least first radiation having a first spectrum and at least one second LED adapted to output second radiation having a second spectrum different than the first spectrum, an illumination control method, comprising acts of:

independently controlling at least a first intensity of the first radiation and a second intensity of the second radiation in response to user operation of at least one user interface; and

variably regulating power to at least one of the at least one first LED and the at least one second LED.

121. In an illumination apparatus comprising at least one first LED adapted to output at least first radiation having a first spectrum and at least one second LED adapted to output second radiation having a second spectrum different than the first spectrum, an illumination control method, comprising an act of:

a) independently controlling at least a first intensity of the first radiation and a second intensity of the second radiation in response to user operation of at least one user interface, wherein each of the at least one first LED and the at least one second LED is associated with a switch, and wherein the act a) includes an act of:

controlling the at least one first LED and the at least one second LED by turning the respective switches on and off at high speeds.

122. In an illumination apparatus comprising at least one first LED adapted to output at least first radiation having a first spectrum and at least one second LED adapted to output second radiation having a second spectrum different than the first spectrum, an illumination control method, comprising an act of:

a) independently controlling at least a first intensity of the first radiation and a second intensity of the second radiation in response to user operation of at least one user interface, wherein the act a) includes acts of:

a1) receiving at least one network signal including lighting information; and

a2) controlling at least the first intensity and the second intensity based at least in part on the lighting information.

123. The illumination method of claim **122**, wherein the act a1) includes an act of:

receiving the at least one network signal based at least in part on the user operation of the at least one user interface.

124. The illumination method of claim **122**, wherein the at least one network signal includes address information and lighting information for a plurality of illumination apparatus, wherein the lighting information includes intensity values for LEDs of the plurality of illumination apparatus, wherein the illumination apparatus has an address, and wherein the act a2) includes an act of:

a3) processing the at least one network signal based on the address of the illumination apparatus and the address information in the at least one network signal to recover the intensity values for at least the first and second LEDs of the illumination apparatus.

125. The illumination method of claim **124**, wherein the address information relates to an arrangement of data packets in the at least one network signal, and wherein the act a3) includes an act of:

processing the at least one network signal based on the address of the illumination apparatus and the arrangement of data packets in the at least one network signal to recover the intensity values for at least the first and second LEDs of the illumination apparatus.

126. The illumination method of claim **122**, wherein the at least one user interface includes a central network controller, and wherein the act a1) includes an act of: receiving the at least one network signal from the central network controller.

127. The illumination method of claim **122**, wherein the at least one network signal is formatted using a DMX protocol, and wherein the act a2) includes an act of:

controlling the at least one first LED and the at least one second LED based at least in part on the DMX protocol.

128. The illumination method of claim **122**, wherein the act a2) further includes an act of:

implementing a pulse width modulation technique to control at least the first intensity of the first radiation and the second intensity of the second radiation.

129. The illumination method of claim **122**, wherein each of the at least one first LED and the at least one second LED is associated with a switch, and wherein the act a2) further includes an act of:

controlling the at least one first LED and the at least one second LED by turning the respective switches on and off at high speeds.

130. An illumination apparatus, comprising:

at least one first LED adapted to output at least first radiation having a first spectrum;

at least one second LED adapted to output second radiation having a second spectrum different than the first spectrum; and

at least one controller coupled to the at least one first LED and the at least one second LED and configured to respond to at least one signal formatted at least in part using a DMX protocol, the at least one signal including lighting information based at least in part on user operation of at least one user interface in communication with the at least one controller, the at least one controller further configured to independently control at least a first intensity of the first radiation and a second intensity of the second radiation in response to the lighting information.

131. The apparatus of claim **130**, in combination with the at least one user interface.

132. The combination of claim **131**, wherein the at least one user interface includes a central network controller.

133. The illumination apparatus of claim **130**, further including at least one modular connection to facilitate coupling of the at least one controller to the at least one first LED and the at least one second LED.

134. The illumination apparatus of claim **133**, wherein:

the at least one first LED and the at least one second LED are supported by a first substrate;

the at least one controller is supported by a second substrate; and

the at least one modular connection is configured to facilitate at least one of a mechanical coupling and an electrical coupling of the first substrate and the second substrate.

135. The illumination apparatus of claim **130**, wherein the at least one controller further is configured as an addressable controller capable of receiving the at least one signal as at least one network signal including lighting information for a plurality of illumination apparatus.

136. The illumination apparatus of claim **135**, wherein the lighting information includes intensity values for LEDs of the plurality of illumination apparatus, and wherein the addressable controller is configured to process the at least one network signal based on an address of the addressable controller to recover from the lighting information the intensity values for at least the first and second LEDs of the illumination apparatus.

137. The illumination apparatus of claim **136**, wherein the at least one network signal includes address information.

138. The illumination apparatus of claim **137**, wherein the address information relates to an arrangement of data packets in the at least one network signal.

139. The illumination apparatus of claim **136**, wherein the addressable controller has an alterable address.

140. The illumination apparatus of claim **136**, in combination with the at least one user interface, wherein the at least one user interface is a central network controller that is configured to generate the at least one network signal.

141. The illumination apparatus of claim **130**, wherein the at least one controller is configured to implement a pulse width modulation technique to control at least the first intensity of the first radiation and the second intensity of the second radiation.

142. The illumination apparatus of claim **130**, wherein:

the at least one controller includes a first switch and a second switch respectively associated with the at least one first LED and the at least one second LED; and

the at least one controller is configured to control the at least one first LED and the at least one second LED by turning the first and second switches on and off at high speeds.

143. An illumination apparatus, comprising:

at least one first LED adapted to output at least first radiation having a first spectrum;

at least one second LED adapted to output second radiation having a second spectrum different than the first spectrum;

at least one controller coupled to the at least one first LED and the at least one second LED and configured to respond to user operation of at least one user interface in communication with the at least one controller, the at least one controller further configured to independently control at least a first intensity of the first radiation and a second intensity of the second radiation in response to the user operation; and

at least one modular connection to facilitate coupling of the at least one controller to the at least one first LED and the at least one second LED.

144. The illumination apparatus of claim **143**, wherein:

the at least one first LED and the at least one second LED are supported by a first substrate;

the at least one controller is supported by a second substrate; and

the at least one modular connection is configured to facilitate at least one of a mechanical coupling and an electrical coupling of the first substrate and the second substrate.

* * * * *